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DIAMETER AND HEIGHT DISTRIBUTIONS IN IMPROVED AND UNIMPROVED *PINUS RADIATA*

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EXECUTIVE SUMMARY

Diameter and height distributions for seedlots representing a range of genetic improvement ratings were compared for seven large-block genetic gain trials at six sites at mid-rotation (age 14, 15 or 16) and at one site from age five to mid-rotation. Differences among seedlots were statistically significant for mean diameter and mean height and generally reflected their genetic improvement rating. Standard deviation, skewness, and kurtosis, however, were not significantly different among seedlots. Since variance of seedlot diameter and height and the shape of frequency distributions do not appear to change significantly with increasing genetic improvement, it appears that models predicting diameter distributions from stand parameters do not need to be altered for genetically improved seedlots.

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ABSTRACT

Diameter and height distributions for seedlots representing a range of genetic improvement ratings were compared at seven sites of large-block genetic gain trials at mid-rotation (age 14, 15 or 16) and at one site for year five and annually from age 8 to 16. These are the first data comparing tree size distributions for operationally planted improved vs. unimproved plantation conifers when planted in "pure" blocks. Differences among seedlots were statistically significant for mean diameter and mean height and generally reflected the genetic improvement rating. Standard deviation, skewness and kurtosis were not significantly different among seedlots. However, diameter distributions of higher rated seedlots sometimes appeared very slightly more skewed to the right and flatter than the lower rated seedlots, similarly to changes in distributions observed as stands age. Models predicting diameter distributions from stand parameters do not appear to require alteration for genetically improved seedlots.

INTRODUCTION

Predictions of forest growth and resulting distributions of log sizes are important in intensively managed plantation forests. One approach is to use stand level models to predict stand parameters (such as mean top height, stand basal area, and wood volume), and then to predict a diameter distribution based on the predicted stand parameters. STANDPAK, a modelling system widely used for *Pinus radiata* (D. Don) in New Zealand (West 1993, Whiteside 1990), uses this approach.

An alternative method of predicting tree size distributions is through a single-tree model, in which individual tree identity in a stand is maintained and individual tree growth is predicted. Two such models have been used to test the effect on stand growth of a reduced diameter variance resulting from genetic improvement (Mitchell 1975, Nance and Bey 1979). Reduced diameter variance in both cases resulted in a prediction of significantly reduced growth. In Mitchell's simulations, the stand with the least variance grew slightly faster than the control stand, but crop trees (the largest in the stand) grew slower than those in the control stand because of increased competition. Nance and Bey found that reducing diameter variance reduced estimates of total volume production and average diameter when compared to a woodsrun control. In biological terms, these model predictions suggest that a reduced variance produces stands in which trees grow more uniformly, showing less expression of dominance and delayed death of smaller trees.

Radiata pine plantations in New Zealand are established using genetically improved stock originating from either open-pollinated or control-pollinated clonal seed orchards (Carson *et al.* 1990). Genetic quality is determined by the parentage of the seed used to produce the planting stock, and is quantified through the assignment of an improvement rating (called a "GF" rating) which is assigned by the New Zealand Seed Certification Service (Vincent 1987a & 1987b, 1990). Since two-thirds of this GF rating is determined by parental rankings for growth (the other

third is determined by stem form), GF ratings provide a guide to a seedlot's genetic worth for growth.

With the use of planting stock of increasingly higher genetic quality, it becomes important to determine the effect of genetic improvement on diameter distributions in order to accurately predict log size and resulting timber yields. Very little data comparing tree size distributions of improved and unimproved forest stands has been published. Spirek *et al.* (1981) fitted coefficients of a Weibull distribution to diameter and height data from open-pollinated progeny tests and found weak differences among them. These progeny trials, however, were planted in either row-plots or single-tree plots, and, therefore, may not be indicative of performance when progeny are planted in "pure" stands. A study of cottonwood comparing percentiles of the cumulative diameter distribution of ramets from seven clones planted in large blocks on two sites (Knowe *et al.* 1994) suggested that genetic differences influenced the mean quadratic diameter, but had very little influence on diameter distributions, except perhaps on the lowest quartile. Janssen and Sprinz (1987) fitted probability density functions to data from large-block trials comparing seed collected from plus trees and neighbouring trees. Predicted diameter distributions suggested that distributions for improved seedlots were flatter than for unimproved seedlots.

The objective of this study was to compare tree size distributions for improved and unimproved *P. radiata* when planted in trials as "pure" blocks.

METHODS

Large-block genetic gain trials were planted in a randomised complete block design with six replicate blocks per site on several sites in 1978 (three sites, four trials: RO 2103/1, RO 2103/2, WN 377, and NN 530/2), 1979 (two sites: RO 2103/3, and NN 530/1), and 1980 (one site: SD 682) (Figure 1). Sites in the genetic gain trials were chosen to represent a range of growth performance. Blocks were 8 x 8 tree squares except for RO 2103/2, for which they were 10 x 10 trees. Seedlots in all trials represented a range of genetic qualities and were rated for growth and stem form performance (GF) by the New Zealand Seed Certification Service. The 1978 trials included a bulk collection without selection from a stand of the local land-race (GF2), a climbing select seedlot, that is, seed collected from the largest trees in a land-race stand located in the region of the planting site (GF7), open-pollinated seed from a 25-clone clonal seed orchard (GF14), and a control-pollinated seedlot with one improved female parent and approximately seven to 12 improved pollen parents (GF22). The 1979 and 1980 trials included a local climbing select seedlot (GF7), a mixture of seed from controlled pollinations among a large number of improved parents (GF14), and an open-pollinated seedlot from an orchard with clones selected primarily for their long internodes (GF8).

In 1986, 48 permanent sample plots (PSP) of 0.1 ha were established (Dunlop and Ellis, 1996) at the four 1978 trial sites for seedlots assigned genetic improvement ratings of GF7 and GF14, and similarly 36 plots were established in 1992 for GF2 and GF22 seedlots. Forty-four PSP were similarly established in 1986 in all seedlots at the three trial sites planted in 1979 and 1980. At least two border rows were left between each PSP plot. All trials except one were treated with a direct sawlog regime (planted at 1111 stems per ha, then both thinned to 300 stems per ha and pruned to 6m height in two steps). The exception was RO 2103/2, which was treated with a pulpwood regime (planted at 711 stems per ha with only 2m height pruning and no thinning). Significant mortality occurred as a result of competition in the pulpwood regime but

not in the sawlog regime. Height of a sample of trees (approximately 12 trees per plot) and diameter (at height 1.4m) of every tree (approximately 30 per plot) were measured annually after plot establishment. Diameter and height of all trees in the pulpwood regime trial were also measured at age five, before PSP plot establishment. (See Carson *et al.* 1991, Carson *et al.* 1994, Dunlop and Carson 1995, Skinner and Carson 1994, and Skinner *et al.* 1994 for details of the trials and measurements).

Parameters of mean and standard deviation for height and diameter, and skewness and kurtosis for their distributions for each plot were calculated for the age 14 or 15 year assessment of all trials, and for the age 5 and ages 8-16 year assessments in the trial RO 2103/2. Analysis of variance was used to examine differences among seedlot diameters and heights for all parameters. First height and then diameter parameters were compared across sites in two analyses, one comparing the age 15 assessment on sites with GF2, GF7, GF14, and GF22 seedlots and another comparing the age 14 assessments on sites with GF7, GF14, and GF8 (long internode) seedlots. Sources of variation included site, replication within site, seedlot improvement rating, and seedlot rating by site interaction. Second, the parameters for height and then diameter were compared across ages for the site treated with a pulpwood regime. Sources of variation included age, replication, seedlot improvement rating, and the interactions among age and replication, seedlot rating and age, and seedlot rating and replication. Separate analyses were carried out with GF rating first assumed to be a random effect, then a fixed effect. Frequency distributions for height and diameter measurements of all trees of each seedlot in a trial were plotted for each site at age 16 years for trials RO 2103/1, RO 2103/2, and WN 377, age 15 for trial NN 530/2, age 14 for trials RO 2103/3, NN 530/1 and SD 682, and also at age 5 for trial RO 2103/2.

RESULTS

Comparisons Across Sites

As expected, the overall mean diameter and mean height were significantly different among sites (see Tables 1-3, Appendix 1). Standard deviation, skewness, and kurtosis of diameter and height, however, were not significantly different among sites, except for standard deviation of diameter for the 1978 trials, which was clearly less for all seedlots at NN 530/2 than at the other sites (Table 1).

Differences in mean diameter and mean height among seedlots (Tables 1-3) in both the 1978 and 1979 trials were statistically significant ($P<=0.01$) (Appendices 1a-1b for the 1978 trials and Appendices 1c-1d for the 1979 trials) with similar results under the assumptions of genetic improvement ratings being either random or fixed effects. Mean height and diameter generally reflected the genetic improvement rating for all trial sites treated with a direct sawlog regime. For the pulpwood regime the highest rated seedlot did not have the highest mean diameter, but it had the highest mean top diameter (Tables 1 and 4), indicating that the largest 100 trees in the GF22 seedlot were larger than the largest 100 trees in the lower-rated seedlots.

In contrast to results for mean diameter and mean height, differences among seedlots for standard deviation, skewness, and kurtosis were not significant ($P<=0.05$) for any of the analyses (Appendix 1). Inspection of frequency distributions suggests that they are not different for seedlots with different improvement ratings, except that there was sometimes a tendency for diameters of seedlots with higher ratings to have slightly flatter distributions and to be very

slightly skewed to the right. This tendency was most pronounced in the pulpwood regime (Figures 2-5, Appendix 2). The range of diameters did not decrease with increasing genetic improvement; if anything there was a slight trend toward an increased standard deviation for diameter in the faster growing seedlots.

Comparison Across Stand Ages to Mid-Rotation

As expected, mean and standard deviation for diameter and height of the stand treated with the pulpwood regime (RO 2103/2) differed significantly with stand age ($P<0.0001$) (Tables 4-5). Skewness differed significantly among stand ages for diameter ($P<0.05$) but not for height, while kurtosis did not differ with age for either diameter or height. As the stands aged, frequency distributions became flatter and more skewed to the right (see Figures 2, 4, 6 and 7).

Seedlots with different improvement ratings were significantly different for diameter ($P<=0.0002$) and for height ($P<=0.05$) over ages five to 16 years (Tables 4-5, Appendix 3), with similar results under the assumptions of genetic improvement ratings being either random or fixed effects. These differences resulted in substantial increases of basal area and volume as genetic improvement rating increased (Figure 6). In contrast, standard deviation, skewness, and kurtosis were not significantly different among seedlots across ages to mid-rotation for either height or diameter (Tables 4-5, Figures 3, 5, 7 and 8, Appendix 3).

DISCUSSION AND CONCLUSIONS

These data do not support the hypothesis that genetically improved seedlots grown in a plantation have reduced variance in diameter or height. Both unimproved and improved stands had similar diameter and height distributions with no reduction in range, suggesting that reduced growth will not result from genetic improvement, as hypothesised by Mitchell (1975) and Nance and Bey (1979).

Standard deviation of diameter increased with increasing stand age, resulting in a flatter distribution as tree size increased. At fixed ages, however, there were no significant differences among standard deviations of seedlot diameters. Visual inspection of frequency distributions sometimes showed a slight trend toward a greater standard deviation in the faster growing seedlots, as was suggested for loblolly pine open-pollinated families (Janssen and Sprinz, 1987). Further, although skewness of the distribution of seedlot diameter was not significantly different either across ages or at a fixed age across sites, frequency distributions sometimes appeared to be very slightly skewed to the right in the highest rated seedlots (for which competition would be more severe) compared to the other seedlots. This is similar to results comparing cottonwood clones (Knowe *et al.* 1994), where tree size distributions of the best clones differed in their lowest quartile.

Competition from weeds had a direct effect on diameter distributions of Douglas-fir in a xeric environment where resources were limiting (Knowles *et al.* 1992). Lack of vegetation control was associated with decreased growth of larger trees and diameter distributions with smaller mean and less variance. The relatively low standard deviations for diameter at sites NN 530/1 and NN 530/2 might be explained by the severe weed competition present at these sites.

The changes in tree size distributions with increasing genetic improvement appear to change in the same pattern as observed when a stand ages. As a stand ages, individual trees get larger and encounter greater competition, diameter distributions shift to the right, become slightly flatter and often slightly skewed to the right. Since the most-genetically-improved seedlots are the largest, it is not surprising that they have distributions more like those for slightly older, unimproved trees.

Seedlots examined in this analysis are genetic mixtures similar to those which have been and continue to be widely planted in New Zealand. Each seedlot is made up of trees with a range of genetic quality for growth, which would have been the source of some of the variation in growth among trees. Individual tree heritability for growth of radiata pine is about 0.2 (Kumar *et al.* 1995), suggesting that most of the variation is environmental. This suggests that diameter distributions of trees in single clone blocks may be slightly less variable, but that such stands will still have substantial variability in tree size, as was the case with cottonwood clones (Knowe *et al.*, 1994).

Since diameter and height distributions for improved and unimproved *P. radiata* seedlots appear similar, diameter and height distributions predicted from stand variables do not appear to require alteration for genetically improved *P. radiata* if the stand parameters are correctly specified. Given the same stand parameters of basal area, height, and stocking, the same distribution would be expected for both improved and unimproved seedlots.

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APPENDICES

Table 1. Mid-rotation diameter (age 15) for four seedlots of different genetic quality planted in four large-block trials in 1978.

Diameter	Seedlot quality (GF rating)	Experiment No. RO 2103/1	RO 2103/2[a]	WN 377	NN 530/2
Mean DBH	2	35.6	27.5	37.0	29.8
	7	35.9	29.2	38.8	30.2
	14	38.3	31.3	42.7	30.4
	22	39.2	29.9	44.2	33.6
Mean Top DBH	2	40.7	37.4	41.8	33.1
	7	40.9	37.6	44.1	33.8
	14	44.6	39.0	49.4	34.3
	22	46.2	39.8	50.0	36.5
No. of trees	2	83	93	47	44
	7	85	180	89	87
	14	90	169	91	93
	22	82	128	48	44
Std Dev	2	6.19	6.67	4.54	2.62
	7	5.10	5.96	5.23	3.68
	14	6.41	5.70	6.08	3.72
	22	6.43	7.29	7.09	3.93
Skewness	2	0.08	-0.03	0.36	0.02
	7	-0.34	-0.22	0.02	-0.54
	14	-0.69	-0.29	0.03	0.14
	22	-0.34	-0.40	-1.59	-0.08
Kurtosis	2	-0.01	-0.29	0.40	0.03
	7	0.03	-0.04	-0.15	1.50
	14	0.67	-0.06	-0.46	-0.31
	22	-0.31	-0.12	4.03	-0.14

[a] Treated with a pulpwood regime. All other sites were treated with a sawlog regime.

Table 2. Mid-rotation height (age 15) for four seedlots of different genetic quality planted in four large-block trials in 1978.

Height	Seedlot quality (GF rating)	Experiment No. RO 2103/1	RO 2103/2[a]	WN 377	NN 530/2
Mean HT	2	26.1	25.6	25.8	20.4
	7	26.1	25.9	25.5	20.5
	14	27.2	26.1	27.4	21.1
	22	26.8	26.6	27.4	22.6
Mean Top HT	2	26.8	27.1	26.2	20.5
	7	27.0	27.1	26.1	21.1
	14	28.2	27.2	28.0	22.1
	22	28.0	27.6	27.7	23.5
No. of trees	2	73	43	36	40
	7	80	83	79	86
	14	77	88	75	89
	22	75	59	33	42
Std Dev	2	1.72	2.06	1.70	1.82
	7	1.57	1.67	1.94	1.57
	14	1.83	1.77	1.83	2.00
	22	1.84	1.96	1.59	1.42
Skewness	2	0.04	-0.69	-0.15	-0.14
	7	-0.20	-0.45	-0.05	-0.33
	14	-0.88	-0.54	0.12	0.15
	22	-0.13	-0.42	-0.21	-0.13
Kurtosis	2	-0.05	2.58	-0.45	-0.80
	7	0.49	-0.37	-0.25	-0.14
	14	3.50	0.37	0.02	-0.53
	22	-0.68	0.73	0.23	-0.17

[a] Treated with a pulpwood regime. All other sites were treated with a sawlog regime.

Table 3. Mid-rotation diameter and height (age 14) for three seedlots of different genetic quality planted in three large-block trials in 1979 and 1980.[a]

Diameter	Seedlot quality (GF rating)	Experiment No. NN 530/1	RO 2103/3	SD 682
Mean DBH	7	31.9	34.4	34.4
	8	30.6	32.4	34.7
	14	32.7	35.0	36.0
Mean Top DBH	7	35.3	38.7	37.4
	8	34.1	37.1	37.9
	14	36.4	38.9	39.2
No. of trees	7	91	73	47
	8	91	73	75
	14	90	74	90
Std Dev	7	3.29	4.44	3.07
	8	3.32	4.44	3.24
	14	3.45	4.22	3.43
Skewness	7	0.09	0.09	-0.58
	8	0.36	0.07	-0.41
	14	-0.09	-0.09	-0.47
Kurtosis	7	-0.06	0.64	1.50
	8	-0.11	-0.46	0.11
	14	-0.62	0.39	0.01

Height	Seedlot quality (GF rating)	Experiment No. NN 530/1	RO 2103/3	SD 682
Mean HT	7	21.0	24.3	18.8
	8	21.9	24.4	19.2
	14	22.9	25.2	19.9
Mean Top HT	7	21.0	24.5	19.3
	8	22.4	25.1	19.9
	14	23.3	25.7	20.4
No. of trees	7	88	69	41
	8	88	69	64
	14	89	69	75
Std Dev	7	1.27	1.45	1.15
	8	1.53	1.55	1.67
	14	1.48	1.24	1.53
Skewness	7	0.04	0.27	-0.72
	8	0.34	-0.21	0.01
	14	-0.12	-0.07	-0.04
Kurtosis	7	-0.46	-0.39	0.63
	8	0.58	-0.02	-0.58
	14	0.27	-0.57	1.01

[a] All sites treated with a sawlog regime.

Table 4. Diameter at ages 5 and 8-16 for four seedlots of different genetic quality planted in a large-block trial (RO2103/2).[a]

Diameter	Seedlot quality (GF rating)	Age (years) 5	8	9	10	11	12	13	14	15	16
Mean DBH	2	9.9	–[b]	–	–	–	–	–	26.6	27.5	29.0
	7	10.4	19.6	21.4	23.0	24.8	26.0	27.2	28.3	29.2	30.0
	14	10.2	20.3	22.3	24.2	26.0	27.4	28.8	30.2	31.3	32.3
	22	10.4	–	–	–	–	–	–	28.8	29.9	31.0
Mean Top DBH	2	–	–	–	–	–	–	–	35.8	37.4	39.0
	7	–	24.5	26.9	29.1	31.4	33.1	34.7	36.3	37.6	38.9
	14	–	25.2	27.9	30.3	32.3	34.2	35.9	37.6	39.0	40.4
	22	–	–	–	–	–	–	–	38.3	39.8	40.9
No. trees	2	197	–	–	–	–	–	–	93	93	187
	7	202	185	185	185	182	181	181	180	180	180
	14	196	176	176	176	176	146	173	172	169	168
	22	198	–	–	–	–	–	–	129	128	188
Std Dev	2	2.0	–	–	–	–	–	–	6.2	6.7	6.6
	7	1.9	3.3	3.8	4.3	4.5	4.8	5.2	5.6	5.9	6.3
	14	2.1	3.4	3.9	4.3	4.7	5.1	5.3	5.6	5.7	6.0
	22	2.4	–	–	–	–	–	–	7.0	7.3	7.5
Skewness	2	0.38	–	–	–	–	–	–	-0.04	-0.03	-0.07
	7	0.13	-0.18	-0.27	-0.29	-0.10	-0.13	-0.15	-0.19	-0.22	-0.24
	14	0.41	0.19	0.06	-0.11	-0.29	-0.39	-0.37	-0.36	-0.29	-0.32
	22	0.09	–	–	–	–	–	–	-0.41	-0.40	-0.42
Kurtosis	2	0.15	–	–	–	–	–	–	-0.28	-0.29	-0.11
	7	-0.18	0.70	0.66	0.57	0.03	0.00	0.03	-0.05	0.05	-0.10
	14	0.06	0.27	0.26	0.19	0.16	0.21	0.25	0.11	0.06	-0.09
	22	-0.12	–	–	–	–	–	–	-0.12	-0.12	-0.21

[a] Treated with a pulpwood regime, that is, unthinned, low pruned only.
[b] Data not available.

Table 5. Height at ages 5 and 8-16 for four seedlots of different genetic quality planted in a large-block trial (RO2103/2).[a]

Height	Seedlot quality (GF rating)	Age (years) 5	8	9	10	11	12	13	14	15	16
Mean HT	2	5.8	–[b]	–	–	–	–	–	24.2	25.6	27.2
	7	5.9	12.8	14.6	16.4	18.6	20.5	22.5	24.1	25.9	27.2
	14	6.0	12.9	14.8	16.7	18.7	20.6	22.6	24.4	26.1	27.4
	22	6.0	–	–	–	–	–	–	25.1	26.6	28.4
Mean Top HT	2	–	–	–	–	–	–	–	25.8	27.1	29.0
	7	–	13.6	15.6	17.3	19.5	21.3	23.7	25.5	27.1	28.5
	14	–	13.8	15.7	17.6	19.7	21.5	23.6	25.4	27.2	28.8
	22	–	–	–	–	–	–	–	26.1	27.6	29.5
No. trees	2	197	–	–	–	–	–	–	45	43	83
	7	202	90	88	90	89	90	86	84	83	83
	14	196	90	89	92	92	76	91	90	88	88
	22	198	–	–	–	–	–	–	61	59	86
Std Dev	2	0.9	–	–	–	–	–	–	2.0	2.1	2.3
	7	0.8	1.1	1.2	1.3	1.4	1.5	1.7	1.8	1.7	1.8
	14	0.9	1.3	1.4	1.5	1.6	1.5	1.7	1.6	1.8	2.1
	22	1.1	–	–	–	–	–	–	2.0	1.9	2.1
Skewness	2	0.48	–	–	–	–	–	–	-0.68	-0.69	-0.69
	7	-0.34	-0.55	-0.67	-0.61	-0.63	-0.52	-0.46	-0.65	-0.45	-0.75
	14	0.19	-0.28	-0.32	-0.39	-0.65	-0.09	-0.10	-0.38	-0.54	-0.34
	22	-0.05	–	–	–	–	–	–	-0.19	-0.42	-1.40
Kurtosis	2	0.73	–	–	–	–	–	–	2.37	2.58	1.69
	7	0.10	0.10	0.58	0.55	0.43	0.06	-0.10	0.39	0.37	0.35
	14	0.03	-0.24	-0.25	0.61	1.67	-0.57	-0.35	0.17	0.37	0.24
	22	-0.09	–	–	–	–	–	–	0.31	0.73	3.73

[a] Treated with a pulpwood regime, that is, unthinned and low pruned only.
[b] Data not available.

Fig 1. Location of large block genetic gain trials.

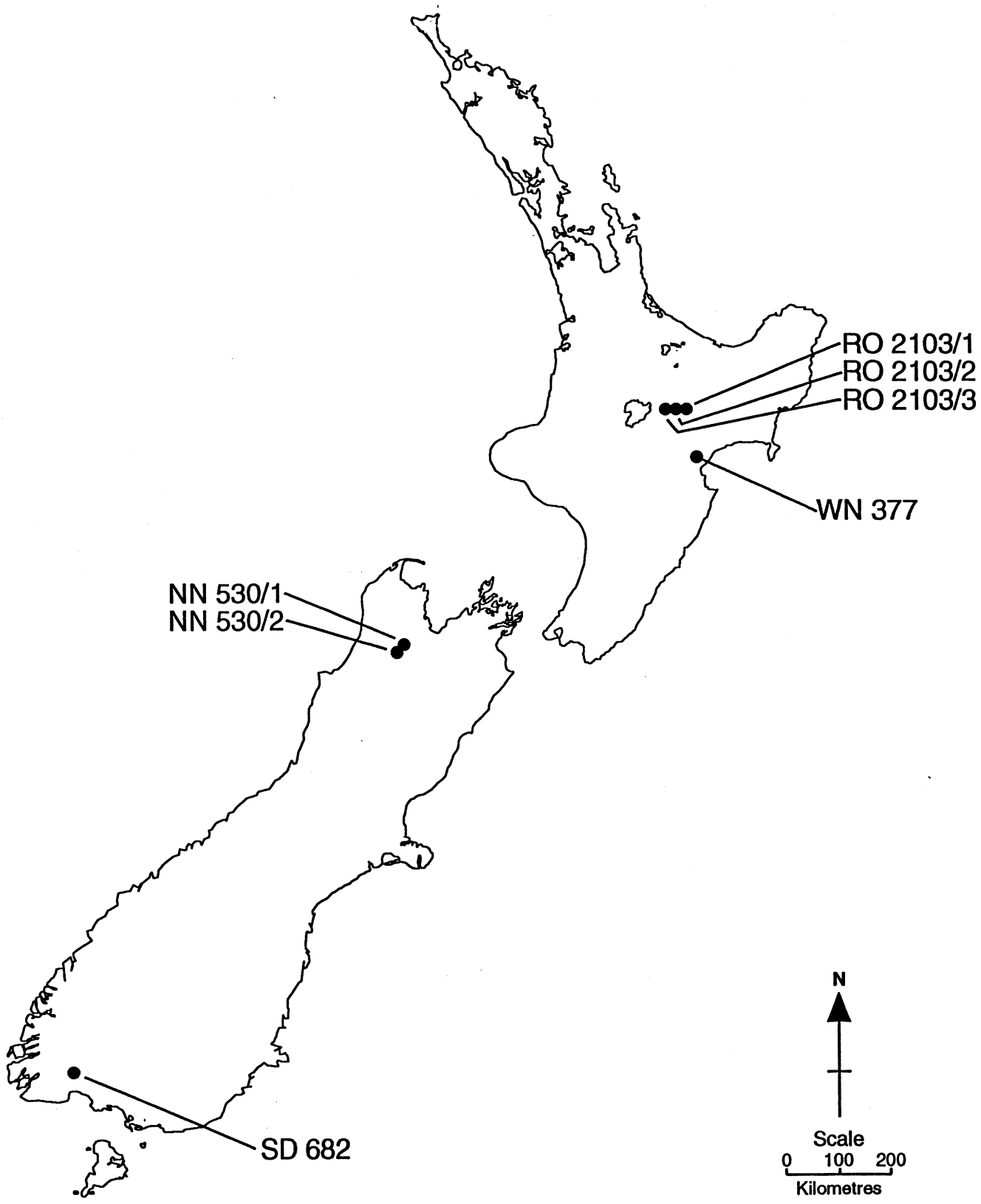
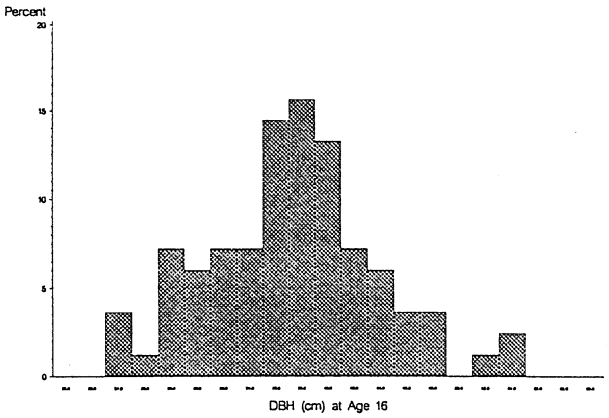
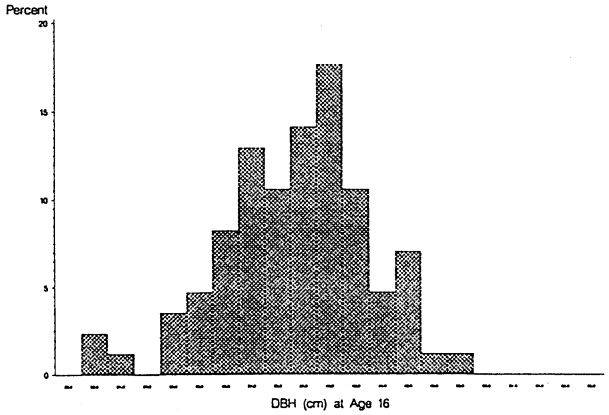


Figure 2.

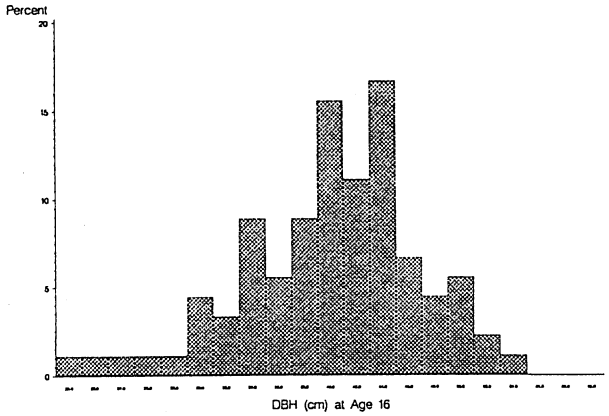
1978 Genetic Gain Trial RO 2103/1
Kaingaroa, Sawlog Regime
GF 2 : R74/1027



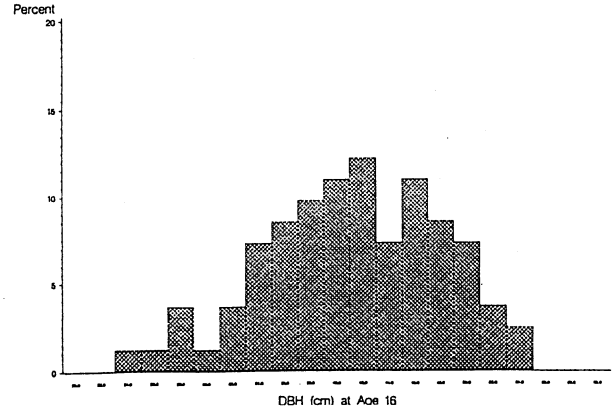
1978 Genetic Gain Trial RO 2103/1
Kaingaroa, Sawlog Regime
GF 7 : R/76/01



1978 Genetic Gain Trial RO 2103/1
Kaingaroa, Sawlog Regime
GF 14 : WN/76/A2/3



1978 Genetic Gain Trial RO 2103/1
Kaingaroa, Sawlog Regime
GF 22 : 850-55x850-96



Diameter Range 20 - 54 cm

1978 Genetic Gain Trial RO 2103/2
Kaingaroa, Pulpwood Regime
GF 2 : R74/1027

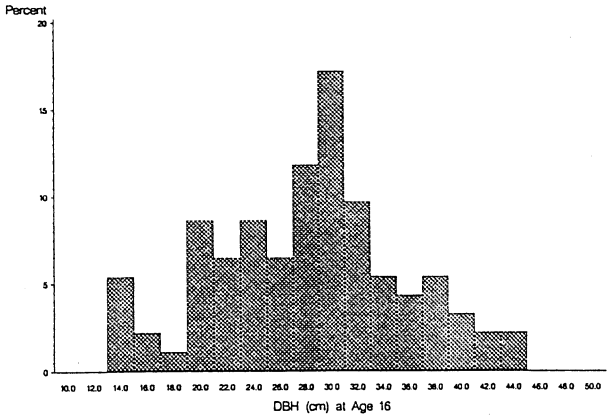
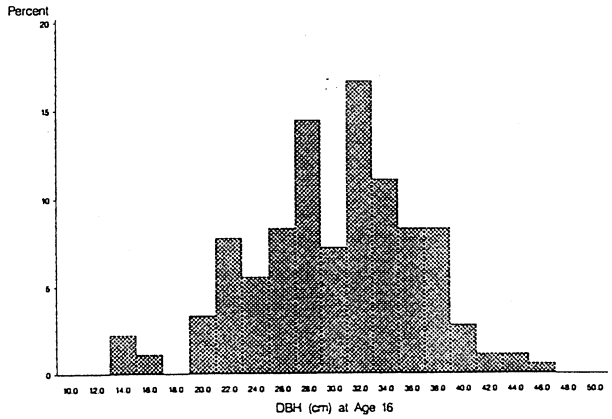
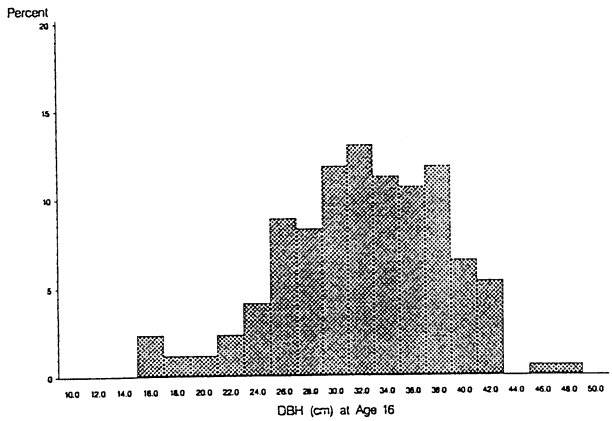


Figure 3.

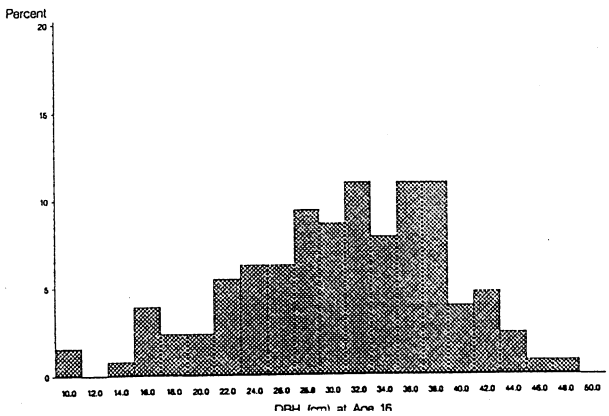
1978 Genetic Gain Trial RO 2103/2
Kaingaroa, Pulpwood Regime
GF 7 : R/76/01



1978 Genetic Gain Trial RO 2103/2
Kaingaroa, Pulpwood Regime
GF 14 : WN/76/A2/3



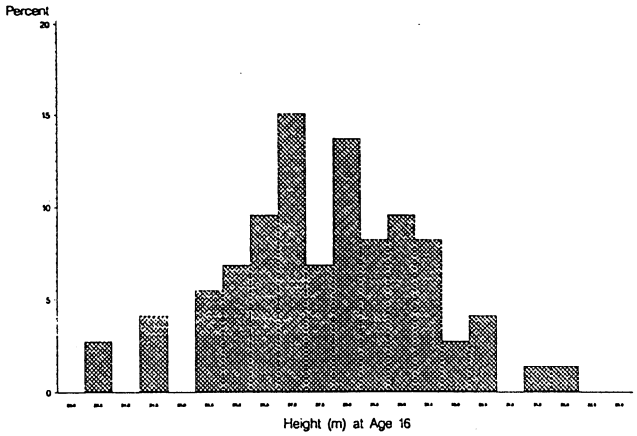
1978 Genetic Gain Trial RO 2103/2
Kaingaroa, Pulpwood Regime
GF 22 : 850-55x850-96



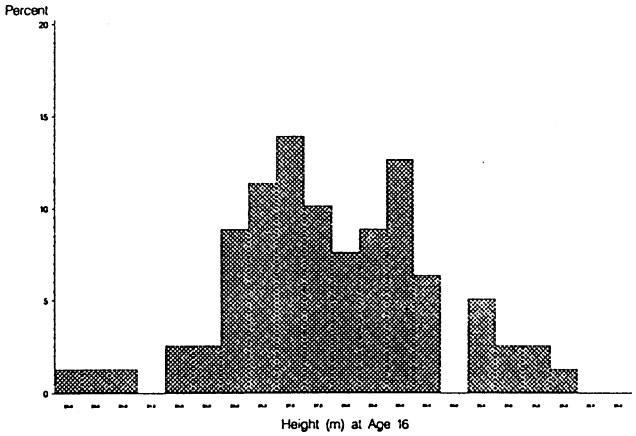
Diameter Range 10 - 48 cm

Figure 4.

1978 Genetic Gain Trial RO 2103/1
Kaingaroa, Sawlog Regime
GF 2 : R74/1027

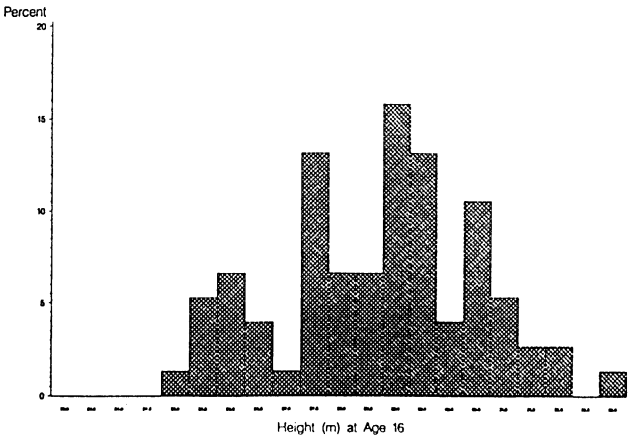


1978 Genetic Gain Trial RO 2103/1
Kaingaroa, Sawlog Regime
GF 7 : R/76/01



1978 Genetic Gain Trial RO 2103/1
Kaingaroa, Sawlog Regime
GF 14 : WN/76/A2/3

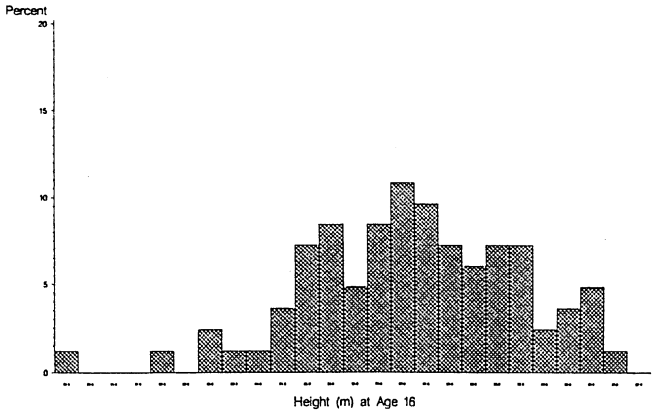
1978 Genetic Gain Trial RO 2103/1
Kaingaroa, Sawlog Regime
GF 22 : 850 – 55x850 – 96



Height Range 23 - 33 m

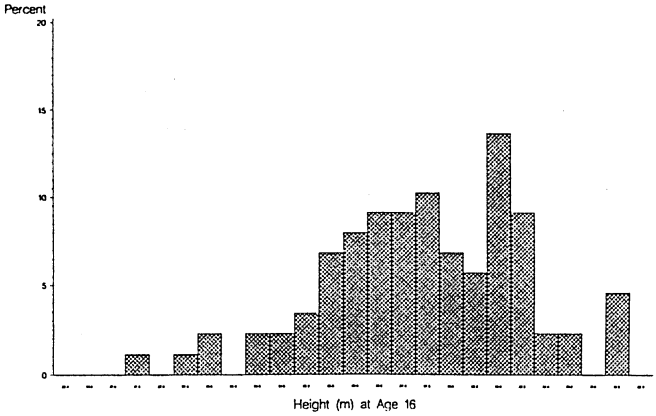
Figure 5.

1978 Genetic Gain Trial RO 2103/2
Kaingaroa, Pulpwood Regime
GF2 : R74/1027



1978 Genetic Gain Trial RO 2103/2
Kaingaroa, Pulpwood Regime
GF7 : R76/01

1978 Genetic Gain Trial RO 2103/2
Kaingaroa, Pulpwood Regime
GF 14 : WN/76/A2/3



1978 Genetic Gain Trial RO 2103/2
Kaingaroa, Pulpwood Regime
GF 22 : 850 – 55x850 – 96

Height Range 20 - 32 m

Figure 6a. **Basal area and volume of four seedlots of different genetic quality planted in a large-block trial (RO 2103/2)**

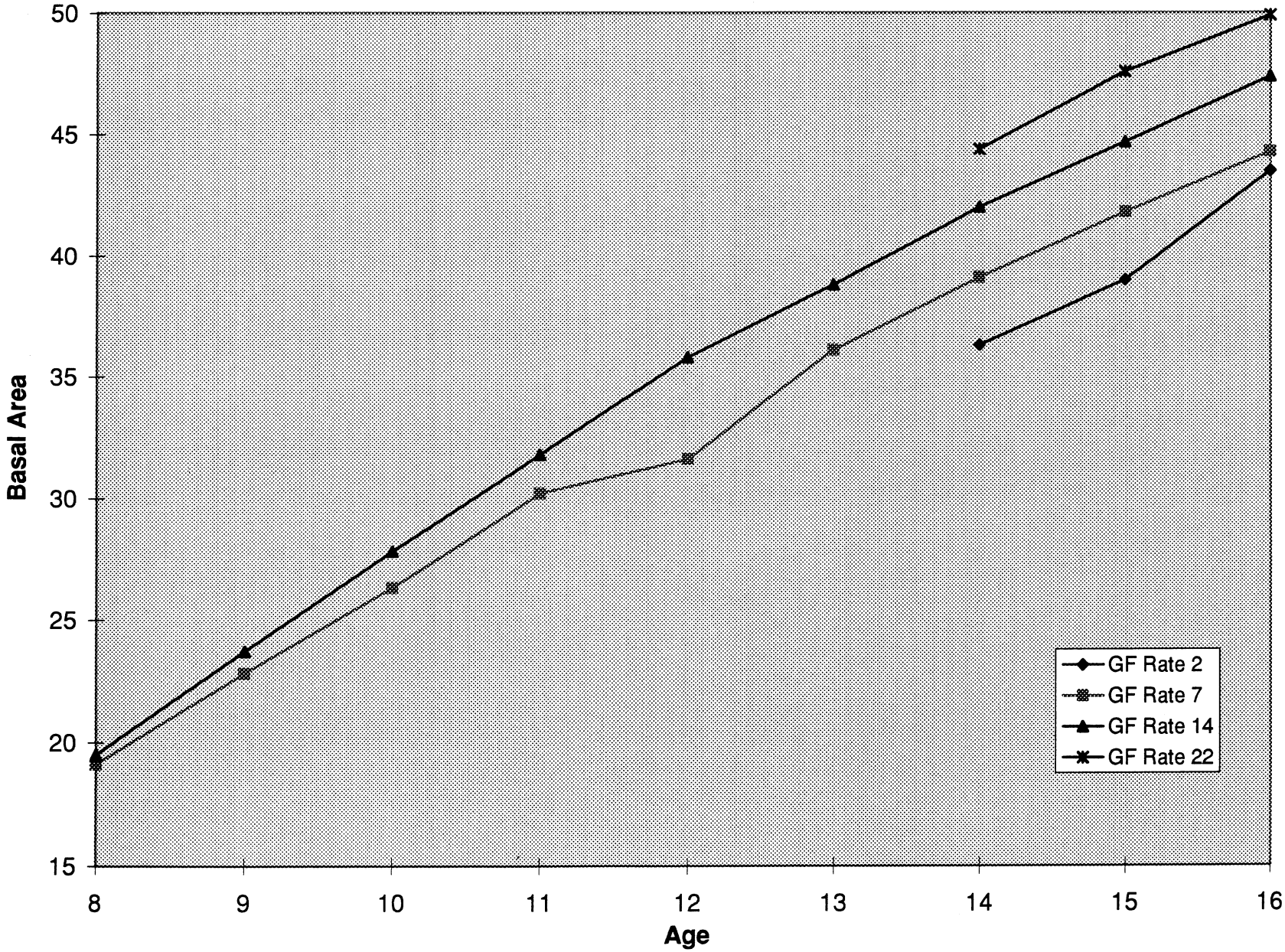


Figure 6b.

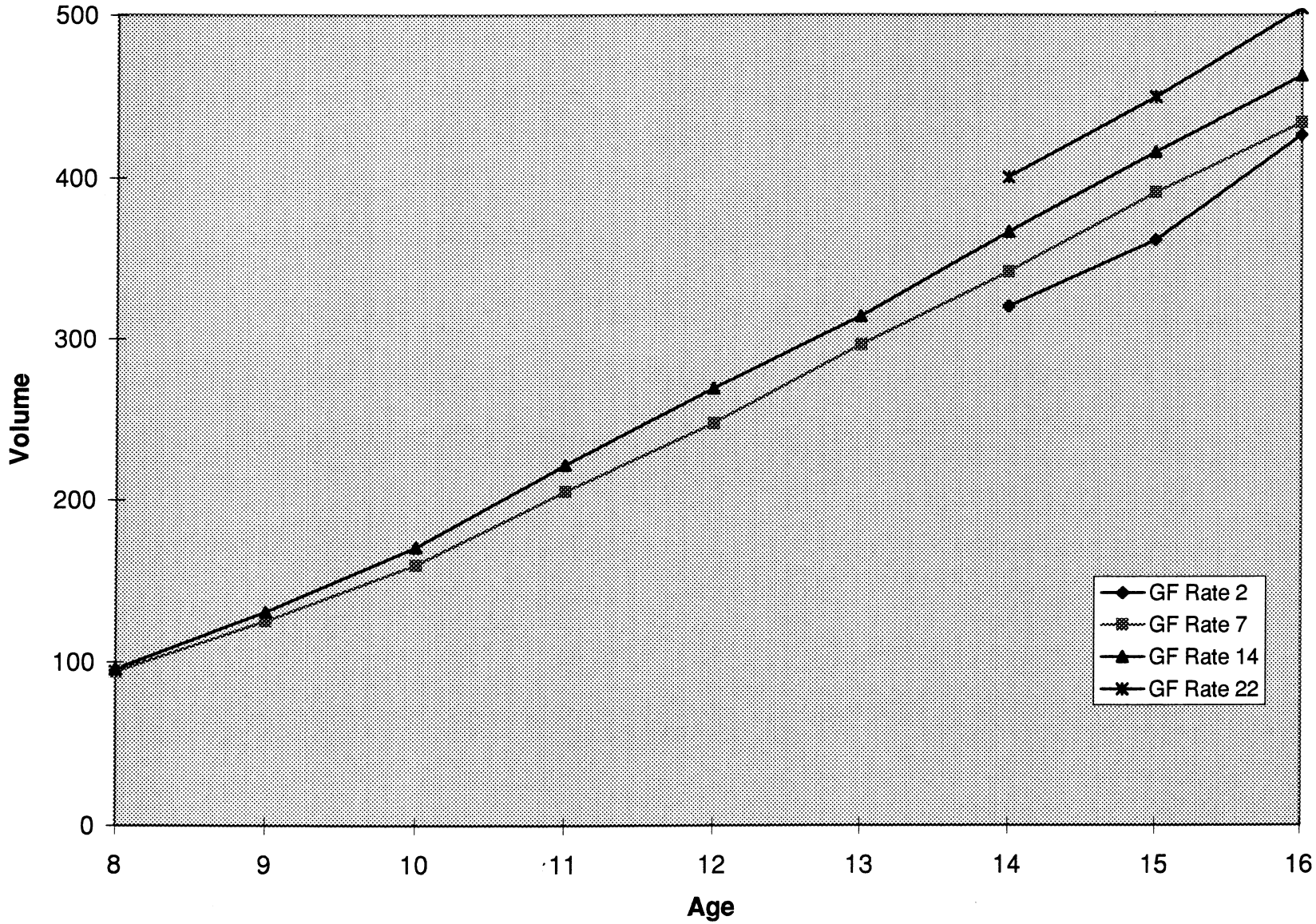
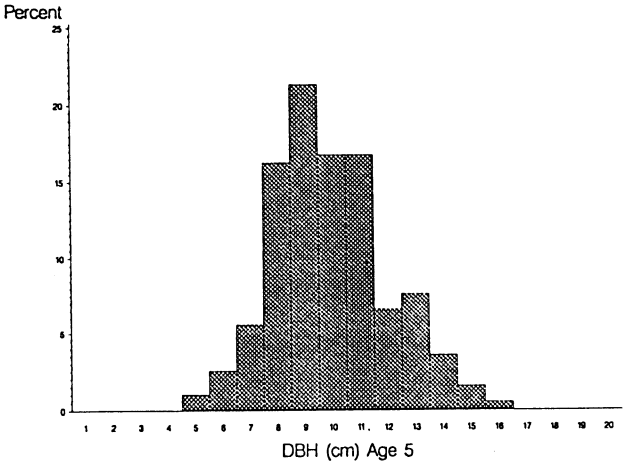
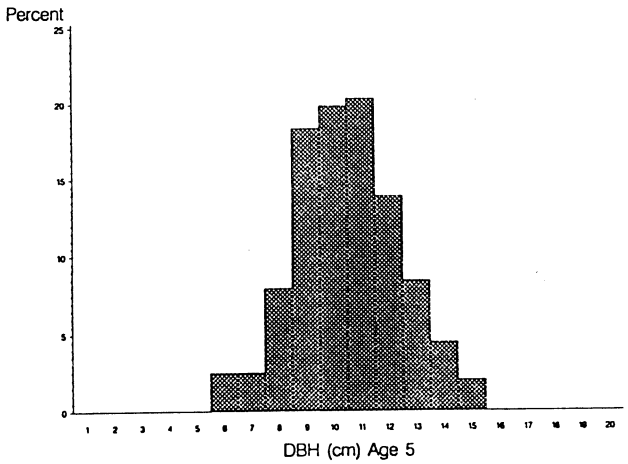

500
400
300
200
100
0
Volume
8
9
10
11
12
13
14
15
16
Age
GF Rate 2
GF Rate 7
GF Rate 14
GF Rate 22

Figure 7.

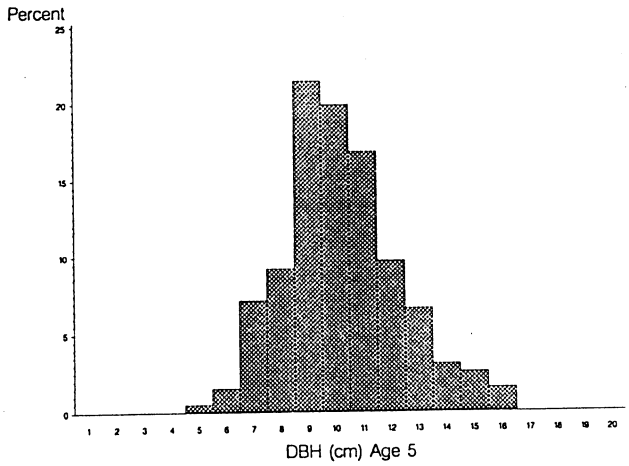
1978 Genetic Gain Trial, RO 2103/2 – Kaingaroa, Pulpwood Regime
Kaingaroa Bulk : GF2



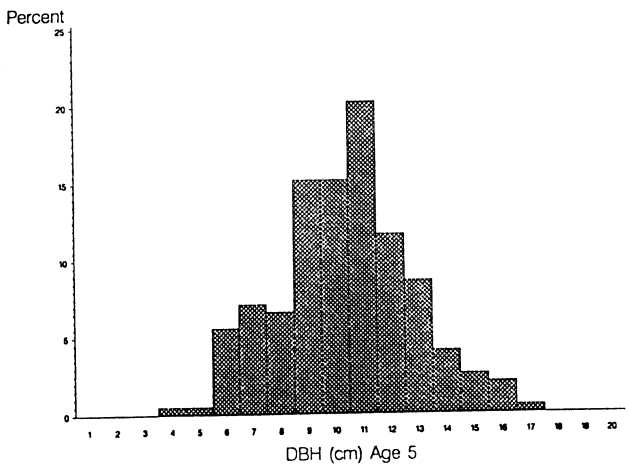
1978 Genetic Gain Trial, RO 2103/2 – Kaingaroa, Pulpwood Regime
Kaingaroa Climbing Select : GF7



1978 Genetic Gain Trial, RO 2103/2 – Kaingaroa, Pulpwood Regime
Gwavas Seed Orchard : GF14



1978 Genetic Gain Trial, RO 2103/2 – Kaingaroa, Pulpwood Regime
Cross 850–55 x 850–96 : GF22



Diameter Range 3 - 17 cm

1978 Genetic Gain Trial, RO 2103/2 – Kaingaroa, Pulpwood Regime
Kaingaroa Bulk : GF2

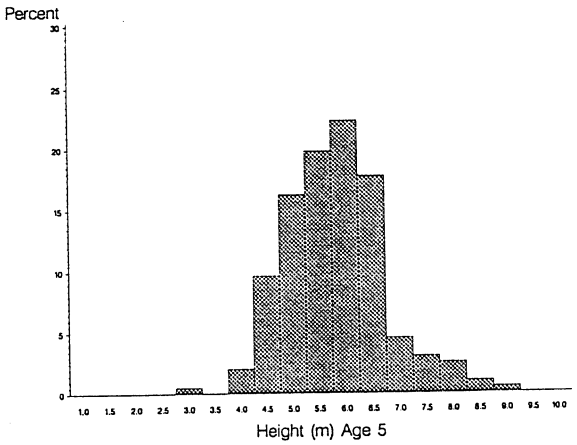
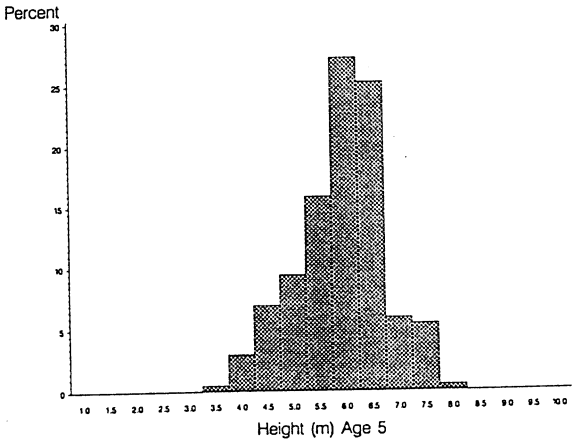
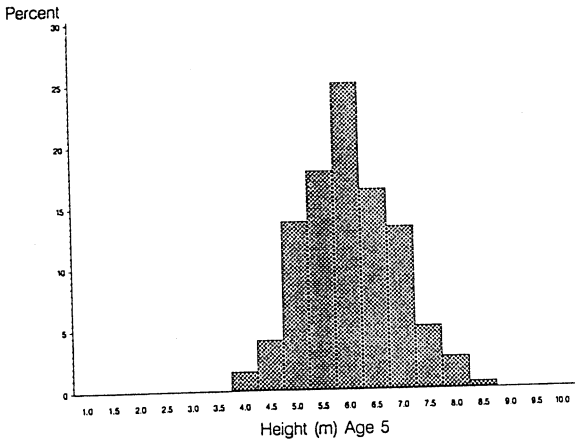


Figure 8.

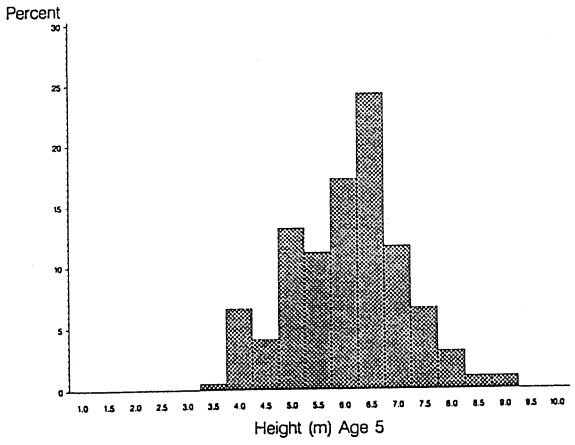
1978 Genetic Gain Trial, RO 2103/2 – Kaingaroa, Pulpwood Regime
Kaingaroa Climbing Select : GF7



1978 Genetic Gain Trial, RO 2103/2 – Kaingaroa, Pulpwood Regime
Gwavas Seed Orchard : GF14



1978 Genetic Gain Trial, RO 2103/2 – Kaingaroa, Pulpwood Regime
Cross 850 – 55 x 850 – 96 : GF22



Height Range 3 - 9 m

Appendix 1

Analysis of variance for mean, standard deviation, skewness and kurtosis of diameter and height (ages 14 or 15) over sites (random model)

APPENDIX 1a.

Random model analysis of diameter over sites in the 1978 genetic gain trial

Dependent Variable: MEAN DBH

	Type IV		Denominator			
Source	DF	MS	DF	MS	F value	Pr > F
Site	3	410.62	10.42	7.61	53.93	0.0001
Rep(Site)	20	4.02	43	3.10	1.30	0.2323
GF	3	62.93	9.22	6.99	8.99	0.0042
GF * Site	9	7.11	43	3.10	2.29	0.0334
Error	43	3.10				

Dependent Variable: STANDARD DEVIATION DBH

	Type IV		Denominator			
Source	DF	MS	DF	MS	F value	Pr > F
Site	3	26.20	4.22	0.89	29.52	0.0028
Rep(Site)	20	0.95	43	1.27	0.75	0.7558
GF	3	2.39	9.56	1.16	2.05	0.1734
GF * Site	9	1.16	43	1.27	0.91	0.5215
Error	43	1.27				

Dependent Variable: SKEWNESS DBH

	Type IV		Denominator			
Source	DF	MS	DF	MS	F value	Pr > F
Site	3	0.83	4.71	0.43	1.94	0.2471
Rep(Site)	20	0.15	43	0.34	0.43	0.9771
GF	3	0.16	9.28	0.61	0.26	0.8529
GF * Site	9	0.62	43	0.34	1.81	0.0932
Error	43	0.34				

Dependent Variable: KURTOSIS DBH

	Type IV		Denominator			
Source	DF	MS	DF	MS	F value	Pr > F
Site	3	1.67	10.38	1.73	0.96	0.4461
Rep(Site)	20	1.08	43	0.83	1.30	0.2304
GF	3	1.33	9.27	1.55	0.86	0.4967
GF * Site	9	1.57	43	0.83	1.89	0.0788
Error	43	0.83				

APPENDIX 1b.

Random model analysis of height over sites in the 1978 genetic gain trial

Dependent Variable: MEAN HEIGHT

	Type IV		Denominator			
Source	DF	MS	DF	MS	F value	Pr > F
Site	3	101.13	12.33	1.21	83.83	0.0001
Rep(Site)	20	1.05	43	0.63	1.66	0.0815
GF	3	8.46	9.37	0.85	9.92	0.0029
GF * Site	9	0.86	43	0.63	1.36	0.2341
Error	43	0.63				

Dependent Variable: STANDARD DEVIATION HEIGHT

	Type IV		Denominator			
Source	DF	MS	DF	MS	F value	Pr > F
Site	3	0.18	4.23	0.06	2.88	0.1599
Rep(Site)	20	0.12	43	0.11	1.13	0.3531
GF	3	0.17	10.21	0.05	3.63	0.0517
GF * Site	9	0.05	43	0.11	0.43	0.9133
Error	43	0.11				

Dependent Variable: SKEWNESS HEIGHT

	Type IV		Denominator			
Source	DF	MS	DF	MS	F value	Pr > F
Site	3	0.25	0.21	0.05	4.97	0.6737
Rep(Site)	20	0.23	43	0.48	0.47	0.9640
GF	3	0.05	9.97	0.26	0.19	0.9014
GF * Site	9	0.25	43	0.48	0.53	0.8428
Error	43	0.48				

Dependent Variable: KURTOSIS HEIGHT

	Type IV		Denominator			
Source	DF	MS	DF	MS	F value	Pr > F
Site	3	5.13	3.12	1.21	4.25	0.1274
Rep(Site)	20	0.90	43	1.81	0.50	0.9521
GF	3	0.38	9.46	2.01	0.19	0.9009
GF * Site	9	2.02	43	1.81	1.11	0.3733
Error	43	1.81				

APPENDIX 1c.

Random model analysis of diameter over sites in the 1979/1980 genetic gain trial

Dependent Variable: MEAN DBH

	Type IV		Denominator			
Source	DF	MS	DF	MS	F value	Pr > F
Site	2	33.18	7.36	2.56	12.96	0.0039
Rep(Site)	14	2.59	24	1.31	1.98	0.0686
GF	2	19.30	4.19	1.39	13.91	0.0142
GF * Site	4	1.39	24	1.31	1.06	0.3977
Error	24	1.31				

Dependent Variable: STANDARD DEVIATION DBH

	Type IV		Denominator			
Source	DF	MS	DF	MS	F value	Pr > F
Site	2	3.80	0.39	0.14	28.02	0.3806
Rep(Site)	14	0.45	24	0.67	0.68	0.7679
GF	2	0.19	4.42	0.32	0.60	0.5886
GF * Site	4	0.31	24	0.66	0.47	0.7591
Error	24	0.66				

Dependent Variable: SKEWNESS DBH

	Type IV		Denominator			
Source	DF	MS	DF	MS	F value	Pr > F
Site	2	0.37	3.53	0.30	1.23	0.3924
Rep(Site)	14	0.44	24	0.35	1.24	0.3102
GF	2	0.47	4.32	0.22	2.14	0.2265
GF * Site	4	0.22	24	0.35	0.62	0.6540
Error	24	0.35				

Dependent Variable: KURTOSIS DBH

	Type IV		Denominator			
Source	DF	MS	DF	MS	F value	Pr > F
Site	2	2.04	0	0.02	109.65	0.9942
Rep(Site)	14	1.06	24	2.05	0.51	0.9010
GF	2	2.67	4.47	0.90	2.97	0.1511
GF * Site	4	0.87	24	2.05	0.42	0.7896
Error	24	2.05				

APPENDIX 1d.

Random model analysis of height over sites in the 1979/1980 genetic gain trial

Dependent Variable: MEAN HEIGHT

	Type IV		Denominator			
Source	DF	MS	DF	MS	F value	Pr > F
Site	2	95.72	10.26	0.86	111.20	0.0001
Rep(Site)	14	0.78	24	0.25	3.05	0.0079
GF	2	7.98	4.13	0.38	20.73	0.0070
GF * Site	4	0.39	24	0.25	1.52	0.2270
Error	24	0.25				

Dependent Variable: STANDARD DEVIATION HEIGHT

	Type IV		Denominator			
Source	DF	MS	DF	MS	F value	Pr > F
Site	2	0.001	3.21	0.12	0.01	0.9918
Rep(Site)	14	0.59	24	0.07	0.81	0.6529
GF	2	0.36	4.10	0.14	2.62	0.1849
GF * Site	4	0.14	24	0.07	1.92	0.1396
Error	24	0.07				

Dependent Variable: SKEWNESS HEIGHT

	Type IV		Denominator			
Source	DF	MS	DF	MS	F value	Pr > F
Site	2	0.91	4.09	0.69	1.31	0.3627
Rep(Site)	14	0.49	24	0.43	1.12	0.3932
GF	2	0.23	4.13	0.65	0.36	0.7206
GF * Site	4	0.66	24	0.43	1.51	0.2294
Error	24	0.43				

Dependent Variable: KURTOSIS HEIGHT

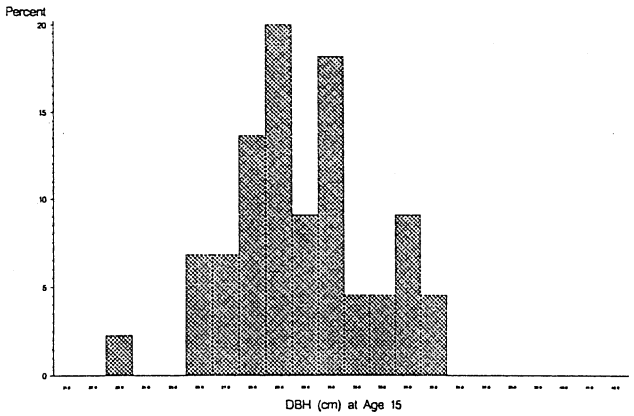
	Type IV		Denominator			
Source	DF	MS	DF	MS	F value	Pr > F
Site	2	2.46	4.43	2.77	0.89	0.4736
Rep(Site)	14	1.51	24	1.27	1.19	0.3439
GF	2	0.62	4.09	2.59	0.24	0.7959
GF * Site	4	2.62	24	1.27	2.06	0.1184
Error	24	1.27				

Appendix 2

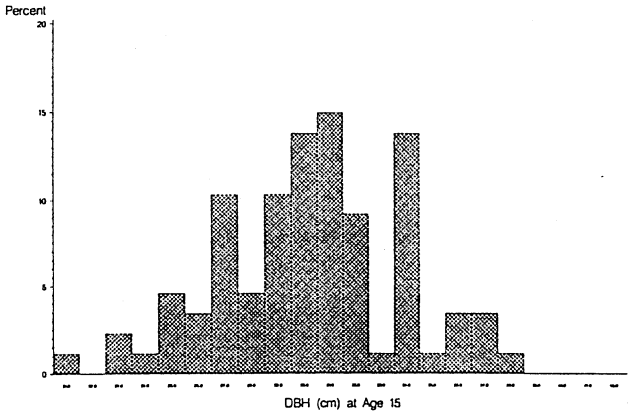
Diameter and height frequency distributions (ages 14, 15, or 16)
for several large-block trial sites

Appendix 2a

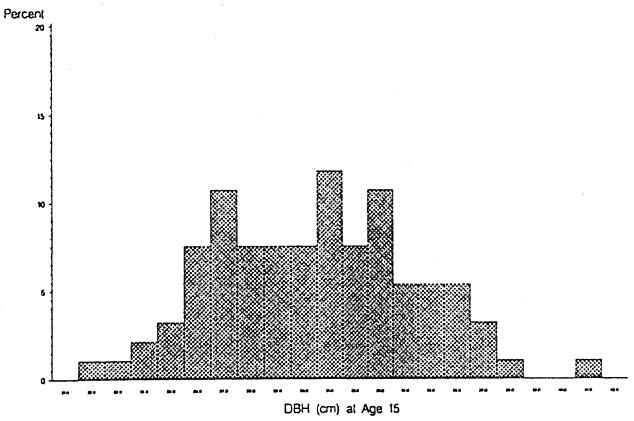
1978 Genetic Gain Trial NN 530/2
Golden Downs, Sawlog Regime
GF 2 : R74/1027



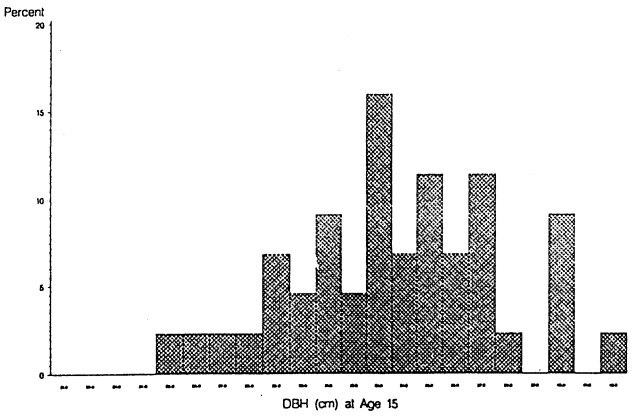
1978 Genetic Gain Trial NN 530/2
Golden Downs, Sawlog Regime
GF 7 : NN/C/75/2



1978 Genetic Gain Trial NN 530/2
Golden Downs, Sawlog Regime
GF 14 : WN/76/A2/3



1978 Genetic Gain Trial NN 530/2
Golden Downs, Sawlog Regime
GF 22 : 850 – 55x850 – 96

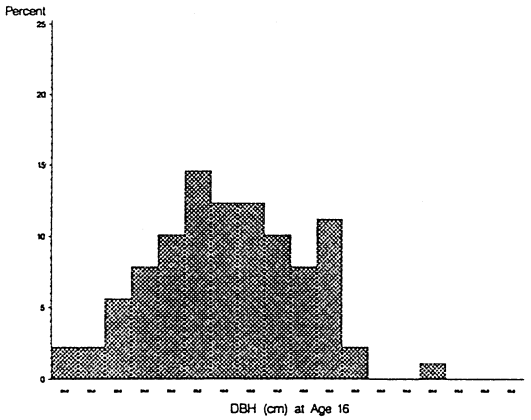


Diameter Range 21 - 42 cm

Appendix 2b

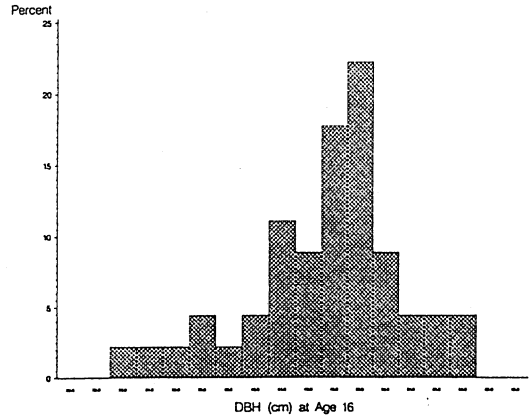
1978 Genetic Gain Trial WN 377
Mohaka, Sawlog Regime
GF 2 : R74/1027

1978 Genetic Gain Trial WN 377
Mohaka, Sawlog Regime
GF 7 : WN/C/75/15



1978 Genetic Gain Trial WN 377
Mohaka, Sawlog Regime
GF 14 : WN/76/A2/3

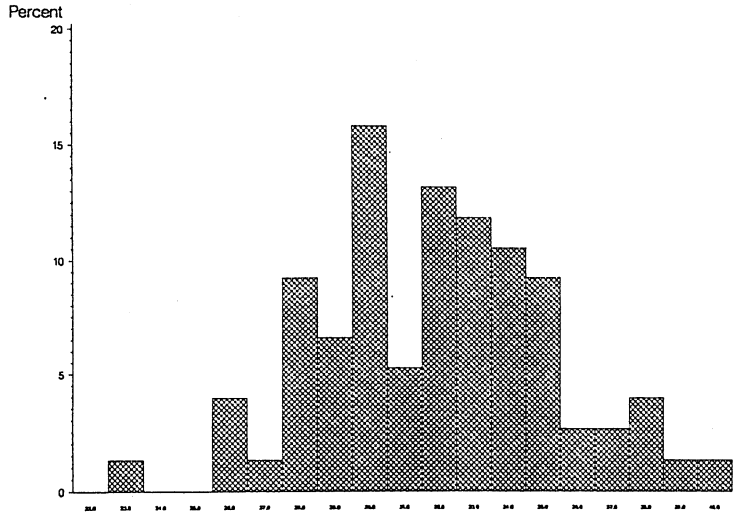
1978 Genetic Gain Trial WN 377
Mohaka, Sawlog Regime
GF 22 : 850 – 55x850 – 96



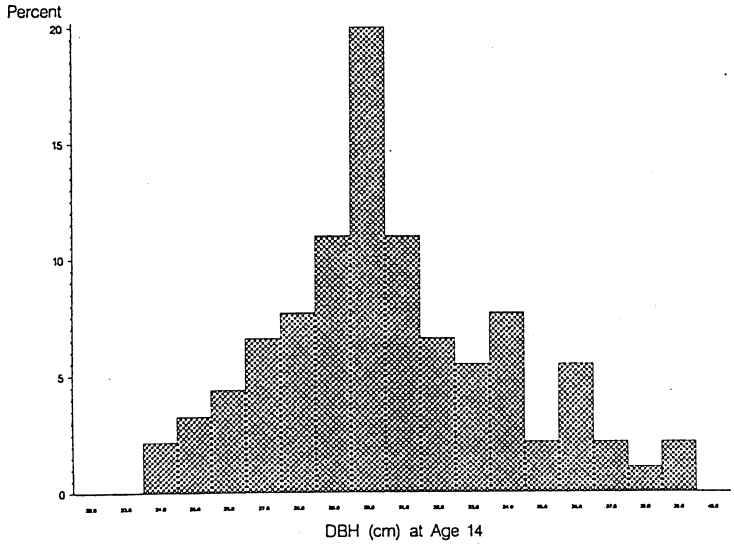
Diameter Range 28 - 62 cm

Appendix 2c

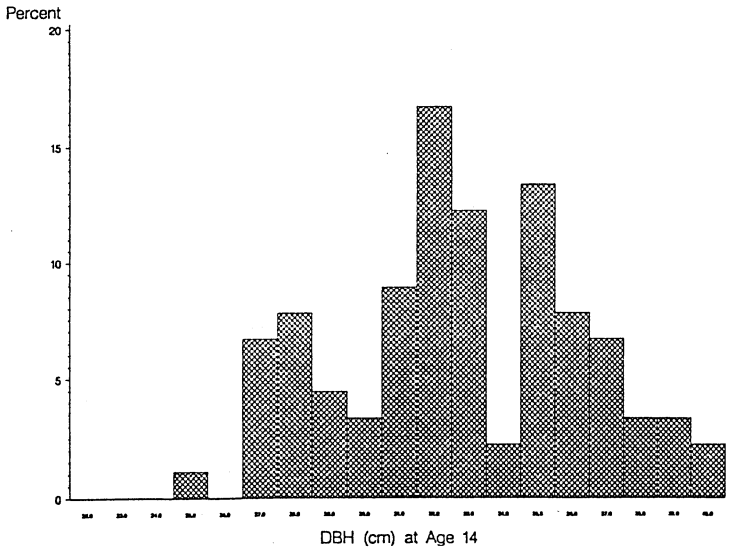
1979 Genetic Gain Trial NN 530/1
Golden Downs, Sawlog Regime
GF 7 : R/76/01



1979 Genetic Gain Trial NN 530/1
Golden Downs, Sawlog Regime
LI 19 (GF8) : FRI78/2301



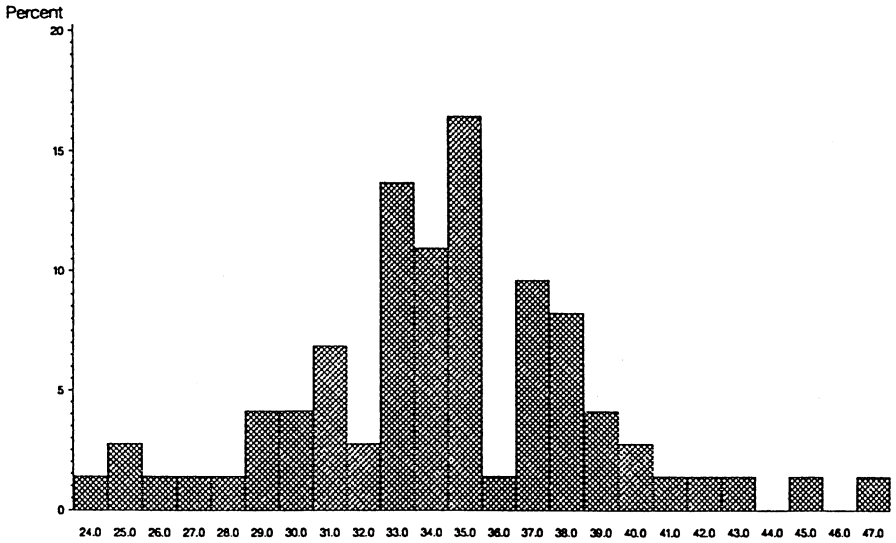
1979 Genetic Gain Trial NN 530/1
Golden Downs, Sawlog Regime
GF14: FRI78/2300



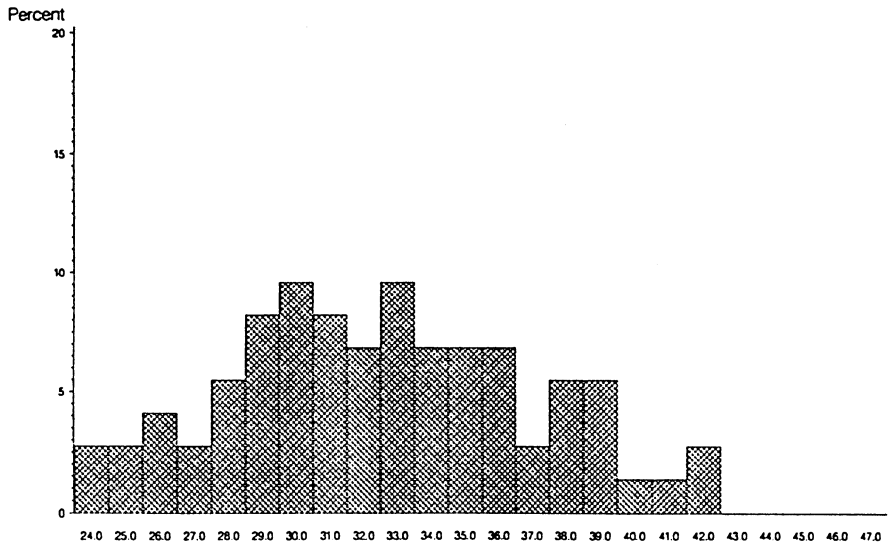
Diameter Range 23 - 40 cm

Appendix 2d

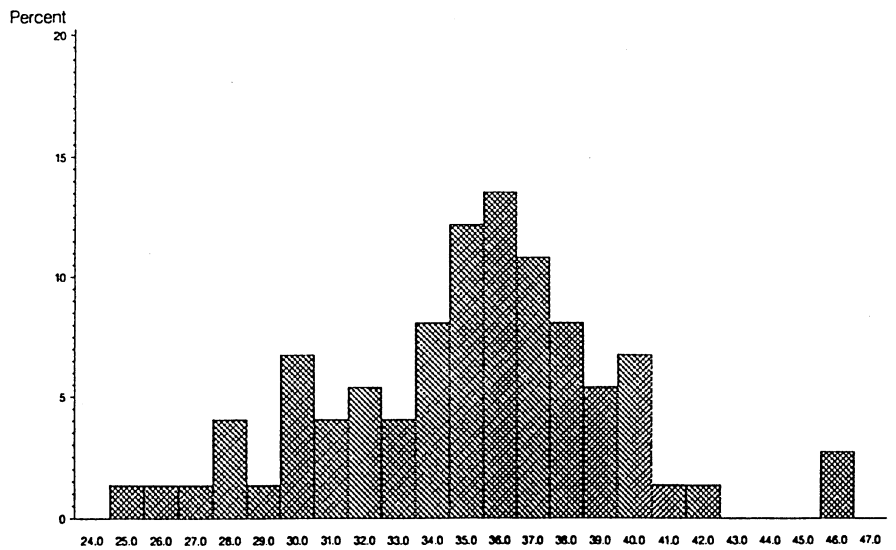
1979 Genetic Gain Trial RO 2103/3
Kaingaroa, Sawlog Regime
GF7 : R/76/01



1979 Genetic Gain Trial RO 2103/3
Kaingaroa, Sawlog Regime
LI19 (GF8) : FRI78/2301



1979 Genetic Gain Trial RO 2103/3
Kaingaroa, Sawlog Regime
GF14 : FRI78/2300

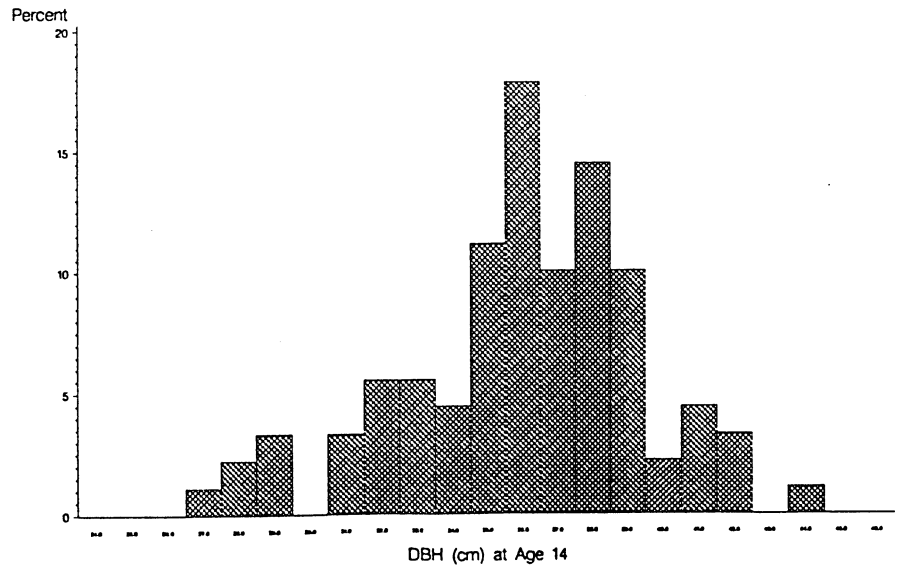


Appendix 2e

1980 Genetic Gain Trial SD 682
Dean, Sawlog Regime
GF7 : SD/C/76/2

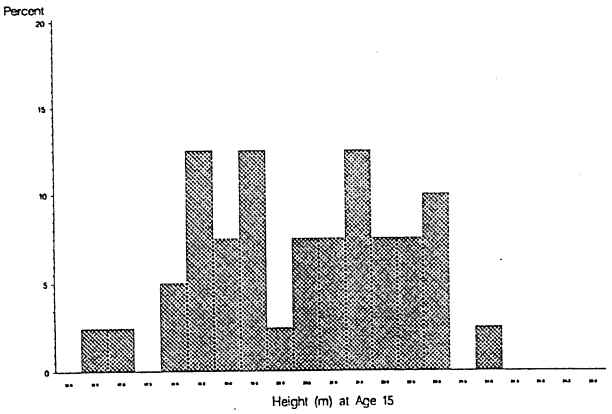
1980 Genetic Gain Trial SD 682
Dean, Sawlog Regime
LI19 (GF8) : FRI78/2301

1980 Genetic Gain Trial SD 682
Dean, Sawlog Regime
GF14: FRI78/2300

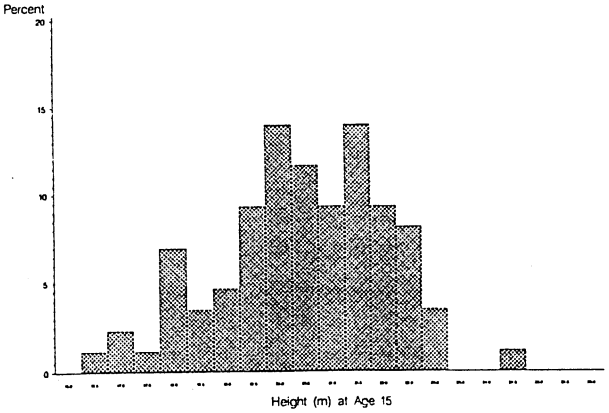


Appendix 2f

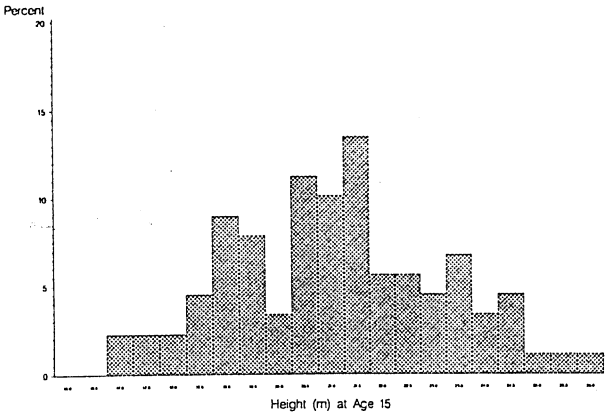
1978 Genetic Gain Trial NN 530/2
Golden Downs, Sawlog Regime
GF 2 : R74/1027



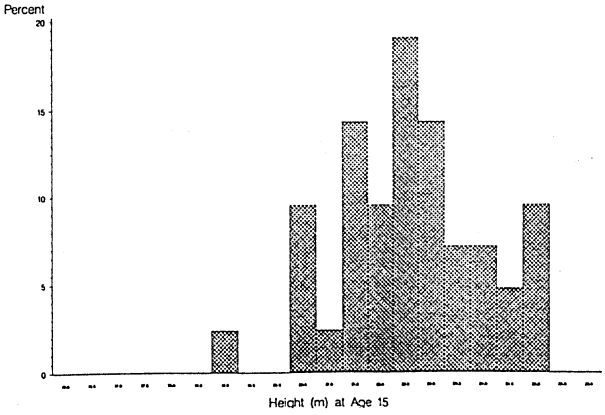
1978 Genetic Gain Trial NN 530/2
Golden Downs, Sawlog Regime
GF 7 : NN/C/75/2



1978 Genetic Gain Trial NN 530/2
Golden Downs, Sawlog Regime
GF 14 : WN/76/A2/3



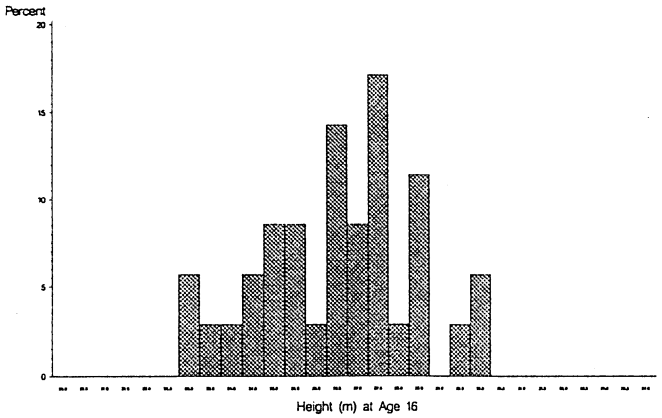
1978 Genetic Gain Trial NN 530/2
Golden Downs, Sawlog Regime
GF 22 : 850 – 55x850 – 96



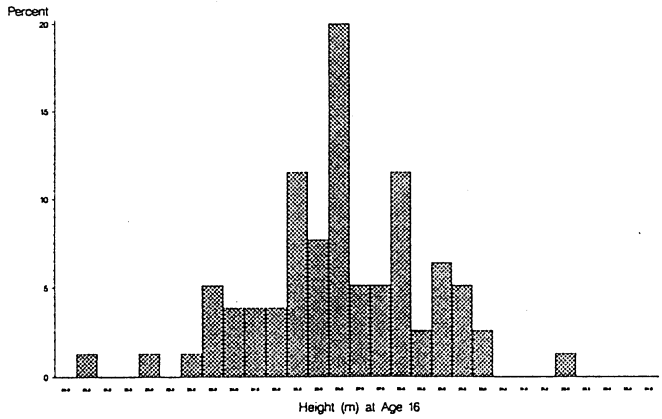
Height Range 16 - 26 m

Appendix 2g

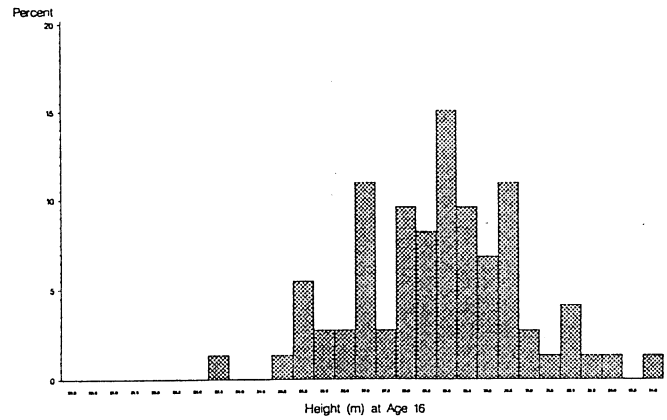
1978 Genetic Gain Trial WN 377
Mohaka, Sawlog Regime
GF 2 : R74/1027



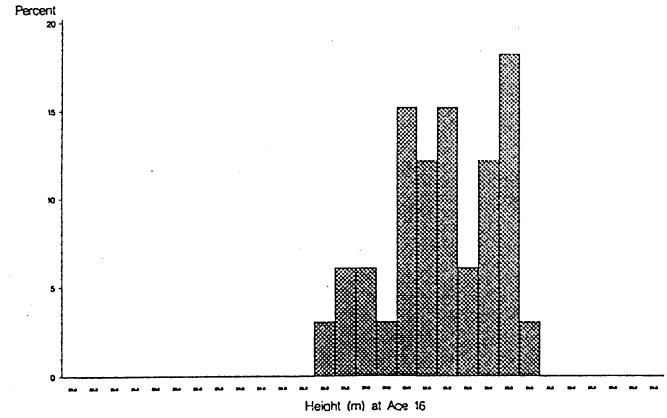
1978 Genetic Gain Trial WN 377
Mohaka, Sawlog Regime
GF 7 : WN/C/75/15



1978 Genetic Gain Trial WN 377
Mohaka, Sawlog Regime
GF 14 : WN/76/A2/3



1978 Genetic Gain Trial WN 377
Mohaka, Sawlog Regime
GF 22 : 850 – 55x850 – 96



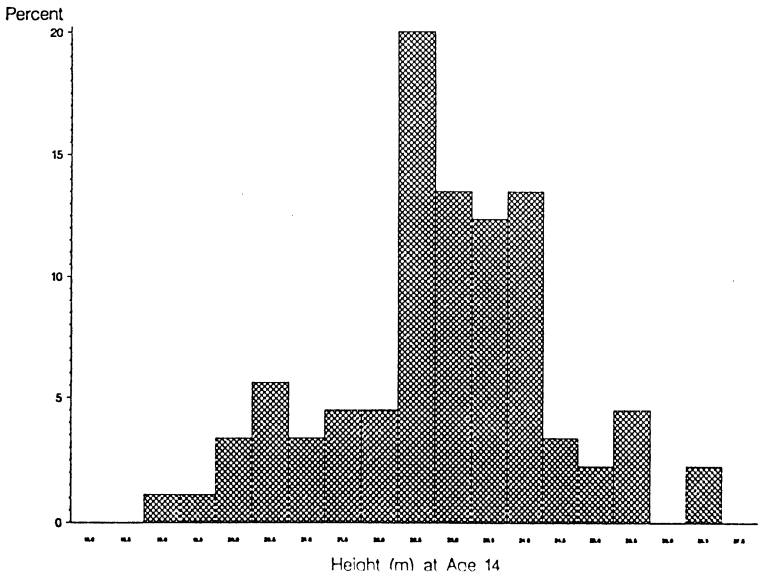
Height Range 20 - 34 m

Appendix 2h

1979 Genetic Gain Trial NN 530/1
Golden Downs, Sawlog Regime
GF 7 : R/76/01

1979 Genetic Gain Trial NN 530/1
Golden Downs, Sawlog Regime
LI 19 (GF8) : FRI78/2301

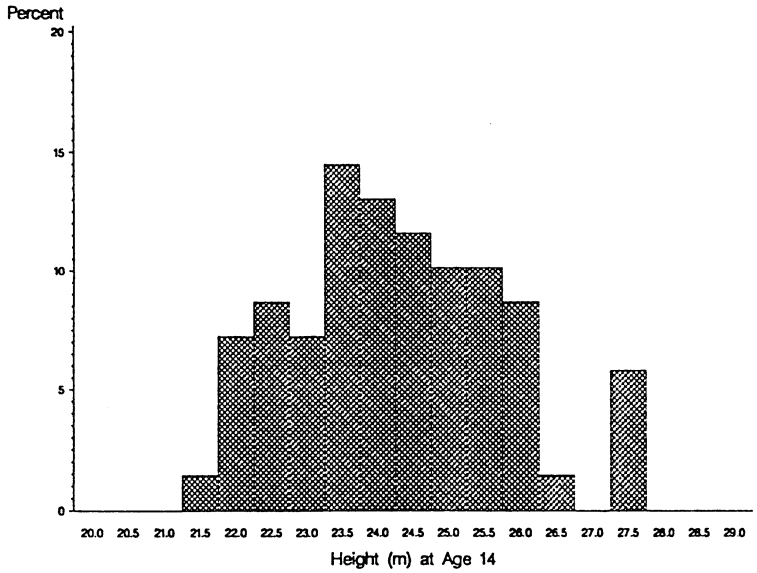
1979 Genetic Gain Trial NN 530/1
Golden Downs, Sawlog Regime
GF14: FRI78/2300



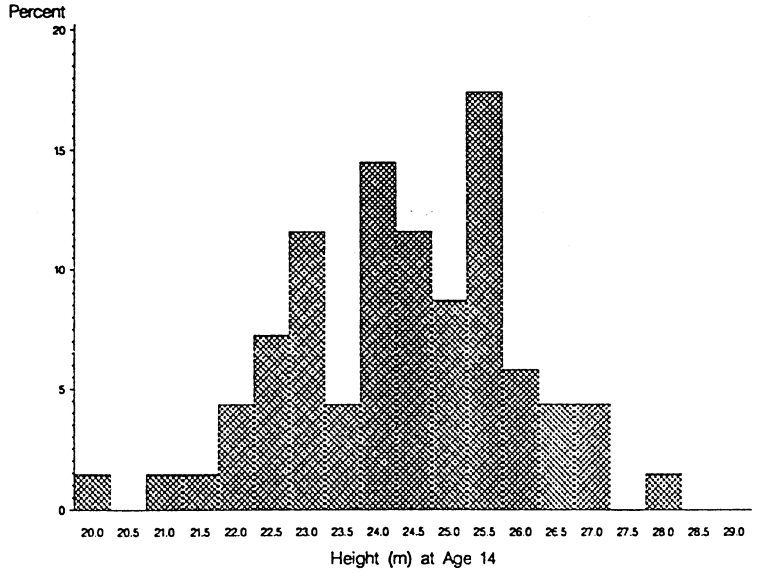
Height Range 18 - 27 m

Appendix 2i

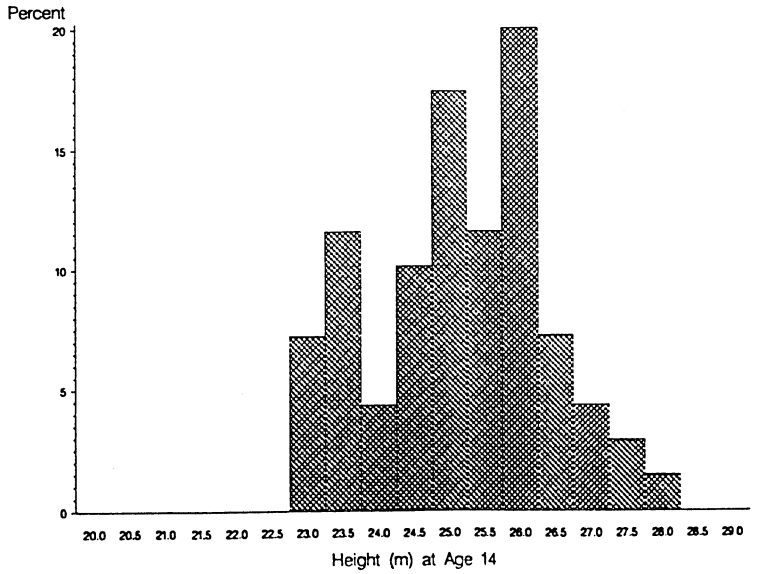
1979 Genetic Gain Trial RO 2103/3
Kaingaroa, Sawlog Regime
GF7 : R/76/01



1979 Genetic Gain Trial RO 2103/3
Kaingaroa, Sawlog Regime
LI19 (GF8) : FRI78/2301

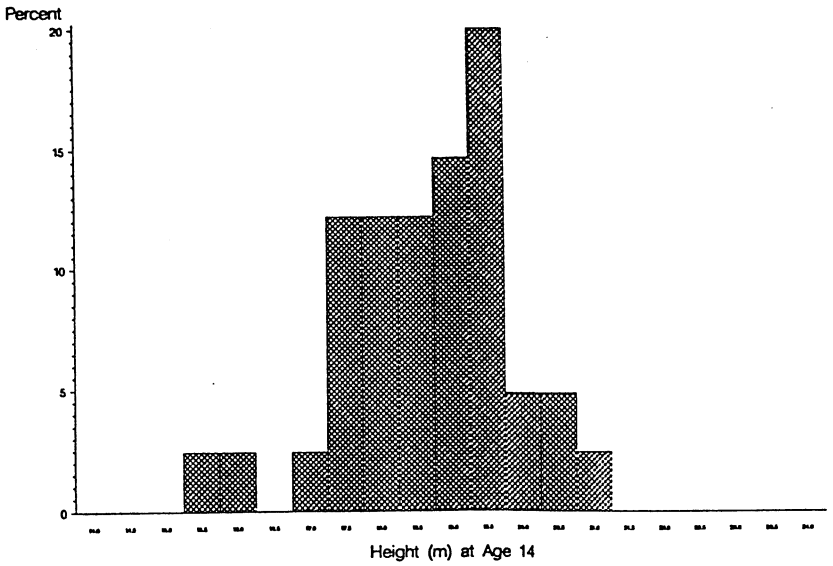


1979 Genetic Gain Trial RO 2103/3
Kaingaroa, Sawlog Regime
GF14 : FRI78/2300

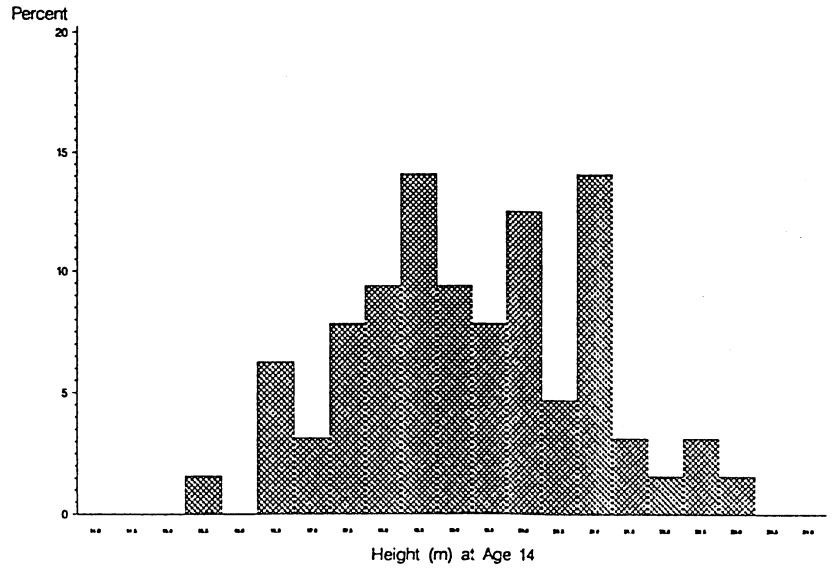


Appendix 2j

1980 Genetic Gain Trial SD 682
Dean, Sawlog Regime
GF7 : SD/C/76/2

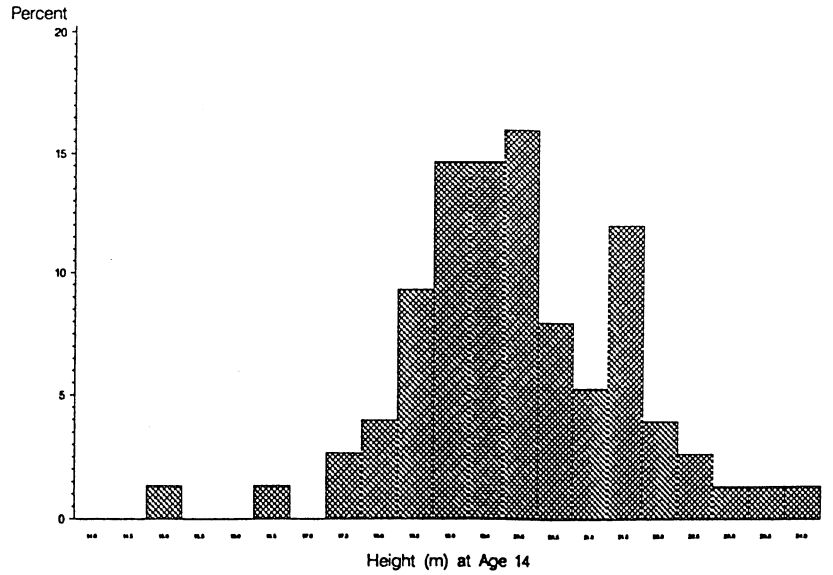


1980 Genetic Gain Trial SD 682
Dean, Sawlog Regime
LI19 (GF8) : FRI78/2301



1980 Genetic Gain Trial SD 682
Dean, Sawlog Regime

GF14: FRI78/2300



Appendix 3

Appendix 3. Analysis of variance for mean, standard deviation, skewness and kurtosis of diameter and height over ages 5 and 8-16 (random model)

APPENDIX 3a.

Random model analysis of diameter over age in the 1978 Kaingaroa pulpwood regime (RO 2103/2)

Dependent Variable: MEAN DBH

	Type IV		Denominator			
Source	DF	MS	DF	MS	F value	Pr > F
Age	10	672.98	15.07	1.47	457.58	0.0001
Rep	5	4.01	16.14	1.69	2.36	0.0865
GF	3	18.01	28.55	2.82	6.37	0.0019
Age * Rep	45	0.14	64	0.14	0.98	0.5160
GF * Age	15	1.55	64	0.14	11.00	0.0001
GF * Rep	15	2.92	64	0.14	20.71	0.0001
Error	64	0.14				

Dependent Variable: STANDARD DEVIATION DBH

	Type IV		Denominator			
Source	DF	MS	DF	MS	F value	Pr > F
Age	10	33.31	14.74	0.19	173.33	0.0001
Rep	5	3.02	16	1.47	2.05	0.1254
GF	3	3.23	17.48	1.52	2.12	0.1339
Age * Rep	45	0.11	64	0.10	1.05	0.4198
GF * Age	15	0.19	64	0.10	1.91	0.0385
GF * Rep	15	2.55	64	0.10	25.28	0.0001
Error	64	0.10				

Dependent Variable: SKEWNESS DBH

	Type IV		Denominator			
Source	DF	MS	DF	MS	F value	Pr > F
Age	10	0.33	12.51	0.09	3.83	0.0143
Rep	5	0.23	17.37	0.26	0.91	0.4970
GF	3	0.22	21.14	0.29	0.77	0.5243
Age * Rep	45	0.43	64	0.05	0.86	0.7018
GF * Age	15	0.09	64	0.05	1.89	0.0410
GF * Rep	15	0.43	64	0.05	8.60	0.0001
Error	64	0.05				

Dependent Variable: KURTOSIS DBH

	Type IV		Denominator			
Source	DF	MS	DF	MS	F value	Pr > F
Age	10	0.07	2.43	0.07	0.96	0.5965
Rep	5	0.74	17.71	0.95	0.77	0.5786
GF	3	0.81	15.20	0.87	0.93	0.4501
Age * Rep	45	0.18	64	0.26	0.71	0.8831
GF * Age	15	0.13	64	0.26	0.52	0.9221
GF * Rep	15	1.56	64	0.26	6.11	0.0001
Error	64	0.26				

APPENDIX 3b.

Random model analysis of height over age in the 1978 Kaingaroa pulpwood regime (RO 2103/2)

Dependent Variable: MEAN HEIGHT

	Type IV		Denominator			
Source	DF	MS	DF	MS	F value	Pr > F
Age	9	841.84	15.31	.024	3548.00	0.0001
Rep	5	1.24	17.43	0.74	1.67	0.1943
GF	3	2.70	20.44	0.81	3.32	0.0403
Age * Rep	45	0.12	64	0.10	1.20	0.2446
GF * Age	15	0.22	64	0.10	2.14	0.0187
GF * Rep	15	1.23	64	0.10	12.21	0.0001
Error	64	0.10				

Dependent Variable: STANDARD DEVIATION HEIGHT

	Type IV		Denominator			
Source	DF	MS	DF	MS	F value	Pr > F
Age	9	1.92	15.79	0.11	17.28	0.0001
Rep	5	0.80	22.63	0.17	0.51	0.7679
GF	3	0.14	22.76	0.19	0.76	0.5267
Age * Rep	45	0.07	64	0.06	1.28	0.1774
GF * Age	15	0.10	64	0.06	1.70	0.0745
GF * Rep	15	0.24	64	0.06	4.28	0.0001
Error	64	0.06				

Dependent Variable: SKEWNESS HEIGHT

	Type IV		Denominator			
Source	DF	MS	DF	MS	F value	Pr > F
Age	9	0.38	5.07	0.11	3.55	0.0867
Rep	5	0.95	17.31	1.25	0.76	0.5914
GF	3	0.57	15.39	1.16	0.48	0.6963
Age * Rep	45	0.19	64	0.21	0.96	0.5458
GF * Age	15	0.12	64	0.21	0.57	0.8892
GF * Rep	15	2.08	64	0.21	10.07	0.0001
Error	64	0.21				

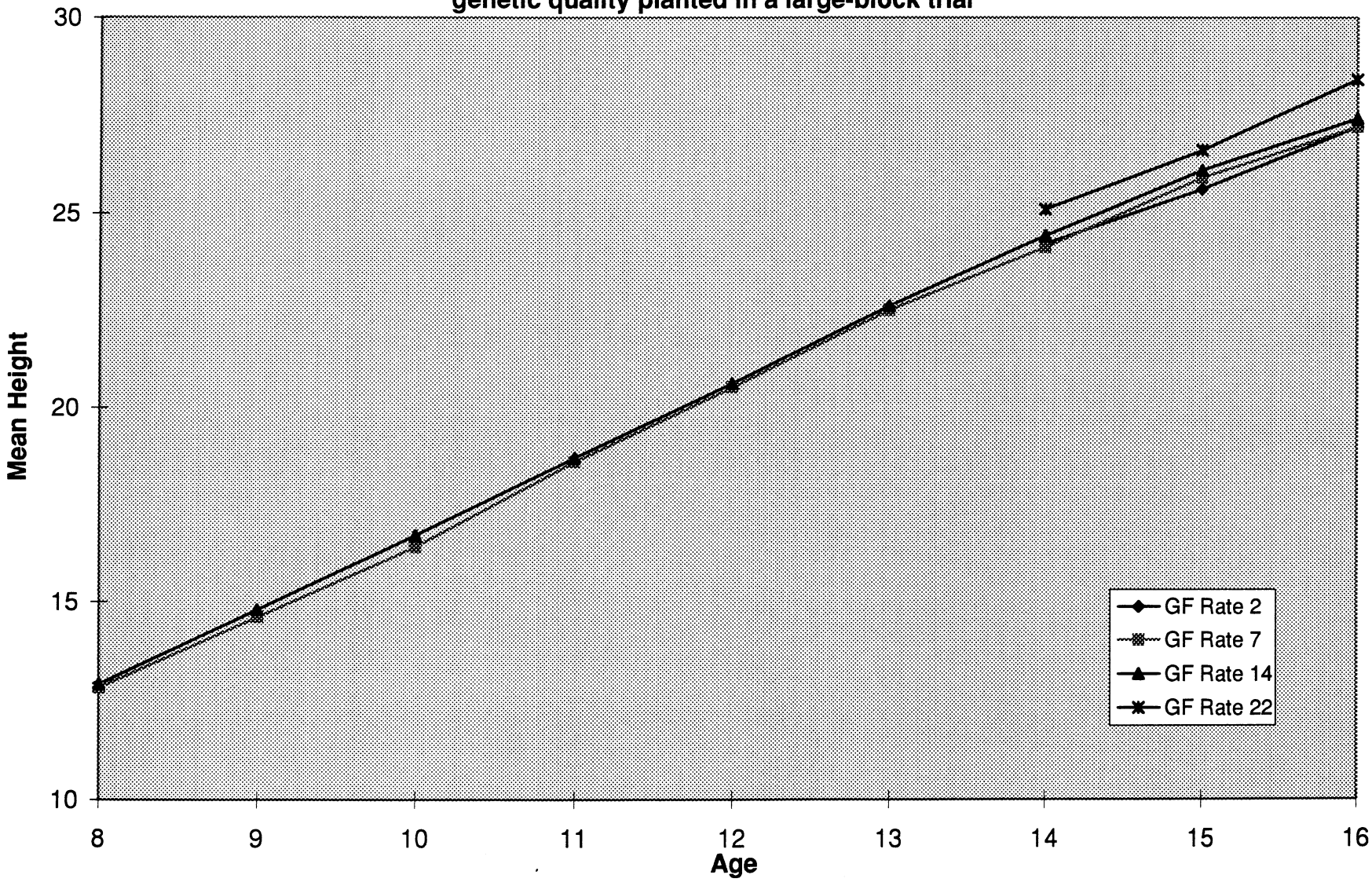
Dependent Variable: KURTOSIS HEIGHT

	Type IV		Denominator			
Source	DF	MS	DF	MS	F value	Pr > F
Age	9	1.13	3.23	0.55	2.05	0.2887
Rep	5	1.52	20.59	2.91	0.52	0.7568
GF	3	0.91	16.02	2.61	0.35	0.7923
Age * Rep	45	1.04	64	1.33	0.78	0.8105
GF * Age	15	0.83	64	1.33	0.63	0.8429
GF * Rep	15	4.42	64	1.33	3.32	0.0004
Error	64	1.33				

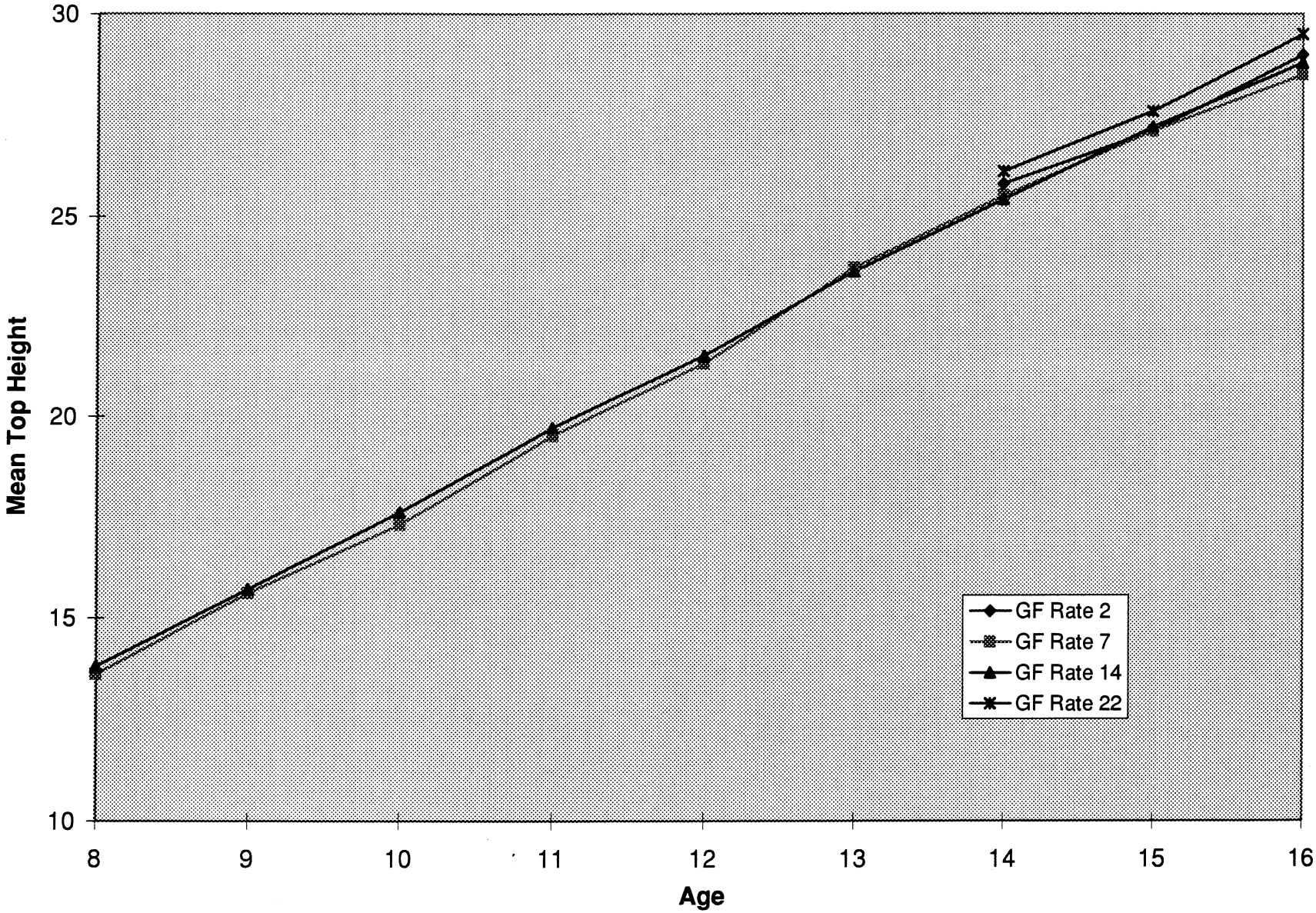
Appendix 4

Diameter, mean top diameter, height and mean top height of seedlots in the large-block trial RO 2103/1.

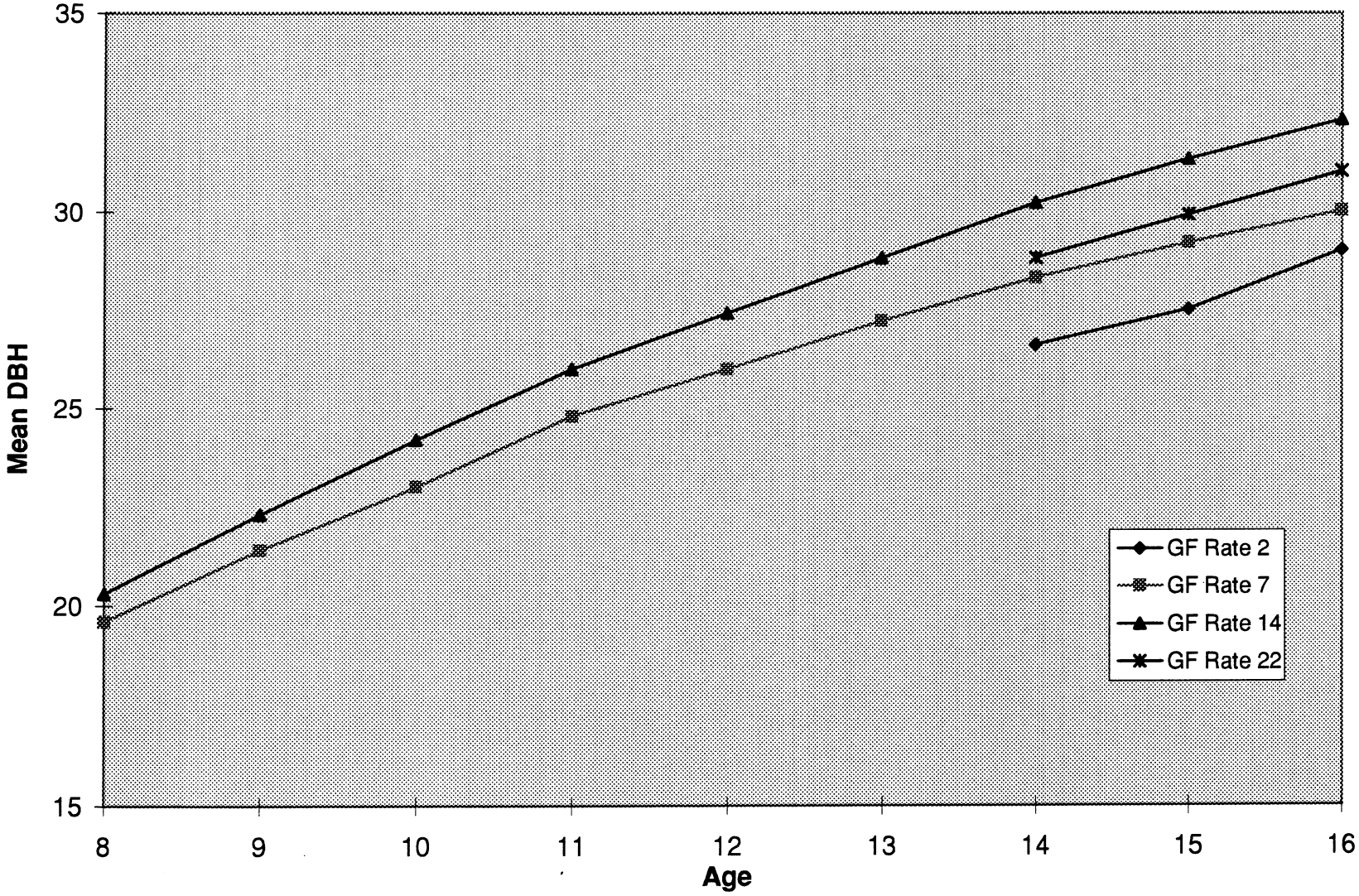
Appendix 4a. **Mean height, MTH, mean DBH and MTD of four seedlots of different genetic quality planted in a large-block trial**



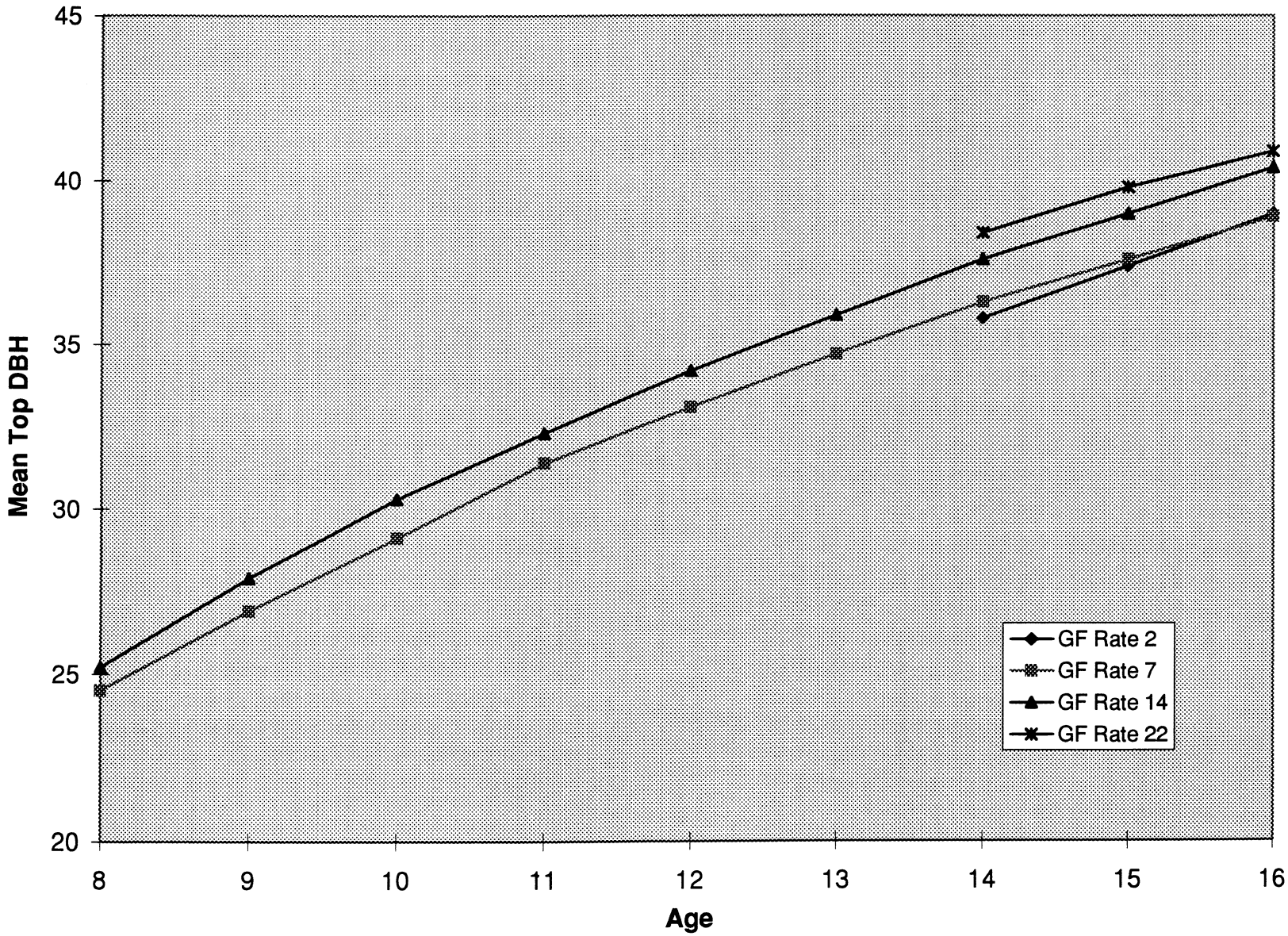
Appendix 4b.


30
25
20
15
10
Mean Top Height
8
9
10
11
12
13
14
15
16
Age
GF Rate 2
GF Rate 7
GF Rate 14
GF Rate 22

Appendix 4c.


35
30
25
20
15
Mean DBH
8
9
10
11
12
13
14
15
16
Age
GF Rate 2
GF Rate 7
GF Rate 14
GF Rate 22

Appendix 4d.


45
40
35
30
25
20
Mean Top DBH
8
9
10
11
12
13
14
15
16
Age
GF Rate 2
GF Rate 7
GF Rate 14
GF Rate 22