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THE EFFECT OF SILVICULTURE ON GENETIC GAIN IN GROWTH of *Pinus radiata* AT ONE-THIRD ROTATION

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EXECUTIVE SUMMARY

A trial planted on six sites representing five growth modelling regions and a range of site qualities in New Zealand was used to examine silviculture by seedlot interaction. Four seedlots with differing genetic potential for growth were grown under six different silvicultural regimes, including four stocking treatments from 100 to 600 stems per ha with a standard thinning ratio, and pruned and unpruned treatments. Differences among sites were large for mean top height (8.1-13.7m), basal area (8-20m^2/ha) and volume (25-100m^3/ha) at age eight from planting. Differences among silvicultural treatments were large for basal area (4-17m^2/ha) and volume (17-86m^3/ha), and smaller but significant for mean top height (10.1-11.6m), with increased growth at higher stockings. Differences among seedlots were statistically significant for all traits, but larger for basal area (11.7-13.2m^2/ha) and volume (49.1-57.1m^3/ha) than for height (10.6-11.1m). The influence of site and silviculture on tree growth was much larger than the influence of genetics, with differences in basal area and volume among sites and silvicultural regimes being on average about eight times greater than differences among seedlots. Genetically different seedlots performed similarly relative to each other over the range of sites and silviculture, with a non-significant silviculture by seedlot interaction in every analysis.

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ABSTRACT

A trial planted on six sites representing five growth modelling regions and a range of site qualities in New Zealand was used to examine silviculture by seedlot interaction. Four seedlots with differing genetic potential for growth were grown under six different silvicultural regimes, including four stocking treatments from 100 to 600 stems per ha with a standard thinning ratio, and pruned and unpruned treatments. Differences among sites were large for mean top height (8.1-13.7m), basal area (8-20m^2/ha) and volume (25-100m^3/ha) at age eight from planting. Differences among silvicultural treatments were large for basal area (4-17m^2/ha) and volume (17-86m^3/ha), and smaller but significant for mean top height (10.1-11.6m), with increased growth at higher stockings. Differences among seedlots were statistically significant for all traits, but larger for basal area (11.7-13.2m^2/ha) and volume (49.1-57.1m^3/ha) than for height (10.6-11.1m). The influence of site and silviculture on tree growth was much larger than the influence of genetics, with differences in basal area and volume among sites and silvicultural regimes being on average about eight times greater than differences among seedlots. Genetically different seedlots performed similarly relative to each other over the range of sites and silviculture, with a non-significant silviculture by seedlot interaction in every analysis.

INTRODUCTION

The genetic gain multipliers developed for *Pinus radiata* D. Don are being used to predict yield for stands with silviculture or site characteristics not represented in the data base used for their development (Carson et al. 1997). Use of the multipliers in this way also requires the assumption that growth rate increases must be assumed to be constant over regions, site qualities and silvicultural regimes.

The assumption that growth rates of genetically improved stock do not change with silviculture was supported by the similarity of the multipliers estimated for the pulpwood regime to those from the sawlog regime in the 1978 genetic gain trial series (Carson *et al.* 1997), but this assumption requires further testing. Other studies comparing genetically different seedlots of forest tree species planted at different spacings (Campbell and Wilson 1973, Campbell et al. 1986, Nance et al. 1983, Panetsos 1980, Stonecypher and McCullough 1981) have yielded conflicting results. All of these studies involved relatively few trees measured at young ages and involved either seedlings planted at extremely close spacing or trees in a Nelder design, making inferences to mature plantations difficult.

The 1987 Silviculture/Breeds trials (Skinner *et al.* 1994) are planted on six sites representing five forest regions and contrasting site qualities. A range of silvicultural regimes applied to seedlots of differing genetic worth provides the opportunity to examine the assumption of no differences in genetic gain among sites and silvicultural treatments. Therefore, the aim of this analysis is to further examine the effect of site and silviculture on genetic gain using data from the 1987 Silviculture/Breeds trials at age eight after planting, which is approximately one-third of a rotation.

METHODS

A field trial was planted in 1987 on six sites in five forest regions covering a range of latitudes and a number of site types in New Zealand (Table 1). Six silvicultural treatments were included at each site (Table 2) with a comparison of the effect of final stockings of 100, 200, 400, and 600 stems per hectare with all treatments thinned from an initial to final stocking ratio of 2.5:1 (for all stockings except the 100 stems per hectare treatment at Woodhill, Tahorakuri, and Glengarry, which were established at 500 stems per ha). There were two further treatments comparing pruned and unpruned trees, both planted at 500 stems per hectare with no thinning. However, this comparison was not available at Tahorakuri and Glengarry where the pruned treatment was mistakenly thinned to 200 stems per hectare.

Four seedlots were included in the trial (Table 3) with a balanced comparison of seedlots across all silvicultural treatments and sites. All seedlings were raised in the

FRI nursery in the North Island in five replicated plots and shipped to each site for planting. Each seedlot was treated with each silvicultural treatment in two replicated plots at each trial location. Outer plot rows were planted with open-pollinated orchard seedlot 2/3/85/12, which is very similar to the seedlot 3/3/85/1 in the main experiment, so that all plots had an outer border row of this seedlot and an inner border row of the treatment seedlot. All treatment combinations were randomly allocated to field replications in an incomplete block design. Weed control was applied according to the standard for the forest in which the trial was planted.

Thinning and pruning was carried out in all trials when the approximate average mean crop height of the trial reached 6.2m. Selection of crop trees was for freedom from malformation, large tree size, stem straightness and spacing. Pruning was to leave 4m of green crown, except at Glengarry and Tahorakuri, where it was to a 10cm diameter gauge, and resulted in a similar level of pruning. One permanent sample plot (Dunlop 1995, Ellis and Hayes 1997) in each replication of each treatment was established just before thinning, after which each plot had approximately 25 trees remaining. Diameter of all trees and total height of a sample of about twelve trees per plot were measured annually during winter. Basal area, mean top height, and volume were calculated using standard mensurational methods (Dunlop 1995, Ellis and Hayes 1997).

Plot mean top height (MTH), basal area (BA), and volume at eight years from planting were examined using analysis of variance, both over all sites and for each site individually. For the analyses over all sites, sources of variation included main effects of site, replication within site, silviculture, and seedlot; and also included were the interaction effects of site by silviculture, site by seedlot, silviculture by seedlot, and the three-way interaction. For analyses on individual sites, sources of variation included main effects of replication, silviculture, and seedlot, and a silviculture by seedlot interaction.

RESULTS

Differences Among Sites

Site differences were large and significant for all traits ($P<0.0001$), with site means ranging from 8.1-13.7m for MTH, 8.0-21.1m^2/ha for BA, and 25.2-105.9m^3/ha for volume (Table 4, 5, 6 and 7).

Differences Among Silvicultural Treatments

Overall average differences among silvicultural treatments were large for BA (4.3-18.8m^2/ha) and volume (17.0-85.4m^3/ha) and significant in the combined analysis for all traits including MTH, with a range of 10.1-11.6m (Table 5, 6, 7 and 8). Differences among silvicultural treatments on individual sites were significant ($P<0.0001$) for all traits, except for MTH at Ditchlings and Otago Coast (Figures 1, 2 and 3, Appendix 1).

Overall mean height increased in the thinned treatments as stocking increased from 100 to 600 stems per hectare (Table 8 & Figure 1). Height was not significantly different between the pruned and unpruned treatments either in the overall analysis or in the individual site analyses (Table 5 and 8, and Appendix 1).

Differences in BA among silvicultural treatments correspond very closely to the corresponding differences in volume. Differences in BA and volume among stocking treatments were very large, with substantially increasing BA and volume in the thinned treatments with higher stocking (Table 8, Figures 2 and 3). BA and volume was significantly lower in the pruned than the unpruned treatments. The significant site by silviculture interaction for BA and volume (Table 6 and 7) probably arose from increases in variance associated with increasing differences among silviculture treatments as the site mean increased.

Differences among seedlots

Differences among seedlots were significant for all traits when all data was combined (Table 5, 6, 7 and 9), with seedlot means ranging from 10.7-11.1m for height ($P<0.05$), 12.1-13.5m^2/ha for basal area ($P<0.0001$), and 51.1-58.7m^3/ha for volume ($P<0.0001$). Differences among seedlots were relatively small for height (Table 9) and statistically significant in individual site analyses only at Kaingaroa and Glengarry

(Appendix 1). Differences among seedlots in BA and volume (Table 9) were larger and statistically significant in all individual site analyses for BA ($P<0.05$), and for all individual site analyses for volume ($P<0.05$) except Otago Coast (Appendix 1).

The significant site by seedlot interaction for BA ($P<0.05$) (Table 6) and volume ($P<0.01$) (Table 7) (but not for height, Table 5) were associated with relatively small F-ratios. The significant interactions probably arose from the performance of the long internode seedlot being about the same as the climbing select seedlot at most sites, but worse at Glengarry, and relatively better at Ditchlings for both traits (Figure 4, 5 and 6). The relative ranking of the multinodal seedlots did not appear to differ significantly with site. A difference in variance among seedlots at the different sites (with a slight trend toward larger variance at the faster growth sites) may be also contributing to the significant interaction.

Silviculture by seedlot interaction

The silviculture by seedlot interaction was not significant for MTH, BA, or volume in any analysis (Table 5, 6, and 7, Appendix 1), although there may be a trend toward genetic differences among seedlots being very slightly larger in the faster growing silvicultural treatments (Figures 7, 8 and 9).

Relative magnitude of site, silviculture and seedlot differences

Differences in MTH among sites were 2-6 times as large as differences among silvicultural treatments (Figure 10). In contrast, differences among silvicultural treatments in BA and volume were on average of similar magnitude to site differences (Figures 11 and 12), although on the fastest growing site, differences in BA and volume among silvicultural treatments were almost twice as great as the average differences among sites.

Differences in MTH among sites were 6-14 times greater than genetic differences and silvicultural treatment differences were 1.5 to 4.6 times greater than genetic differences (Figure 10). Differences in BA and volume among sites and differences among silvicultural treatments were on average about eight times greater than genetic differences (Figures 11 and 12).

DISCUSSION

Effects of site and silviculture had the expected effects on basal area and volume in the trials reported here. Site and silviculture both had large effects on growth. Basal area and volume increased with increasing stocking in the thinned treatments, and were greater in plots which were unpruned than those which were pruned.

Height differences among silvicultural treatments were significant, with similar trends to those observed for basal area and volume, that is, a consistant trend with increasing stocking.

Genetic differences in basal area and volume were greater than differences in mean top height, which is consistent with other *P. radiata* trials (Carson et al 1997). The relative ranking of the multinodal seedlots did not appear to differ significantly with site, but the uninodal seedlot had variable performance. The multinodal climbing select and the long-internode seedlots tended to preform similarly. The multinodal open-pollinated and control-pollinated seedlots tended to preform similarly, and were clearly superior to the climbing select and long-internode seedlots. Differences among seedlots are expected to increase as the trials age, as has been observed in other trials.

The control-pollinated seedlot was rated a GF21, but relative to the open-pollinated seedlot (GF14) did not perform as well as the control-pollinated seedlot rated GF22 in the 1978 genetic gain trials (the only seedlot used to estimate the GF22 multiplier to date) (Carson et al. 1997). Linear extrapolation of growth rate of seedlots with GF ratings higher than a GF22 using existing multiplier estimates, therefore, may be overestimated. The confounding of genetic worth for growth and stem form in the GF rating contributes to this anomaly because the GF22 in the 1978 genetic gain trials is better for growth but not as good for form as the GF21 seedlot in the 1987 trials. For example, the diameter rating of the GF22 (4.84) in the 1978 genetic gain trials is substantially larger than for the GF21 (3.08) (Table 3) in the 1987 trials, but the straightness rating for GF22 (0.22) is substantially smaller than for the GF21 (0.65).

There was no suggestion at one-third rotation of a genotype by silviculture interaction. Genetic gain was similar with all silvicultural treatments even though they produced very different growth. There may have been a trend toward greater differences among seedlots on the faster growing sites and silvicultural treatments, but this was slight and not statistically significant.

Differences in tree growth which can be attributed to genetic differences among seedlots are relatively small in comparison to differences in tree growth attributed to site and to silviculture. Predictive models must accurately take the effects of site and silviculture into account before predictions of genetic gain in growth will be valid. Growth models are best developed from data representing a range of sites and silviculture, rather than, for example, from progeny trials which are all treated with a similar silvicultural regime and planted on only a few sites.

CONCLUSIONS

Site and silviculture had a much larger effect on tree growth at one-third rotation than genetic differences among seedlots. Genetically different seedlots performed similarly relative to each other over a wide range of sites and silviculture. Data from this trial should be re-examined when the trees are older, when genetic differences can be expected to be showing a cumulative effect of the impact of crown closure.

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Table 1. Trial sites.

Region	Forest	Latitude	Site	Age of thinning
Northland sands	Woodhill	36° 30'	Medium SI	5.6
Central North Island	Tahorakuri	38° 20'	Medium SI	4.9
Central North Island	Kaingaroa	38° 40'	Low SI	6.8
Hawkes Bay	Glengarry	39° 10'	High BA	4.8
Nelson	Ditchlings	41° 30'	Low SI	5.7
Southland	Otago Coast	46° 00'	High BA	6.9

Table 2. Silvicultural treatments.

Treatment	Stems/ha (final)[1]	Thinned[2]	Pruned[3]	Outer plot size	Inner plot size	No. trees[4]
1	100	yes	yes	0.324	0.196	98
2	200	yes	yes	0.162	0.098	49
3	400	yes	yes	0.081	0.049	49
4	600	yes	yes	0.081	0.051	77
5	500	no	no	0.162	0.098	49
6	500	no	yes	0.162	0.098	49

1. All thinned treatments had thinning ratio of 2.5:1, except for the 100 stems per ha treatment which had an initial stocking of 500 stems per ha at Woodhill, Tahorakuri, and Glengarry, and 250 stems per ha at Kaingaroa, Ditchlings, and Otago Coast.
2. Thinning was carried out at approximately 6.2m mean crop height.
3. Low pruning only.
4. Number of trees in inner plot before thinning.

Table 3. Seedlots.

Number	Growth and Form rating	Diameter rating	Breed	Origin
FRI 79/2320	GF7	-4.09	multinodal	climbing select collection from land race
9/3/86/166	LI28(GF13)	not available	long internode	control-pollination of the "best" five clones
3/3/85/1	GF14	0.52	multinodal	open-pollinated, unrogued, first generation clonal seed orchard
6/3/86/46	GF21	3.08	multinodal	control-pollination of 11 highly ranked mothers with 21 fathers

Table 4. Overall average mean top height, basal area, and volume for sites. Values followed by the same letter do not differ significantly (P=0.05).

Site	Mean top height (m)	Basal area (m^2/ha)	Volume (m^3/ha)
Kaingaroa	8.24 a	7.95 a	25.21 a
Otago Coast	8.07 a	9.35 b	30.22 a
Woodhill	11.14 b	11.01 c	41.64 b
Ditchlings	10.98 b	12.51 d	53.24 c
Tahorakuri	13.10 c	14.73 e	72.02 d
Glengarry	13.88 c	21.09 f	105.90 e

Table 5. Analysis of variance for mean top mean top height across all sites.

Source	df	MS	F	Pr>F
Site	5	256.24	78.29	0.0001
Replication(site)	6	3.27	2.84	0.0121
Silviculture	5	18.27	15.87	0.0001
Site x silviculture	23	1.27	1.11	0.3452
Seedlot	3	3.81	3.31	0.022
Site x seedlot	15	0.55	0.48	0.9482
Silviculture x seedlot	15	1.07	0.93	0.5292
Site x silviculture x seedlot	69	0.92	0.80	0.8468
Error	141	1.15		

Table 6. Analysis of variance for basal area across all sites.

Source	df	MS	F	Pr>F
Site	5	823.60	126.18	0.0001
Replication(site)	6	6.53	3.77	0.0016
Silviculture	5	1484.27	856.73	0.0001
Site x silviculture	23	47.23	27.26	0.0001
Seedlot	3	42.24	24.38	0.0001
Site x seedlot	15	3.72	2.15	0.0109
Silviculture x seedlot	15	2.95	1.70	0.0563
Site x silviculture x seedlot	69	2.99	1.72	0.0034
Error	141	1.73		

Table 7. Analysis of variance for volume across all sites.

Source	df	MS	F	Pr>F
Site	5	35950.25	144.88	0.0001
Replication(site)	6	248.13	4.56	0.0003
Silviculture	5	32433.95	595.42	0.0001
Site x silviculture	23	1972.60	36.21	0.0001
Seedlot	3	1128.76	20.72	0.0001
Site x seedlot	15	130.60	2.40	0.004
Silviculture x seedlot	15	87.27	1.60	0.0802
Site x silviculture x seedlot	69	78.72	1.45	0.034
Error	141	54.47		

Table 8. Overall average mean top height, basal area, and volume for the silvicultural treatments. Values followed by the same letter do not differ significantly (P=0.05).

Silviculture	Mean top height (m)	Basal area (m^2/ha)	Volume (m^3/ha)
100sph, thinned	10.11 a	4.25 a	17.01 a
200sph, thinned	10.18 a	7.71 b	29.66 b
400sph, thinned	11.26 bc	13.89 c	60.81 c
600sph, thinned	11.61 c	18.75 d	85.39 d
500sph, unthinned, unpruned	11.06 b	16.81 e	71.78 e
500sph, unthinned, pruned	11.18 b	15.22 f	63.57 c

Table 9. Overall average mean top height, basal area, and volume for seedlots. Values followed by the same letter do not differ significantly (P=0.05).

Seedlot rating	Mean top height (m)	Basal area (m^2/ha)	Volume (m^3/ha)
GF7	10.74 ab	12.08 a	51.09 a
LI28(GF13)	10.66 a	12.13 a	51.38 a
GF14	11.08 bc	13.39 b	57.71 b
GF21	11.11 c	13.48 b	58.65 b

APPENDIX 1. Individual Site Analysis Of Variance.

Table A. Analysis of variance for mean top height at Woodhill.

Source	df	MS	F	Pr>F
Replication	1	0.00	0	0.952
Silviculture	5	2.18	4.32	0.0065
Seedlot	3	0.22	0.44	0.7235
Silviculture x seedlot	15	0.42	0.84	0.6297
Error	23	0.51		

Table B. Analysis of variance for basal area at Woodhill.

Source	df	MS	F	Pr>F
Replication	1	2.99	4.62	0.0424
Silviculture	5	141.35	218.38	0.0001
Seedlot	3	6.75	10.42	0.0002
Silviculture x seedlot	15	0.52	0.8	0.6627
Error	23	0.65		

Table C. Analysis of variance for volume at Woodhill.

Source	df	MS	F	Pr>F
Replication	1	38.29	1.9	0.181
Silviculture	5	2370.86	117.83	0.0001
Seedlot	3	82.77	4.11	0.0179
Silviculture x seedlot	15	17.30	0.86	0.6112
Error	23	20.12		

Table D. Analysis of variance for mean top height at Tahorakuri.

Source	df	MS	F	Pr>F
Replication	1	0.10	0.21	0.6537
Silviculture	4	4.89	10.07	0.0001
Seedlot	3	0.88	1.81	0.1704
Silviculture x seedlot	12	0.43	0.89	0.5649
Error	25	0.49		

Table E. Analysis of variance for basal area at Tahorakuri.

Source	df	MS	F	Pr>F
Replication	1	3.85	6.45	0.0177
Silviculture	4	411.50	689.61	0.0001
Seedlot	3	6.08	10.19	0.0001
Silviculture x seedlot	12	1.78	2.98	0.0102
Error	25	0.60		

Table F. Analysis of variance for volume at Tahorakuri.

Source	df	MS	F	Pr>F
Replication	1	57.05	1.93	0.1775
Silviculture	4	11690.56	394.62	0.0001
Seedlot	3	277.03	9.35	0.0003
Silviculture x seedlot	12	84.84	2.86	0.0128
Error	25	29.62		

Table G. Analysis of variance for mean top height at Kaingaroa.

Source	df	MS	F	Pr>F
Replication	1	0.01	0.06	0.8076
Silviculture	5	1.25	10.1	0.0001
Seedlot	3	0.40	3.26	0.0398
Silviculture x seedlot	15	0.09	0.76	0.7023
Error	23	0.12		

Table H. Analysis of variance for basal area at Kaingaroa.

Source	df	MS	F	Pr>F
Replication	1	0.00	0.02	0.9024
Silviculture	5	106.82	446.63	0.0001
Seedlot	3	1.92	8.02	0.0008
Silviculture x seedlot	15	0.28	1.19	0.3458
Error	23	0.24		

Table I. Analysis of variance for volume at Kaingaroa.

Source	df	MS	F	Pr>F
Replication	1	0.01	0	0.9642
Silviculture	5	1109.96	349.43	0.0001
Seedlot	3	26.30	8.28	0.0006
Silviculture x seedlot	15	5.79	1.82	0.0949
Error	23	3.18		

Table J. Analysis of variance for mean top height at Glengarry.

Source	df	MS	F	Pr>F
Replication	1	0.35	1.95	0.1744
Silviculture	4	2.58	14.34	0.0001
Seedlot	3	1.99	11.05	0.0001
Silviculture x seedlot	12	0.20	1.09	0.4051
Error	27	0.18		

Table K. Analysis of variance for basal area at Glengarry.

Source	df	MS	F	Pr>F
Replication	1	3.74	2.93	0.0983
Silviculture	4	893.91	701.68	0.0001
Seedlot	3	20.54	16.12	0.0001
Silviculture x seedlot	12	2.78	2.18	0.0449
Error	27	1.27		

Table L. Analysis of variance for volume at Glengarry.

Source	df	MS	F	Pr>F
Replication	1	181.51	4.22	0.0498
Silviculture	4	25951.02	603.07	0.0001
Seedlot	3	914.23	21.25	0.0001
Silviculture x seedlot	12	73.71	1.71	0.1195
Error	27	43.03		

Table M. Analysis of variance for mean top height at Ditchlings.

Source	df	MS	F	Pr>F
Replication	1	6.80	1.87	0.1855
Silviculture	5	8.50	2.34	0.0772
Seedlot	3	2.57	0.71	0.5583
Silviculture x seedlot	15	3.18	0.88	0.5956
Error	21	3.63		

Table N. Analysis of variance for basal area at Ditchlings.

Source	df	MS	F	Pr>F
Replication	1	61.41	13.43	0.0014
Silviculture	5	240.71	52.65	0.0001
Seedlot	3	18.53	4.05	0.0203
Silviculture x seedlot	15	6.49	1.42	0.2251
Error	21	4.57		

Table O. Analysis of variance for volume at Ditchlings.

Source	df	MS	F	Pr>F
Replication	1	1994.23	11.41	0.0028
Silviculture	5	5444.68	31.15	0.0001
Seedlot	3	555.84	3.18	0.0451
Silviculture x seedlot	15	213.95	1.22	0.328
Error	21	174.80		

Table P. Analysis of variance for mean top height at Otago Coast.

Source	df	MS	F	Pr>F
Replication	1	12.84	5.17	0.0331
Silviculture	5	5.90	2.38	0.0722
Seedlot	3	0.55	0.22	0.8811
Silviculture x seedlot	15	1.11	0.45	0.9431
Error	22	2.48		

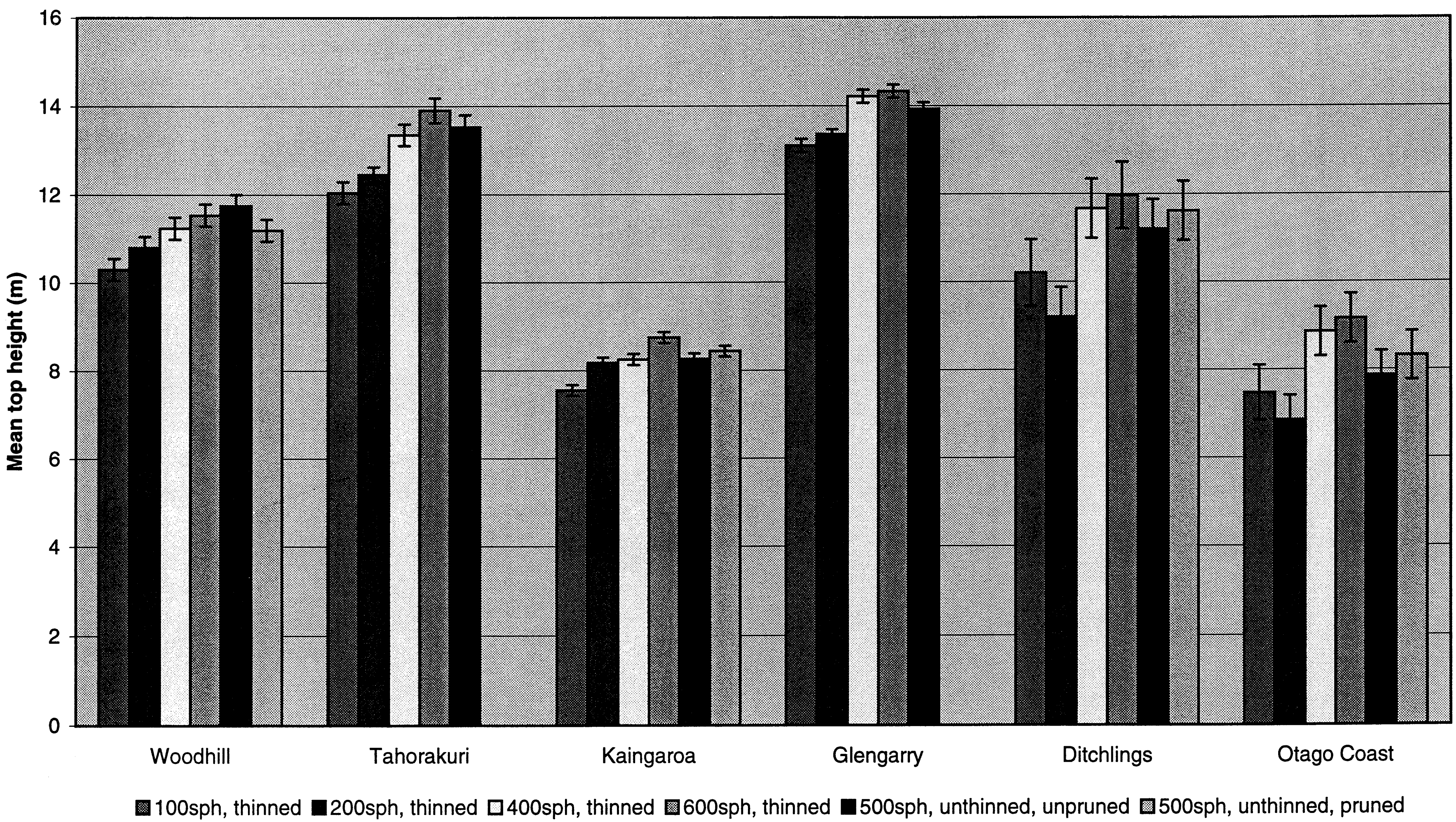
Table Q. Analysis of variance for basal area at Otago Coast.

Source	df	MS	F	Pr>F
Replication	1	4.22	1.18	0.2885
Silviculture	5	147.23	41.23	0.0001
Seedlot	3	11.64	3.26	0.0409
Silviculture x seedlot	15	5.74	1.61	0.1516
Error	22	3.57		

Table R. Analysis of variance for volume at Otago Coast.

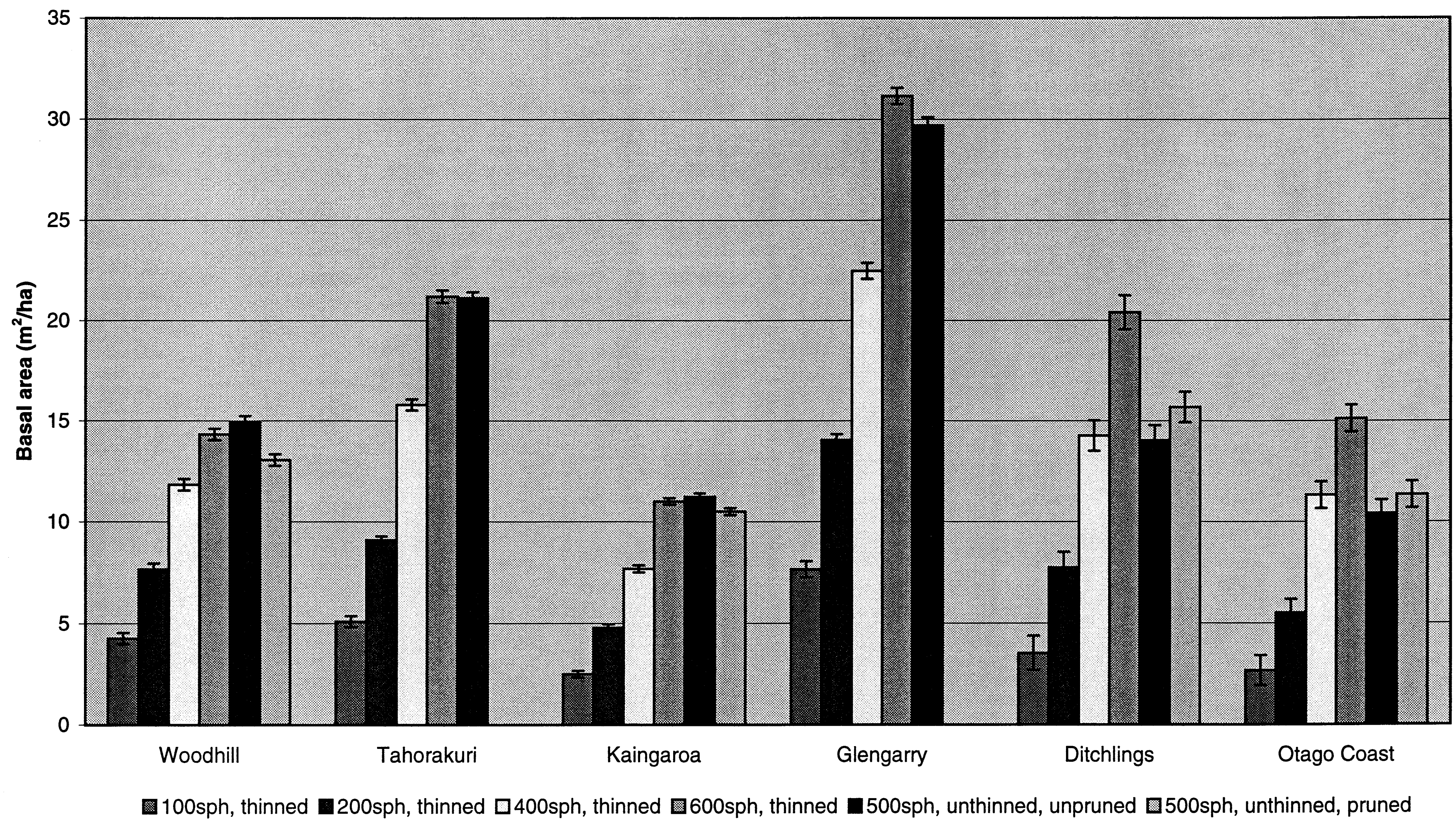
Source	df	MS	F	Pr>F
Replication	1	214.88	3.01	0.0968
Silviculture	5	1924.72	26.95	0.0001
Seedlot	3	135.59	1.9	0.1594
Silviculture x seedlot	15	85.53	1.2	0.3419
Error	46	71.43		

Figure 1: Site and silviculture differences in mean top height



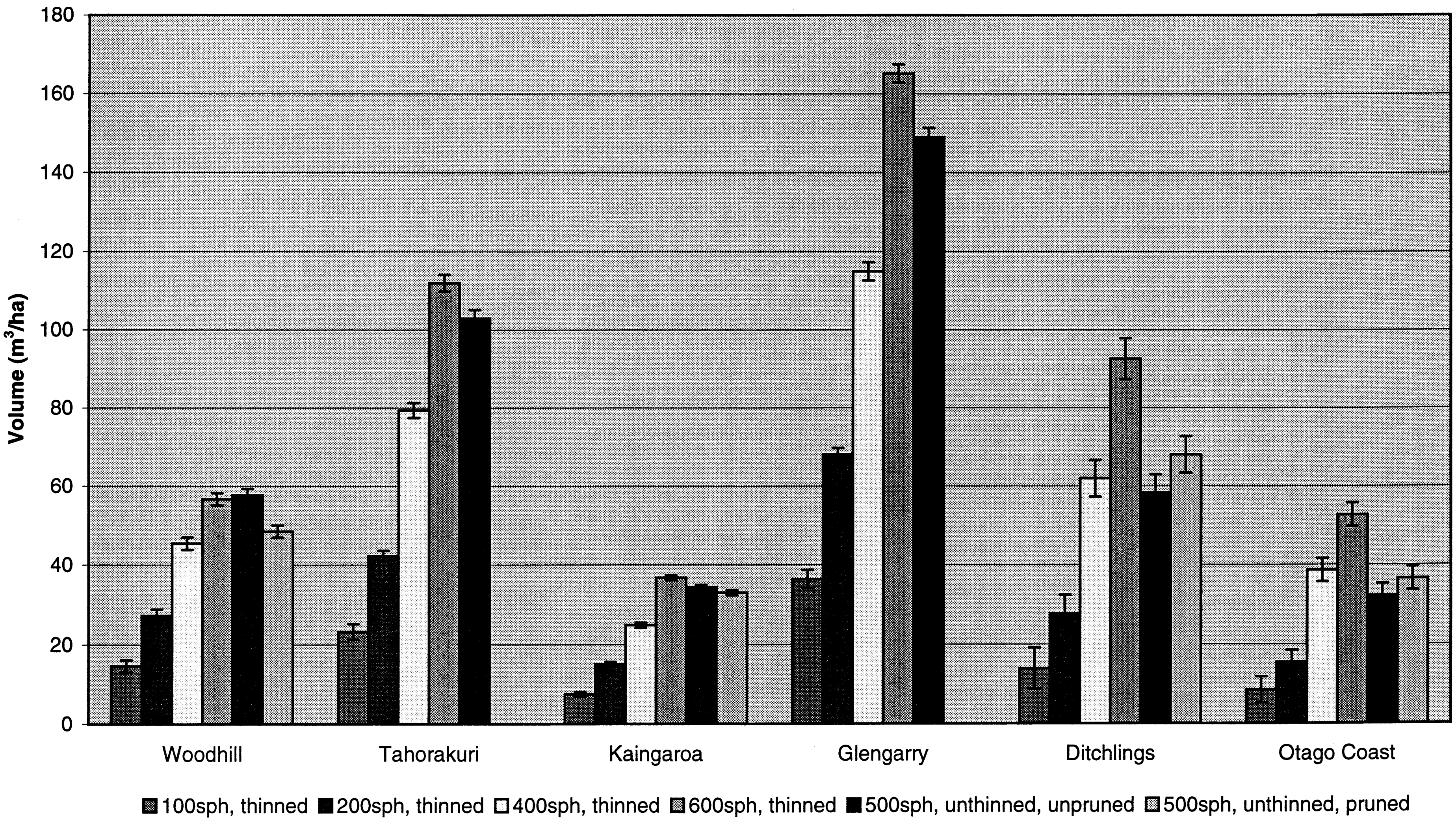
Standard errors are indicated by error bars

Figure 2: Site and silviculture differences in basal area



Standard errors are indicated by error bars

Figure 3: Site and silviculture differences in volume



Standard errors are indicated by error bars

Figure 4. Site and seedlot differences in mean top height.

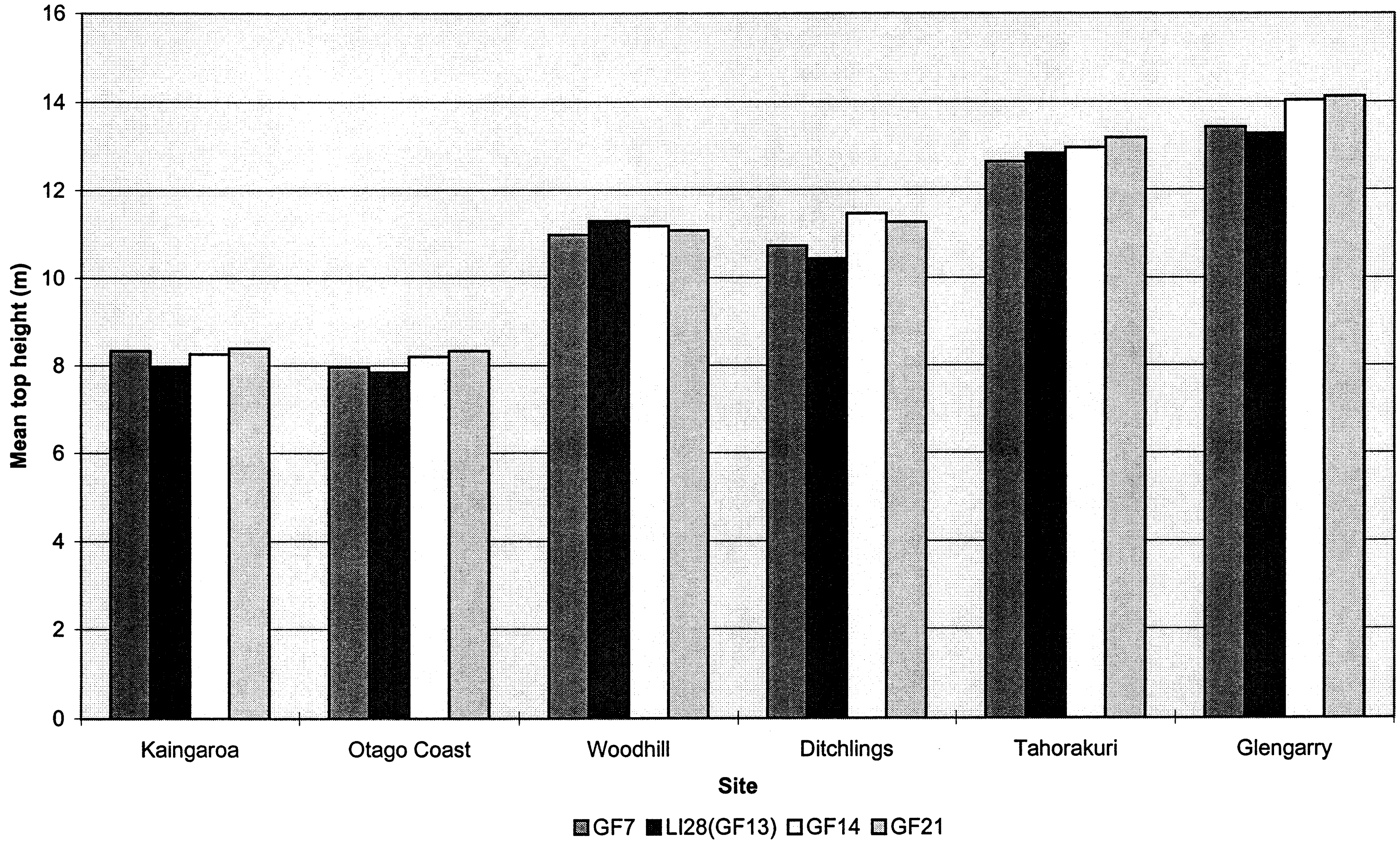


Figure 5. Site and seedlot differences in basal area

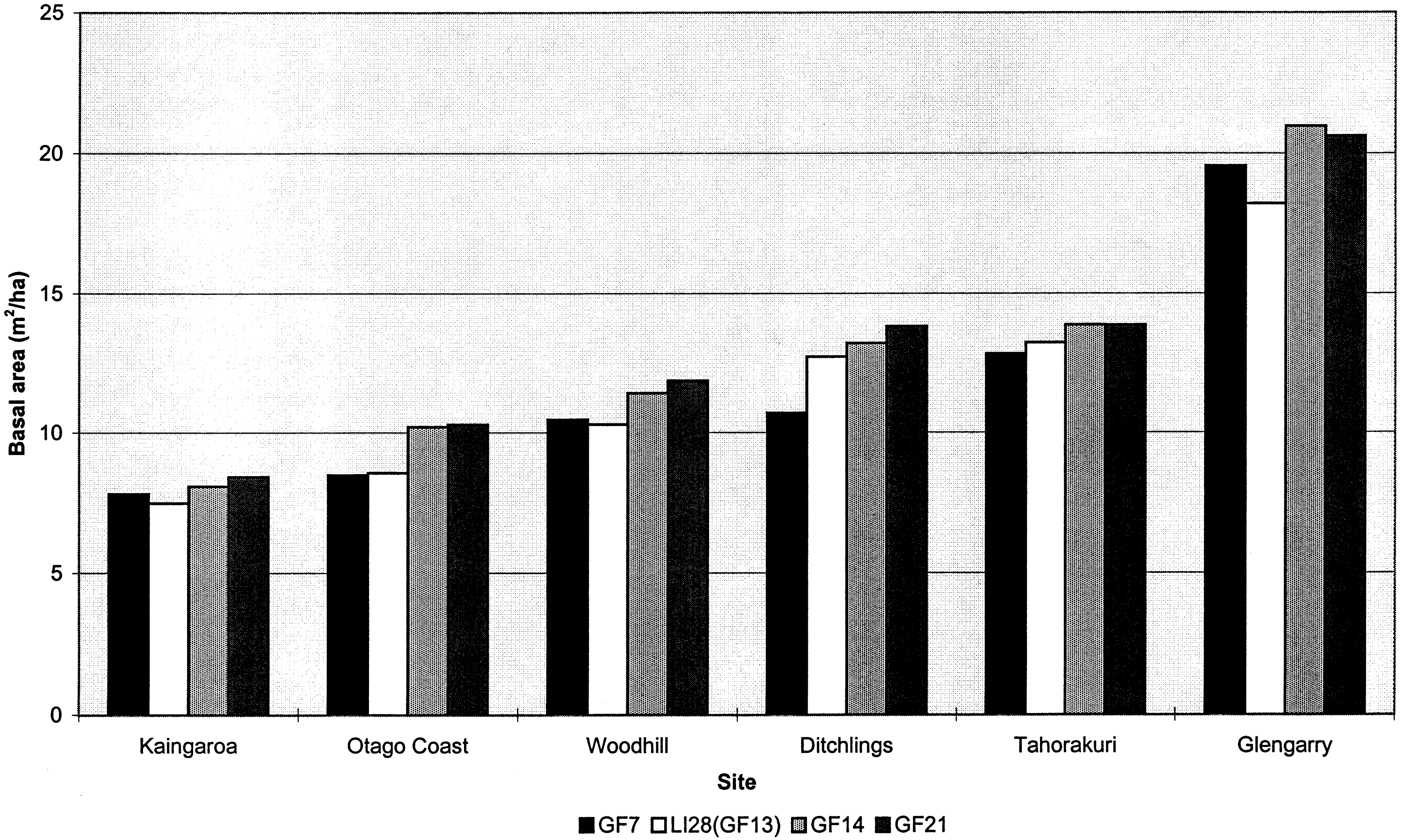


figure 6. Site and seedlot differences in volume.

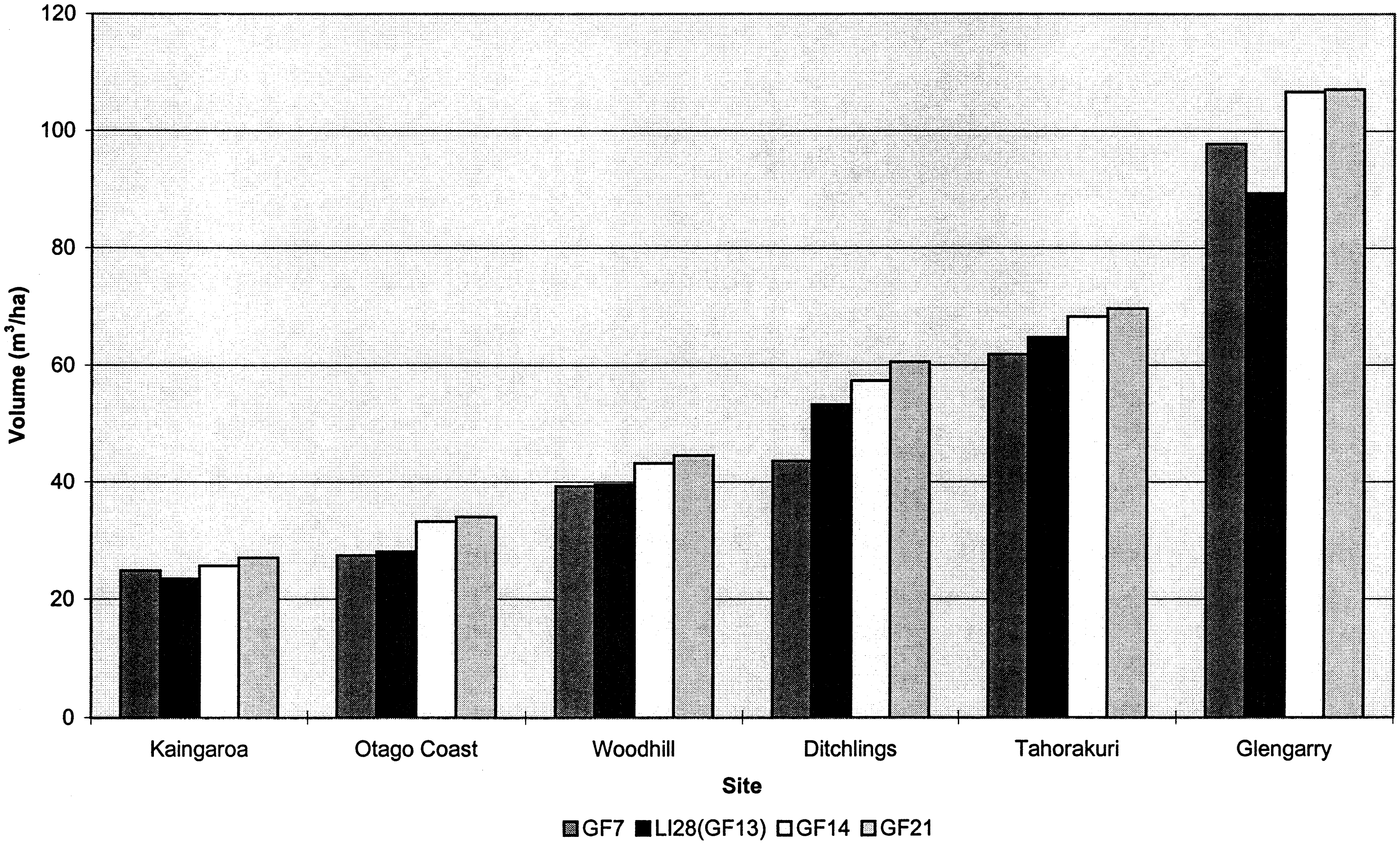


Figure 7. Silviculure and seedlot differences in mean top height.

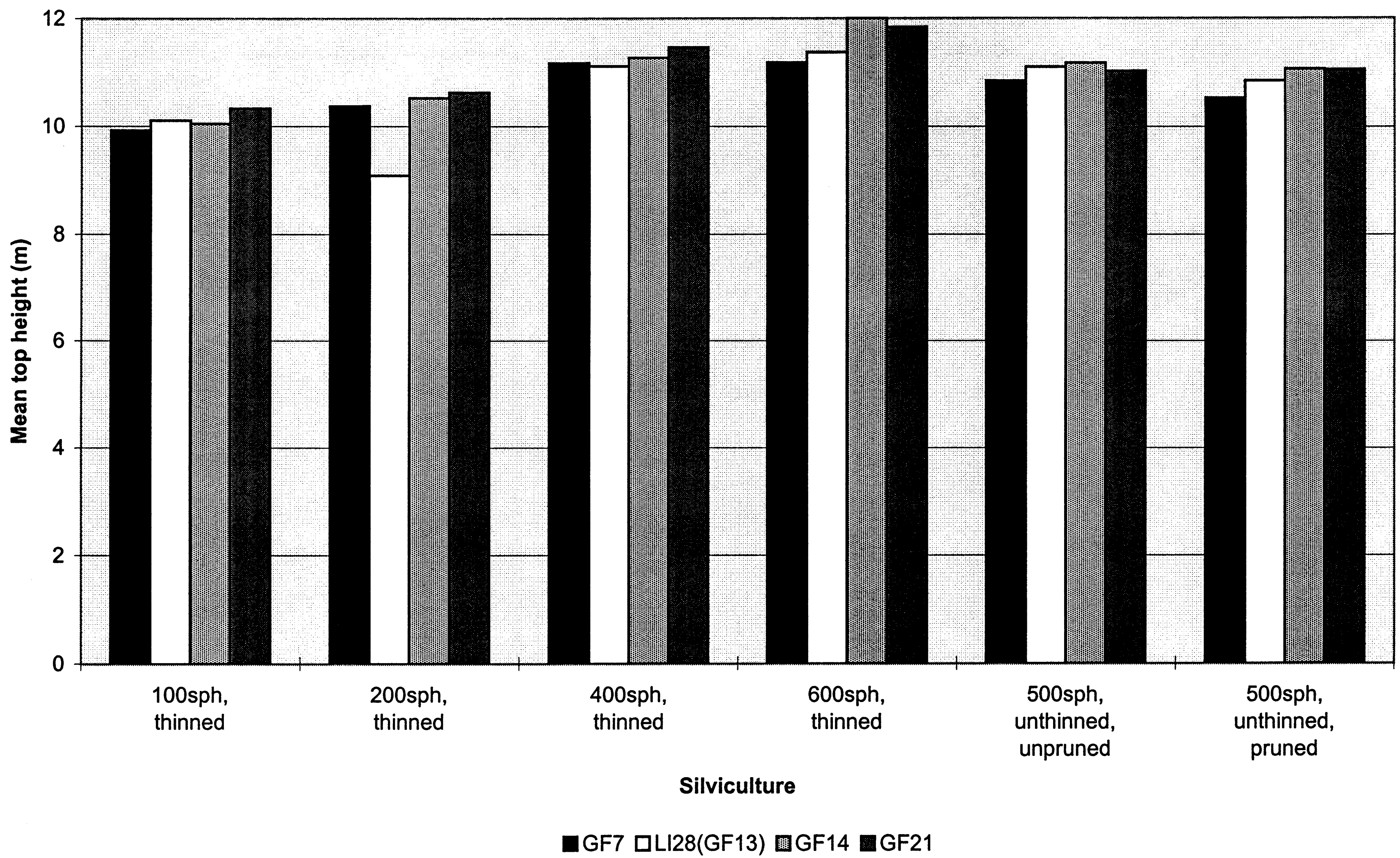


Figure 8. Silviculture and seedlot differences in basal area.

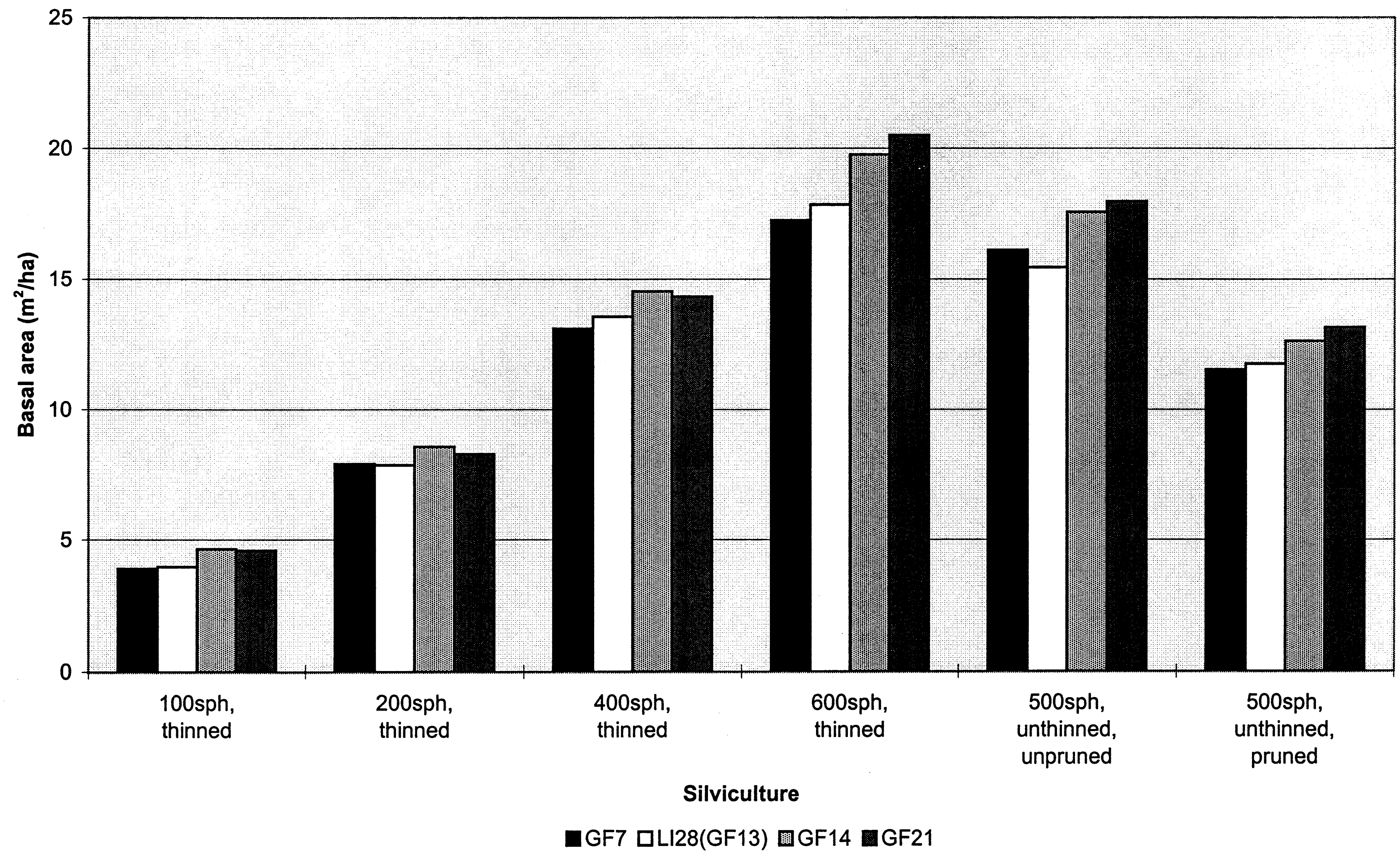


Figure 9. Silviculture and seedlot differences in volume.

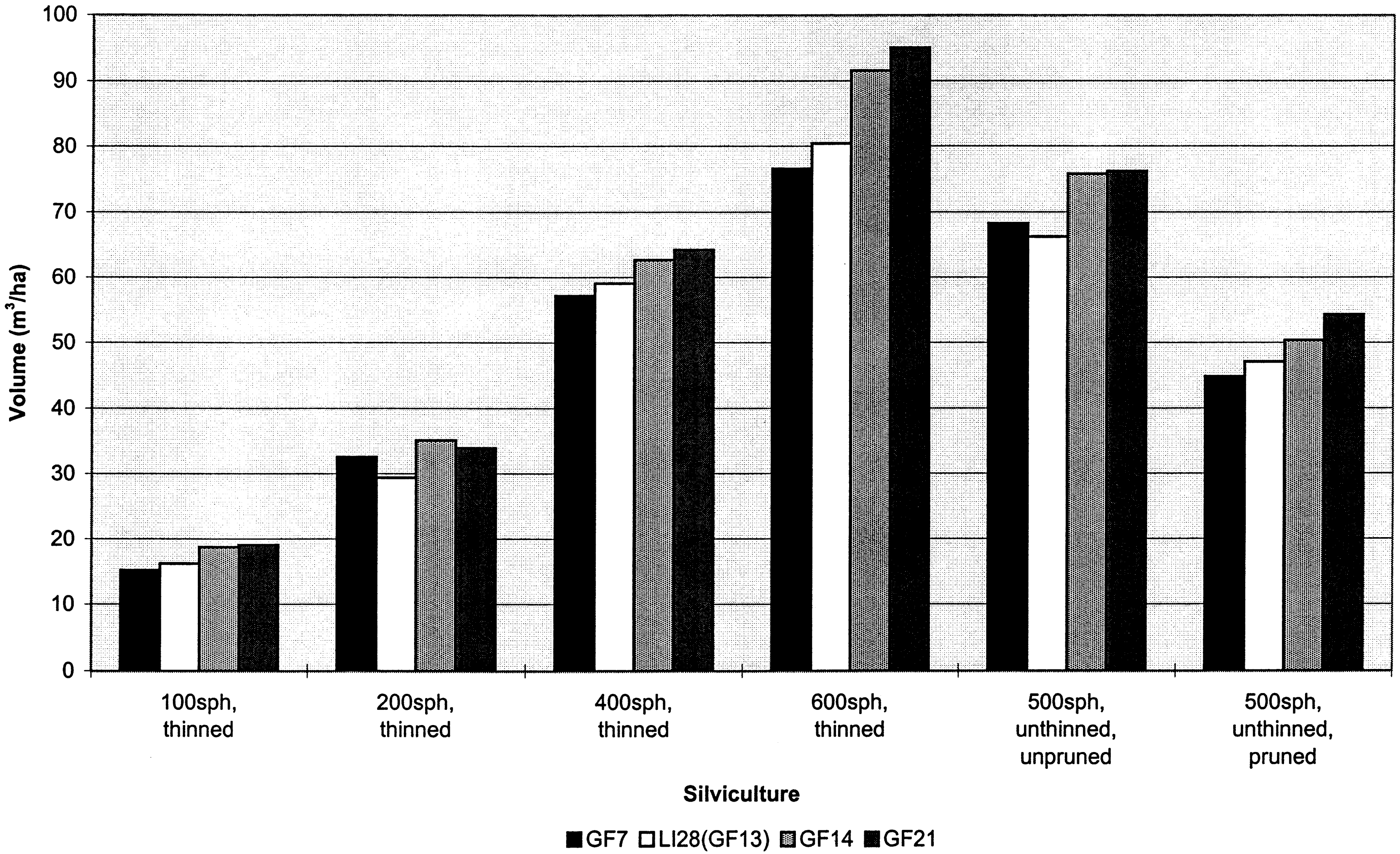


Figure 10. Relative differences in mean top height among sites, silvicultures and seedlots.

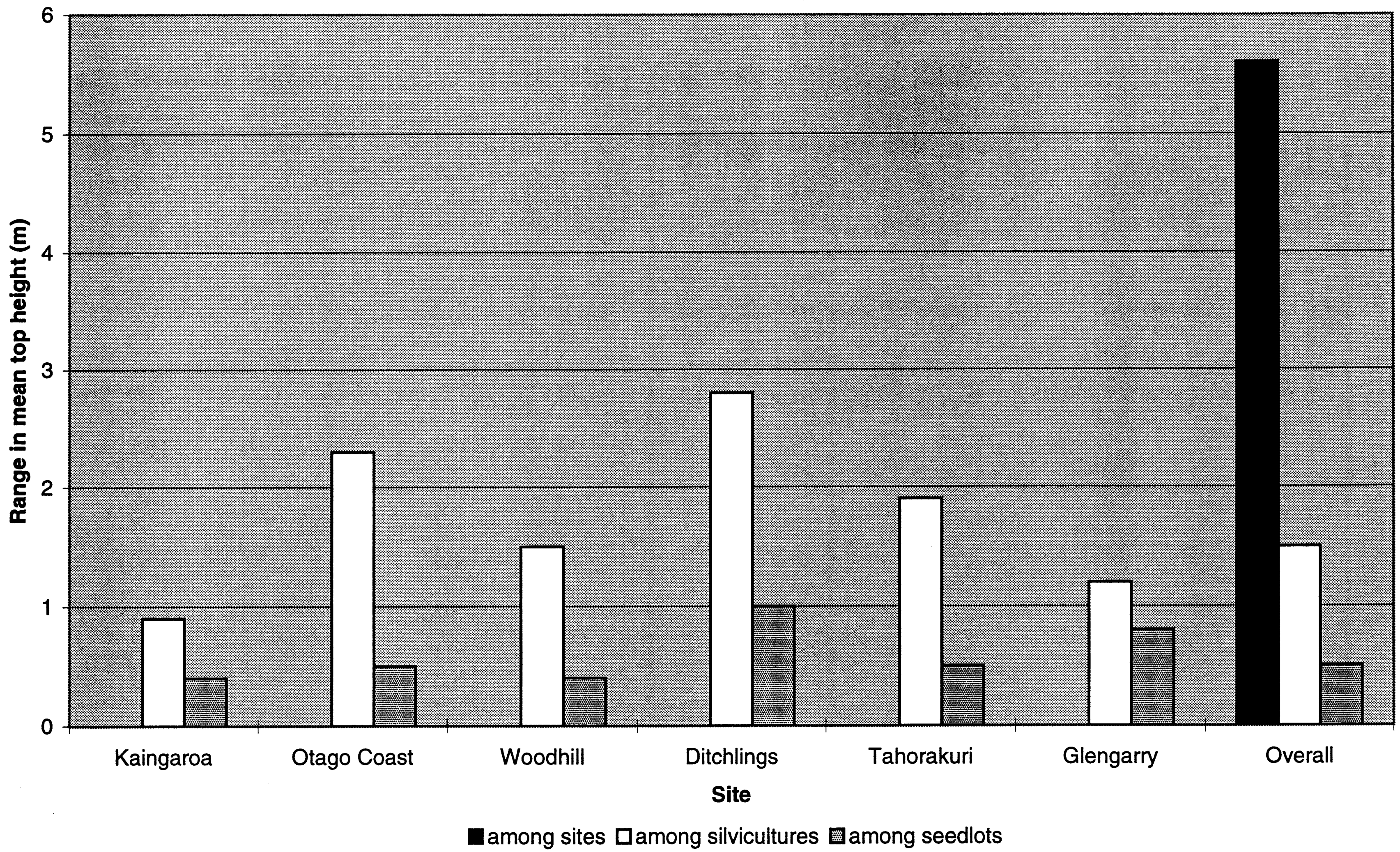


Figure 11. Relative differences in basal area among sites, silvicultures, and seedlots.

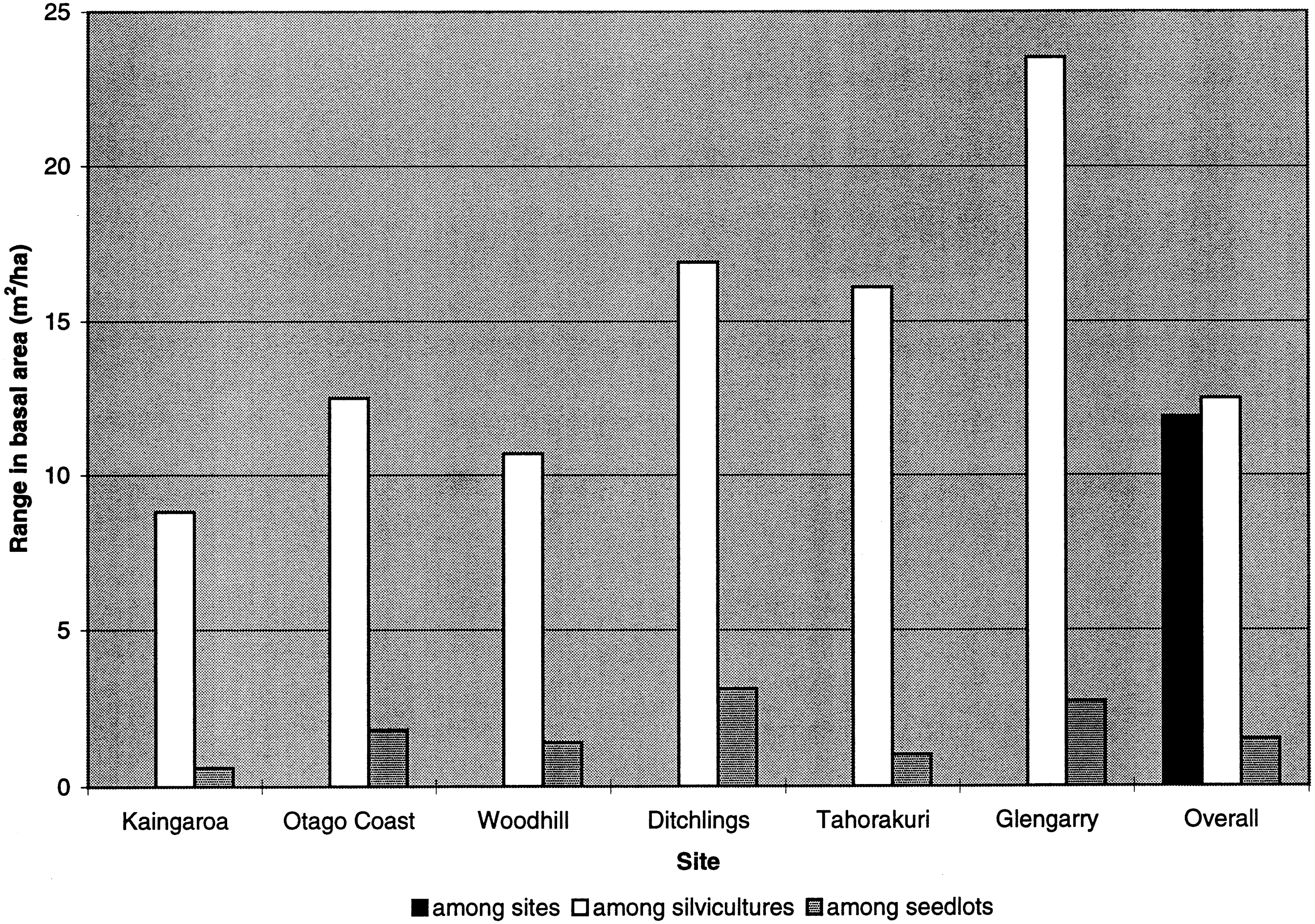


Figure 12. Relative differences in volume among sites, silvicultures, and seedlots.