AN ASSESSMENT OF SWISS NEEDLECAST ON A DOUGLAS_FIR PROVENANCE AND PROGENY TRIAL AT AGE SEVEN YEARS

Report No. 38 February 2004

Charlie Low

Abstract

Swiss needlecast (*Phaeocryptopus guaemannii*) has been on Douglas-fir stands in New Zealand from 1959. Severe defoliation and growth loss has been observed on commercial stands since the 1970s, particularly on stands in the central North Island. Record levels of *Dothistroma pini* infection were reported in Kaingaroa forest in the spring of 2002, so it was decided to assess the Kaingaroa site of the 1996 trial. The assessment was made in February 2003 to allow time for diseased needles to be shed, following the spring flush.

The overall level of needlecast was disturbingly high, ranging from almost entirely denuded trees with less than six months foliage, to slightly over two years for the healthiest trees. American studies comparing growth rate with foliage retention have shown that the healthiest trees on this site would have lost 10% of potential growth and worst trees more than 40%.

Provenances from the Southern end of the natural range were most susceptible to needlecast, particularly those from South of 37 degrees of latitude (Santa Cruz and Los Padres). Provenances from 37 to 39 degrees of latitude were also more susceptible than average with the exception of the Point Reyes provenance, which would have been a wetter environment, with fog-producing sea on three sides of the peninsular.

Provenances from North of 39 degrees had the highest level of needle retention, although this was still fairly poor at just over one full year of foliage. New Zealand seed sources were best of all by a small margin and Weyerhaeuser seed orchard progenies were also good.

There was a significant amount of variation in needle retention for progenies within provenances, although even the best progenies had an average of only 18 months of foliage. Narrow sense heritability was reasonably high at 0.39 when provenance variation was taken out or 0.50 when provenance variation was included with progeny variation. The heritability was around twice as good as that obtained in the age four assessment, which was done in December before some provenances had begun their spring flush.

Keywords
Pseudotsuga menziesii, Phaeocryptopus guaemannii, provenance and progeny trial, needlecast, assessment, heritability

Introduction and Background

Douglas-fir (*Pseudotsuga menziesii*) is New Zealand's second most important timber species after radiata pine. When first introduced to New Zealand it grew very well and formed such dense stands that intercepted close to 100% of available sunlight. Douglas-fir stands had no weeds or undergrowth after canopy closure and the stand interior was extremely dark, even at mid day.

The arrival of Swiss needlecast (*Phaeocryptopus guaemannii*) in 1959 had little immediate impact, but by the 1970s most North Island stands had been drastically defoliated. The disease was named Swiss needlecast because it was first identified on Douglas-fir in Switzerland, but it is endemic to natural stands in America. The disease invades the foliage with fungal hyphae, which causes the trees to shed older foliage as early as one year after infection with a considerable loss of growth, whereas healthy trees can carry as much as10 years of foliage.

An American study (Maguire et al.) found that there was no difference in growth rate between trees with 3.5 years of foliage and those with more foliage. However, trees with less than 3.5 years of foliage showed declining basal area growth on a straight line down to 60% for a tree with only one years foliage.

Early studies in New Zealand Douglas-fir provenance trials showed that provenances from the coastal fog-belt had the best tolerance of the disease. Provenances from further inland were adapted to dry summers and were severely defoliated on wet New Zealand sites.

The Kaingaroa site of the 1996 Douglas-fir provenance and progeny trial showed signs of Swiss needlecast shortly before the assessment at age four. However, it was observed during the assessment that the main shedding of needles occurred shortly after flushing and some provenances had still not flushed at the time of the assessment in early December. Considerable differences in health were found amongst provenances and amongst families within provenances, but there was concern over the correlation with timing of the spring flush. There was also a possibility that the recent arrival of infection meant that many trees had not been challenged by disease.

Conditions for needlecast infection in Kaingaroa forest were ideal for the summer of 2002-2003, with record levels of Dothistroma infection reported on radiata pine. Consequently, it was decided to re-assess the Kaingaroa site in February 2003, while access was not impeded by canopy closure.

Materials and Methods

The establishment, site details and composition of the provenance progeny trial were given by Toby Stovold in Co-op report number 20. The trial design was 30 replicates of single tree plots with the 215 families and various control seedlots divided into 6 sets. The details of provenance origin are shown in Table 1 and details of the control seedlots are shown in Table 2. The progeny of six clones from three seed orchards (Long View, Twin Harbours and Coos Bay) owned by Weyerhaeuser were also planted at Kaingaroa.

The tree branches were visually scored for presence of needles, with the current flush ignored and two points given for each year of branch growth in the mid crown area, with a maximum of 6 points. The same scoring system was used for the first assessment in December 2000 and this assessment in February 2003. After scoring slightly more than half of the trial, heavy bracken was encountered, so the remainder of the trial was not scored.

Scoring was surprisingly difficult, as the amount of healthy foliage varied from virtually nothing in the exposed upper crown, to two or more years on lower crowns sheltered by undergrowth. Consequently scores were estimated as an average needle retention of the whole tree.

Table 1 – Provenance location and number of families successfully raised from the Forest Research 1993 seed collection of *Ps. menziesii*

Provenance	State	Latitude	Number of families planted
Los Padres	California	35° 49’	6
Swanton	California	37° 06’	3
Cascade Ranch	California	37° 08’	13
SF water reserve	California	37° 27’	19
SP Taylor Forest Park	California	38° 02’	10
Point Reyes	California	38° 04’	10
Russian river	California	38° 21’	10
Fort Ross	California	38° 25’	10
Gualala	California	38° 47’	9
Navarro river	California	39° 11’	13
Noyo river	California	39° 25’	20
Rockport	California	39° 47’	6
Arcata	California	39° 59’	15
Brookings	Oregon	42° 06’	7
Ophir	Oregon	42° 36’	3
Myrtle Point	Oregon	43° 06’	5
Coos Bay	Oregon	43° 20’	12
Umpqua river	Oregon	43° 36’	22
Siuslaw forest	Oregon	44° 10’	19
Willamette forest	Oregon	43° 50’	10

Table 2 – Origin of control seedlots

Code	Provenance	Seedlot	Origin
900	Fort Bragg, CA	94/32	Seed Stand, Compartment 55, Rotoehu forest
901	Fort Bragg, CA	94/33	Compartment 1132, Kaingaroa forest (2nd generation ex Rotoehu)
902	Washington	94/128	Compartment 1061, Kaingaroa (3rd generation in New Zealand)
903	Fort Bragg, CA	94/632	Seed Stand, Compartment 115, Golden Downs forest
904	Oregon	94/240	Seed Stand, Eyrewell forest (2nd generation ex Ashley)
905	Oregon	94/180	Seed Stand, Mount Thomas forest (2nd generation ex Ashley)
906	Washington	93/677	Seed stand, Beaumont forest
907	Arcata, CA		Louisiana-Pacific Seed Orchard, Humboldt County, California

Analysis

The analysis model was replicates, provenance and family within provenance, with the replicate effect assumed to be random and the provenance and family effects assumed to be fixed. An analysis was tried incorporating set as an effect, but this resulted in zero degrees of freedom for sets in the type III sums of squares, so the set effect was omitted. Analysis of variance was carried out by PROC GLM of the SAS™ software package and significant differences between provenance means were estimated by the Tukey multiple range test. Variance components were estimated using PROC VARCOMP and these were used to estimate heritability. Provenance and family means were estimated using PROC MEANS and these were used to estimate correlations between traits.

Results and Discussion

Foliage retention was very low across the whole trial, with the average tree having only slightly more than one years foliage (two points on the scoring system) other than the spring flush. There was no doubt in this assessment that all trees were rigorously challenged by the needlecast disease.

There was a moderate amount of variation in needle retention amongst provenances (Table 3), with relatively poor performance from the provenances from the southern end of the range. The Point Reyes provenance appears to be somewhat healthier than its neighbours, probably because it is bounded by the fog-generating sea on three sides. Health appears much better in provenances North of latitude 39°, including the provenance from Willamette forest, even though this comes from the Western slope of the Cascade mountains, a long way from the coastal fog-belt.

Table 3. Provenance means

	Latitude	No.	Age 4 years		Age 7 years	
Provenance	°N	trees	Height (dm)	Needle retention. (1-6)	Needle retention. (1-6)	Survival %
Los Padres	35° 49'	74	21 j	2.54 e	1.44 d	70
Swanton	37° 06'	27	27 abcd	2.91 bcde	1.96 bc	73
Cascade Ranch	37° 08'	200	26 bcdef	2.72 de	1.96 bc	75
SF water reserve	37° 27'	231	22 hij	2.74 cde	2.01 bc	71
SP Taylor FP	38° 02'	135	25 cdefgh	2.73 cde	1.91 bc	78
Pt Reyes	38° 04'	147	24 defgh	2.93 bcde	2.22 ab	76
Russian river	38° 21'	104	26 bcdef	2.77 cde	1.72 cd	77
Fort Ross	38° 25'	147	29 a	3.01 abcd	2.18 ab	69
Gualala	38° 47'	88	27 abc	2.88 bcde	1.97 bc	77
Navarro river	39° 11'	179	28 a	3.09 abcd	2.31 ab	77
Noyo river	39° 25'	267	26 bcdef	3.17 ab	2.27 ab	75
Rockport	39° 47'	63	25 cdefg	2.95 abcd	2.00 bc	82
Arcata	39° 59'	207	26 abcde	3.23 ab	2.30 ab	78
Brookings	42° 06'	75	28 ab	3.12 abc	2.11 abc	82
Ophir	42° 36'	25	25 cdefgh	2.88 bcde	1.96 bc	74
Myrtle Point	43° 06'	57	25 cdefg	3.19 ab	2.35 ab	79
Coos Bay	43° 20'	103	24 fghi	3.35 a	2.49 a	81
Umpqua river	43° 36'	225	22 ghij	3.17 ab	2.10 abc	80
Siuslaw forest	44° 10'	324	24 efghi	3.34 a	2.25 ab	85
Willamette forest	43° 50'	180	21 ij	3.27 ab	2.17 abc	77
Weyco 602 Coos	43° 25'	17	27	3.24	2.44	100
Weyco 605 LV	46° 30'	10	25	3.10	2.56	77
Weyco 606 LV	46° 30'	12	20	3.08	2.08	92
Weyco 608 LV	46° 30'	13	20	3.38	2.45	87
Weyco 610 TH	48° 05'	13	22	3.31	2.38	81
Weyco 612 TH	48° 05'	6	21	3.17	3.00	75
900 Ft Bragg	39° 15'	93	30	3.32	2.66	80
901 Ft Bragg	39° 15'	14	30	3.85	2.79	74
902 Kaingaroa		14	26	3.57	2.46	88
903 Ft Bragg	39° 15'	11	28	3.18	2.50	69
904 Ashley (Eyre)		12	23	3.67	2.45	80
905 Ashley (MT)		17	24	3.35	2.24	94
906 Beaumont		14	25	3.50	2.40	88
907 Arcata	39° 59'	13	27	3.08	2.23	81
Least Significant Difference			2.65	0.40	0.45	

The seedlots from New Zealand seed stands performed very well with above-average needle retention, as did most of the progenies from Weyerhaeuser Seed Orchard clones. Interestingly the New Zealand seedlots were better than the seedlot from the Louisiana-Pacific Seed Orchard at Arcata, even though the orchard itself is well within the fog-belt. There may have been some pollination by clones within the Arcata orchard that were selected from inland locations.

The analysis of variance and the variance components (Tables 4, 5, 6 and 7) showed that there were greater differences in needle retention amongst families within each provenance than between provenances. Narrow sense heritability (H^2) was relatively high at 0.39 after taking out the provenance effect and was higher again (0.50) if the provenance effect is lumped in with the family effect. Broad sense or family mean heritabilities were higher again at 0.58 and 0.65. These were rather lower than the 0.85 found by Randy Johnson (Johnson 1997) in his assessment of selected Douglas-fir progenies in Oregon.

Individual family means (Appendix 1) showed that even the relatively resistant provenances had some susceptible families, so selection based on provenance alone was not effective, although really poor provenances contained no healthy families.

Table 4. Variance components and heritability with provenance and family within provenance structure

Component	Age 4 height	Age 4 needle retention	Age 7 needle retention
Replicate	1.73	0.036	0.023
Provenance	4.87	0.049	0.028
Family(Prov)	2.51	0.029	0.077
Error	26.64	0.599	0.718
H^2	0.34	0.18	0.39
H^2F	0.57	0.40	0.58
Std error	0.06	0.05	0.06

Table 5. Variance components expressed as a percentage of total variance

Component	Age 4 Height	Age 4 needle retention	Age 7 needle retention
Replicate	4.9	5.0	2.7
Provenance	13.6	6.8	3.3
Family(Prov)	7.0	4.1	9.1
Error	74.5	84.1	84.9

Table 6. Variance components and heritability without provenance structure

Component	Age 4 Height	Age 4 needle retention	Age 7 needle retention
Replicate	1.73	0.036	0.023
Family	7.09	0.075	0.103
Error	26.64	0.599	0.718
H^2	0.84	0.44	0.50
H^2F	0.79	0.64	0.65
Std error	0.09	0.06	0.07

Table 7. Variance components expressed as a percentage of total variance

Component	Age 4 height	Age 4 needle retention	Age 7 needle retention
Replicate	4.9	5.0	2.7
Family	20.0	10.5	12.2
Error	75.1	84.5	85.1

Correlations between traits were estimated for individual trees (Table 8) and provenance means. The correlations were rather low, reflecting that the first four years of growth were in the absence of needlecast and the confounding of the spring flush with the first needlecast assessment. The good provenance mean correlation between the two assessments showed that provenance rankings of the two assessments were very similar.

Table 8. Phenotypic correlations between traits

Trait	Age 4 height	Age 4 Needle retention	Age 7 needle retention
Age 4 height	1.00		
Age 4 needle retention	0.14***	1.00	
Age 7 needle retention	0.16***	0.28***	1.00

Table 9. Provenance mean correlations between traits

Trait	Age 4 height	Age 4 Needle retention	Age 7 needle retention
Age 4 height	1.00		
Age 4 needle retention	0.09	1.00	
Age 7 needle retention	0.26	0.86***	1.00

Conclusions

This assessment showed that there is still a lot of variation between provenances within the fog-belt. There is a general trend for provenances from the Southern end of the range, where precipitation is lower to suffer more needlecast than northern provenances in this common garden trial. However there are departures from this trend, which may have been influenced by local fluctuations in the amount of summer fog caused by geology (like Point Reyes). Selecting best progenies within best provenances should provide the greatest gains in resistance to needlecast.

Foliage health in the Kaingaroa site was extremely poor for all trees in 2003. The American study conducted by MaGuire (MaGuire et al. 2002) showed growth losses occurring with the loss of foliage younger than three years and a straight line loss from there down to 60% of potential basal area growth for trees with only one year of foliage.

The serious growth losses associated with bad needlecast underline the importance of this trait to any future selections for seed orchards. Several provenances are identified as not suitable for this site in spite of good early growth. The data from this assessment could be used to provide breeding values for needlecast tolerance, if needlecast is not as severe on either of the other two sites.

Acknowledgements

The author would like to acknowledge the Douglas-fir co-operative for funding the seed collection and establishment of the progeny trial; Rod Cameron for help with the trial assessment and Fletcher Challenge forests for controlling *P. radiata* regeneration.

REFERENCES

Beekhuis, J. 1978: Growth decline in Douglas-fir. A review of Douglas-fir in New Zealand. New Zealand Forest Research Institute Symposium No. 15, 16-19 September, 1974. Edited by R.N. James, E.H. Bunn. New Zealand Forest Service. Pp 119-125

Hood, I. A. 1982: *Phaeocryptopus guaemannii* on *Pseudotsuga menziesii* in southern British Columbia. New Zealand Journal of Forestry Science 12(3) Pp. 415-424

Hood, I. A.; Kershaw, D. G. 1975: Distribution and infection period of *Phaeocryptopus guaemannii* in New Zealand. New Zealand journal of Forestry Science 5: Pp.201-208

Johnson G.R. 1997: Genetic variation in tolerance of Douglas-fir to Swiss needle cast. Silvae Genetica 51: Pp 80-86

Maguire, D. A.; Kanaskie A.; Voelker, W.; Johnson, R.; Johnson, G. 2002: Growth of young Douglas-fir plantations across a gradient in Swiss needle cast severity. Western Journal of Applied Forestry 17(2) Pp 86-95

Stovold G. T. 1997: Establishment Report for the 1996 Douglas-fir progeny tests at three sites. NZ Douglas-fir Co-operative report 20.

Appendix 1. Family means

Provenance	Family	number		Age 4		Age 7	
		planted	assessed	height	n. retention	n. retention	survival
Los Padres	1	17	12	22	2.92	1.60	71
Los Padres	2	10	8	19	2.00	1.00	80
Los Padres	3	15	9	18	2.89	1.67	60
Los Padres	4	13	9	19	2.89	1.63	69
Los Padres	5	32	23	20	2.30	1.10	72
Los Padres	412	18	13	25	2.46	1.92	72
Swanton	141	17	13	28	2.92	2.15	76
Swanton	142	32	23	24	2.78	1.91	72
Swanton	143	15	11	31	3.18	1.82	73
Cascade Ranch	151	18	13	26	2.46	2.17	72
Cascade Ranch	152	17	14	29	3.21	2.77	82
Cascade Ranch	154	16	11	24	2.73	1.56	69
Cascade Ranch	161	14	9	26	2.78	2.00	64
Cascade Ranch	162	36	29	28	2.93	1.88	81
Cascade Ranch	163	32	20	27	2.75	2.20	63
Cascade Ranch	164	16	11	25	2.73	2.20	69
Cascade Ranch	165	18	18	26	2.44	1.41	100
Cascade Ranch	166	34	24	23	2.71	2.15	71
Cascade Ranch	167	18	15	26	2.80	2.21	83
Cascade Ranch	168	16	12	26	3.25	2.18	75
Cascade Ranch	169	12	9	19	1.67	1.00	75
Cascade Ranch	170	18	15	26	2.47	1.23	83
SF Water Reserve	171	36	29	22	2.90	2.28	81
SF Water Reserve	172	16	13	22	2.31	2.33	81
SF Water Reserve	173	16	13	22	2.46	1.58	81
SF Water Reserve	175	17	10	23	2.50	1.78	59
SF Water Reserve	176	17	14	23	3.14	1.91	82
SF Water Reserve	178	13	6	21	2.67	1.67	46
SF Water Reserve	180	18	14	20	2.29	1.50	78
SF Water Reserve	181	16	10	22	2.00	1.33	63
SF Water Reserve	182	16	9	25	2.56	1.25	56
SF Water Reserve	183	16	12	19	3.00	2.00	75
SF Water Reserve	184	34	27	23	3.26	2.61	79
SF Water Reserve	185	16	9	23	2.89	2.57	56
SF Water Reserve	186	14	11	18	2.64	2.40	79
SF Water Reserve	187	18	14	24	2.14	1.38	78
SF Water Reserve	188	16	10	26	2.20	1.33	63
SF Water Reserve	189	32	19	22	3.21	2.56	59
SF Water Reserve	190	15	11	22	3.09	2.13	73
Point Reyes	11	18	14	22	2.87	1.92	78
Point Reyes	12	16	12	24	2.75	1.83	75
Point Reyes	13	18	15	23	3.07	2.36	83
Point Reyes	14	17	14	24	2.71	2.21	82
Point Reyes	15	16	10	22	3.40	2.67	63
Point Reyes	16	9	7	24	2.86	2.17	78
Point Reyes	17	18	12	23	2.50	1.82	67
Point Reyes	18	32	21	26	3.05	2.40	66
Point Reyes	19	16	14	25	2.79	2.17	88
Point Reyes	20	34	28	25	3.07	2.42	82

Appendix 1. Family means (continued)

Provenance	Family	number		Age 4		Age 7	
		Planted	assessed	height	n. retention	n. retention	survival
S. P. Taylor	21	18	14	29	3.29	2.77	78
S. P. Taylor	22	16	12	24	2.67	2.25	75
S. P. Taylor	23	16	13	23	2.77	1.58	81
S. P. Taylor	24	17	14	25	2.57	1.69	82
S. P. Taylor	25	32	22	25	2.77	1.83	69
S. P. Taylor	26	15	10	21	2.90	1.38	67
S. P. Taylor	27	15	15	25	2.40	1.60	100
S. P. Taylor	28	16	13	24	2.85	1.80	81
S. P. Taylor	29	16	12	22	2.50	2.00	75
S. P. Taylor	30	13	10	27	2.60	2.11	77
Russian River	31	8	7	24	2.86	2.29	88
Russian River	32	14	10	24	3.00	1.67	71
Russian River	33	17	14	28	2.86	1.77	82
Russian River	34	16	12	26	2.67	1.58	75
Russian River	35	15	14	27	2.86	1.85	93
Russian River	36	15	12	23	2.67	1.92	80
Russian River	37	18	13	28	2.85	1.15	72
Russian River	38	16	11	23	2.55	1.44	69
Russian River	39	16	11	26	2.64	2.11	69
Fort Ross	51	36	28	28	2.93	2.08	78
Fort Ross	52	16	9	33	2.89	2.25	56
Fort Ross	53	17	12	29	2.92	1.80	71
Fort Ross	54	17	13	27	2.85	2.20	76
Fort Ross	55	29	16	30	2.88	2.07	55
Fort Ross	56	15	10	30	3.20	1.71	67
Fort Ross	57	18	14	28	3.00	2.00	78
Fort Ross	58	16	10	28	2.80	2.30	63
Fort Ross	59	32	22	27	3.24	2.60	69
Fort Ross	60	16	13	29	3.31	2.33	81
Gualala	41	17	12	25	2.92	1.91	71
Gualala	42	17	12	28	3.17	2.92	71
Gualala	43	16	12	25	2.58	1.67	75
Gualala	44	15	14	31	3.21	2.23	93
Gualala	45	18	14	28	2.79	1.69	78
Gualala	47	16	13	26	3.15	2.09	81
Gualala	49	16	11	25	2.18	1.00	69
Navarro river	121	18	14	31	3.36	2.20	78
Navarro river	122	17	13	25	2.77	2.36	76
Navarro river	123	15	10	28	3.00	2.30	67
Navarro river	124	15	11	24	2.64	1.30	73
Navarro river	125	36	31	30	3.26	2.61	86
Navarro river	126	16	11	25	3.36	2.70	69
Navarro river	127	16	14	28	2.64	1.85	88
Navarro river	128	15	11	30	3.27	2.30	73
Navarro river	129	18	14	27	3.00	2.79	78
Navarro river	130	16	11	34	3.18	2.45	69
Navarro river	131	16	14	26	3.21	2.33	88
Navarro river	132	15	10	30	3.20	2.00	67
Navarro river	133	18	15	31	3.13	2.29	83

Appendix 1. Family means (continued)

Provenance	Family	number		Age 4		Age 7	
		planted	assessed	height	n. retention	n. retention	survival
Noyo River	63	16	12	28	3.33	1.78	75
Noyo River	64	15	11	26	3.36	2.45	73
Noyo River	65	18	16	24	3.50	2.53	89
Noyo River	66	16	7	28	3.29	1.89	44
Noyo River	67	16	12	23	3.08	2.00	75
Noyo River	68	15	7	26	3.57	2.50	47
Noyo River	69	17	13	28	3.31	2.54	76
Noyo River	70	16	12	27	3.33	2.82	75
Noyo River	71	18	16	25	3.13	2.07	89
Noyo River	72	30	22	27	3.09	2.33	73
Noyo River	73	18	15	26	3.47	2.33	83
Noyo River	74	32	21	25	3.24	2.94	66
Noyo River	75	16	13	25	3.46	2.75	81
Noyo River	77	18	15	23	3.00	2.14	83
Noyo River	78	18	16	27	2.56	1.06	89
Noyo River	79	12	8	26	3.38	2.14	67
Noyo River	80	16	8	27	3.13	2.25	50
Noyo River	81	16	14	24	3.00	2.33	88
Rockport	91	16	12	21	3.17	2.00	75
Rockport	107	17	15	23	2.60	2.25	88
Rockport	108	11	7	27	3.43	2.17	64
Rockport	109	15	13	28	2.92	2.17	87
Rockport	110	18	16	25	2.94	1.63	89
Arcata	191	18	14	26	3.14	1.86	78
Arcata	192	17	14	28	3.50	2.67	82
Arcata	193	32	26	26	3.08	1.91	81
Arcata	194	15	10	29	3.30	2.30	67
Arcata	195	18	15	26	2.87	2.55	83
Arcata	196	16	14	25	3.07	2.33	88
Arcata	197	16	10	28	3.20	2.50	63
Arcata	198	18	13	26	3.46	2.33	72
Arcata	199	18	16	27	2.75	1.88	89
Arcata	200	17	11	29	3.36	2.40	65
Arcata	201	16	13	29	3.38	2.36	81
Arcata	202	15	11	27	3.00	2.44	73
Arcata	203	17	15	22	3.33	2.57	88
Arcata	204	16	13	21	3.46	2.58	81
Arcata	205	16	12	28	3.83	2.31	75
Ophir	301	18	14	25	3.07	2.40	78
Ophir	303	16	11	24	2.64	1.42	69
Brookings	304	18	16	27	2.88	2.13	89
Brookings	305	15	12	28	3.17	2.42	80
Brookings	307	16	16	27	3.00	1.63	100
Brookings	308	9	7	31	3.14	1.57	78
Brookings	309	16	12	28	3.67	2.50	75
Brookings	310	17	12	26	3.00	2.38	71

Appendix 1. Family means (continued)

Provenance	Family	number		Age 4		Age 7	
		planted	assessed	height	n. retention	n. retention	survival
Coos Bay	314	18	12	23	3.17	2.90	67
Coos Bay	316	16	12	21	3.42	2.17	75
Coos Bay	317	16	13	21	3.46	2.08	81
Coos Bay	320	15	11	22	3.55	2.92	73
Coos Bay	323	16	15	26	3.40	2.46	94
Coos Bay	324	18	18	25	3.28	2.47	100
Myrtle Point	325	11	8	26	2.88	2.50	73
Myrtle Point	326	11	9	26	2.78	2.29	82
Myrtle Point	329	17	11	20	3.45	2.36	65
Myrtle Point	330	16	14	27	3.36	2.00	88
Myrtle Point	334	17	15	25	3.27	2.56	88
Umpqua River	335	17	15	24	3.33	2.20	88
Umpqua River	336	16	15	21	3.07	2.23	94
Umpqua River	337	30	19	21	2.89	1.87	63
Umpqua River	338	10	7	22	3.00	1.86	70
Umpqua River	339	16	11	24	2.82	1.90	69
Umpqua River	340	16	13	21	3.15	2.18	81
Umpqua River	342	17	15	25	3.33	2.07	88
Umpqua River	343	16	13	24	3.31	2.17	81
Umpqua River	345	15	14	21	3.21	2.31	93
Umpqua River	346	13	12	20	3.17	2.00	92
Umpqua River	348	16	11	20	3.27	2.78	69
Umpqua River	350	17	12	23	3.75	2.42	71
Umpqua River	351	18	16	24	3.06	2.18	89
Umpqua River	353	14	11	23	3.45	2.50	79
Umpqua River	354	18	13	24	3.31	1.80	72
Umpqua River	355	16	11	21	3.17	1.67	69
Umpqua River	357	18	17	22	2.82	1.67	94
Siuslaw Forest	361	18	16	26	3.38	2.81	89
Siuslaw Forest	362	16	13	25	3.77	2.85	81
Siuslaw Forest	363	15	14	21	3.29	2.15	93
Siuslaw Forest	364	36	28	23	2.96	1.72	78
Siuslaw Forest	365	16	15	25	3.33	1.82	94
Siuslaw Forest	366	15	11	22	3.27	2.44	73
Siuslaw Forest	367	16	13	24	2.92	1.50	81
Siuslaw Forest	368	17	13	29	3.31	2.50	76
Siuslaw Forest	369	18	17	25	3.35	2.00	94
Siuslaw Forest	370	32	24	25	3.00	2.22	75
Siuslaw Forest	371	15	13	23	3.15	2.18	87
Siuslaw Forest	372	18	17	26	3.59	2.47	94
Siuslaw Forest	373	16	13	21	3.23	2.17	81
Siuslaw Forest	374	32	25	20	3.35	2.16	78
Siuslaw Forest	375	36	31	21	3.55	2.50	86
Siuslaw Forest	378	17	17	24	3.41	2.31	100
Siuslaw Forest	379	16	14	24	3.36	2.54	88
Siuslaw Forest	380	15	14	22	3.64	2.36	93
Siuslaw Forest	381	17	16	28	3.81	2.31	94

Appendix 1. Family means (continued)

Provenance	Family	number		Age 4		Age 7	
		planted	assessed	height	n. retention	n. retention	survival
Willamette Forest	382	36	31	22	3.55	2.33	86
Willamette Forest	383	16	12	22	3.17	2.46	75
Willamette Forest	384	16	15	22	3.20	2.44	94
Willamette Forest	385	16	12	19	3.33	2.36	75
Willamette Forest	386	34	27	24	3.26	2.25	79
Willamette Forest	387	16	11	19	3.45	2.10	69
Willamette Forest	388	15	10	18	3.40	1.88	67
Willamette Forest	389	36	28	19	3.18	2.15	78
Willamette Forest	390	32	23	20	3.00	1.64	72
Willamette Forest	391	16	11	25	3.18	2.09	69
Coos Bay W clone	602	17	17	27	3.24	2.44	100
Long View W clone	605	13	10	25	3.10	2.56	77
Long View W clone	606	13	12	20	3.08	2.08	92
Long View W clone	608	15	13	20	3.38	2.45	87
Twin Harbour clone	610	16	13	22	3.31	2.38	81
Twin Harbour clone	612	8	6	21	3.17	3.00	75
NZ filler (Ft Bragg)	-9	108	92	29	3.41	2.60	85
NZ Fort Bragg	900	116	93	30	3.32	2.66	80
NZ Fort Bragg	901	19	14	30	3.85	2.79	74
NZ Kaingaroa	902	16	14	26	3.57	2.46	88
NZ Fort Bragg	903	16	11	28	3.18	2.50	69
NZ Ashley (Eyre)	904	15	12	23	3.67	2.45	80
NZ Ashley (MT)	905	18	17	24	3.35	2.24	94
NZ Beamont	906	16	14	25	3.50	2.40	88
USA Louisiana-P	907	16	13	27	3.08	2.23	81
							77