SELECTION OF GENETICALLY SUPERIOR *EUCALYPTUS REGNANS* USING FAMILY TESTS

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ABSTRACT

In 1977 tests were established of 141 open-pollinated families of selected plus-trees, and also of some unselected trees, of **Eucalyptus regnans** F. Muell. Several Australian provenances and New Zealand exotic populations were represented. The tests were assessed in June 1980 (3 years from seed sowing) for height growth, resistance to Mycosphaerella leaf blotch disease, branching quality, and stem straightness. Frost tolerance was assessed in 1978.

Family differences (including provenance effects) were most pronounced in height growth, disease resistance, and frost tolerance. Phenotypic correlations between traits were mostly favourable, facilitating simultaneous selection of families for fast growth, good frost-tolerance, and disease resistance, as well as improved branching quality and stem straightness.

Based on these early results, a clonal seed orchard has been established from grafts of 8 of the 55 original New Zealand plus-trees and of 34 new second-generation plus-trees selected from within the family tests. In addition, a seedling seed orchard has been established using bulked seedling progeny of 30 selected families (23 New Zealand, 7 Australian).

INTRODUCTION

Eucalyptus regnans is one of seven *Eucalyptus* species in which genetic improvement programmes are being undertaken in New Zealand (Wilcox 1980). It is presently the most commonly planted eucalypt in all districts except Northland. Most seed used in recent years has been obtained from Tasmania, with lesser amounts from Victoria or from local exotic stands in New Zealand.

The scope and need for genetic improvement in *E. regnans* have been amply demonstrated for frost tolerance (Rook *et al.* 1980; Wilcox *et al.* 1980). Other obvious selection criteria in a breeding programme for this species are rapid growth, freedom from malformation, and good natural branch shedding.

Tests of open-pollinated families of 141 *E. regnans* mother trees from Australia and New Zealand, many of which had been phenotypically selected for fast growth, fine branching, and good stem straightness, were established in 1977. The objectives of these family tests have been fully described by Wilcox (1980). In brief, their role in the breeding programme is to test the progeny of the mother trees so that the best can be identified for inclusion in seed orchards as grafts or seedling progenies; to provide an early source of genetically improved seed; and also to provide a widened genetic base for future selection.

Family differences in growth, disease resistance, stem straightness, and branching quality are reported here from the first assessments carried out at 3 years from seed sowing. Promising parents have been selected for use in seed orchards on the basis of these early results.

MATERIALS AND METHODS

Families

Full particulars of the 141 families, planted in four sets of 36 (A – Tasmania, B – Victoria, C – New Zealand, D – mixed origin), with three families common to Sets C and D, have been given by Wilcox *et al.* (1980). The broad composition of the sets is given in Table 1, and origins are shown in Figs 1 and 2.

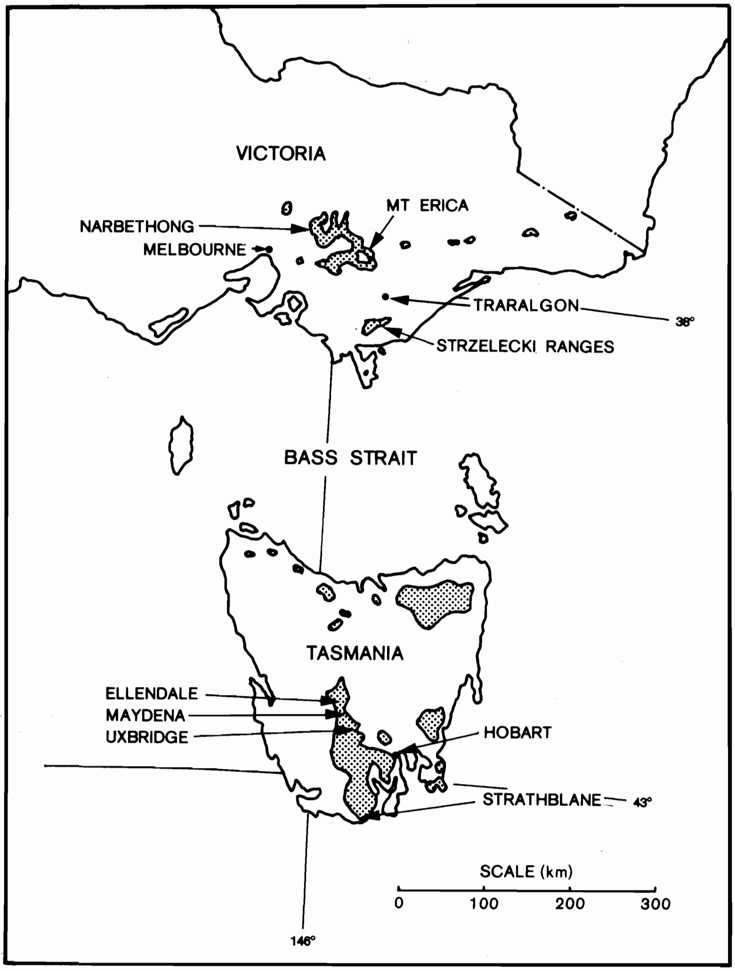

FIG. 1—Native provenances of **E. regnans** represented in New Zealand family tests

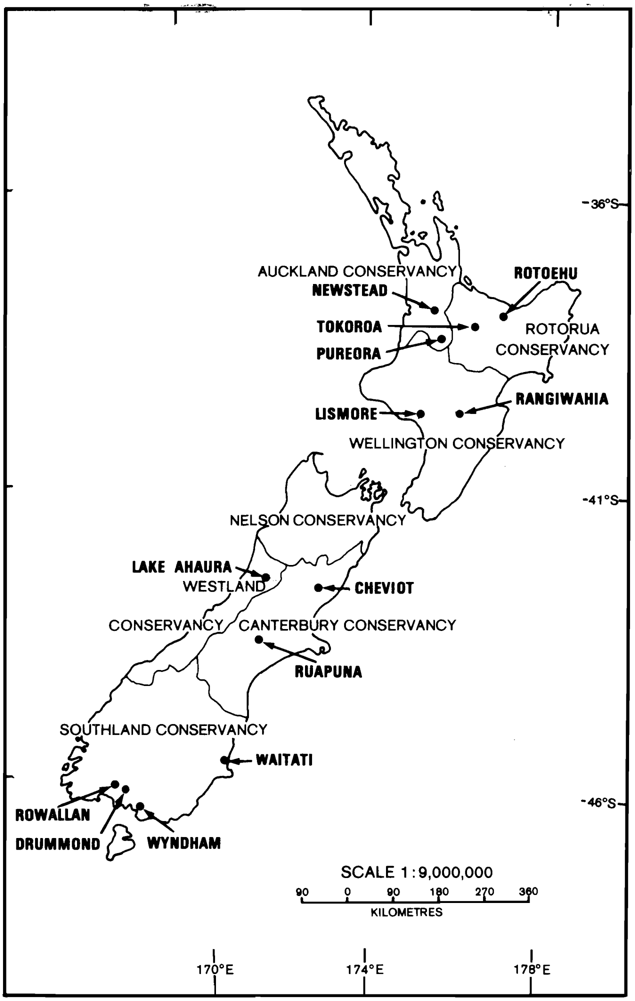

FIG. 2—Origins of **E. regnans** families derived from New Zealand stands

TABLE 1—Classification of **E. regnans** families in the New Zealand breeding programme

Type of family	Number of families in each set				
	A	B	C	D	Total
New Zealand plus-tree	8	—	36	14	55*
New Zealand unselected	—	—	—	2	2
Australian plus-tree	28	17	—	13	58
Australian unselected	—	19	—	7	26

* Three families common to Sets C and D

Description of Tests

The family tests are located in the central North Island at Wiltsdown (Sets A, B, and C) and Kaingaroa (Set D), and were established in November 1977. Each of the four sets was planted as an independent test, using a 36-replicate single-tree plot randomised block design. Plant spacing was 4 × 3 m. Details of the test sites and about raising of the plants have been given by Wilcox *et al.* (1980) *(see also* Wilcox (1982) for brief description of test sites).

Trees in both tests were damaged by winter frosts in 1978. In September 1979 heavy basal branches and double leaders, not necessarily the result of frost damage, were pruned off and the pruning wounds painted with acrylic paint in an attempt to prevent infection by decay fungi such as *Stereum purpureum* (Pers.) Fr.

The Wiltsdown test site rapidly reverted to pasture after the initial cultivation prior to tree establishment, and has been grazed by sheep since August 1978, with negligible damage to the trees.

Assessment Method

Frost damage was assessed in June 1978, as fully described by Wilcox *et al.* (1980), and for completeness these results are summarily recorded again in tables later in this paper. The tests were comprehensively assessed in June or July 1980 as follows:

Height; in metres.

Disease susceptibility; scored on a scale of 1 (no visible disease symptoms) to 9 (the whole crown, including the leader, severely infected). The disease was fungal "leaf blotch" attributed mainly to *Mycosphaerella nubilosa* (Cooke) Hansf.* which is particularly prevalent in wet summers.

Branching quality; scored on a scale of 1 (very coarse, steep-angled branching, including multiple forking) to 9 (small-diameter, flat-angled branching, with no forking). Trees that had to be heavily pruned to remove forks and extra-big branches, whether or not these malformations were obviously the results of earlier frost damage, were given low scores for branching quality.

Stem straightness; scored on a scale of 1 (very crooked) to 9 (very straight).

As well as these four quantitative traits, each tree was classified as having flower buds, or not. Trees of excellent form, growth, and resistance to disease, and which had also escaped serious frost injury in 1978 were provisionally selected as second-generation plus-tree candidates.

Data Analysis

Individual tree data for each set were analysed and family means estimated by the method of fitting constants (least squares) in a two-way crossed classification model without interaction (Table 2). Variance components for families (σ^2_f), replications (σ^2_r), and error (σ^2_e) were estimated using the model shown in Table 2, and repeatability of family means calculated from:

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* **See** end of text for note added in proof.

$$\hat{h}^2_{\bar{F}} = \frac{(N-b)\ \hat{\sigma}^2_f}{(a-1)\ M_1}$$

The statistical significance of differences among families within sets was determined from F-tests and least significant differences.

Phenotypic correlations between traits were calculated from the family means.

TABLE 2—Analysis of variance model for family tests of **E. regnans** based on single-tree plot design and using method of fitting constants

Source	df	SS	MS	E(MS)
Family	a-1	$R(\alpha\|\mu, \beta)$	M_1	$\sigma^2_e + \frac{N-b}{a-1}\sigma^2_f$
Replication	b-1	$R(\beta\|\mu, \alpha)$	M_2	$\sigma^2_e + \frac{N-a}{b-1}\sigma^2_r$
Error	N-a-b+1	T_0-$R(\mu,\alpha,\beta)$	M_3	σ^2_e
Total	N-1			

RESULTS

Genetic Variation

The traits exhibiting the greatest amount of genetic variation as measured by family variances and repeatabilities were disease resistance, frost tolerance, and height growth. Families did differ in branching quality and stem straightness, though repeatabilities for these traits were generally lower than for the other three traits (Table 3).

TABLE 3—Estimates of family variance components (σ^2_f), their percentage contribution to the total phenotypic variance, and family repeatabilities (h^2_F) in **E. regnans** families at 3 years from seed sowing*

Trait	Set A (Tas.)	Set B (Vic.)	Set C (N.Z.)	Set D (Mixed)
Height	0.06 (8%)	0.18 (13%)	0.12 (14%)	0.19 (23%)
(m)	**0.74**	**0.81**	**0.81**	**0.90**
Disease resistance	0.04 (2%)	0.58 (15%)	0.37 (19%)	1.13 (27%)
(1–9)	**0.42**	**0.81**	**0.85**	**0.92**
Frost tolerance	0.02 (4%)	0.06 (7%)	0.06 (10%)	0.15 (15%)
(0–5)	**0.54**	**0.70**	**0.71**	**0.86**
Branching quality	0.01 (0%)	0.12 (4%)	0.20 (5%)	0.24 (8%)
(1–9)	**0.05**	**0.52**	**0.53**	**0.72**
Straightness	0.09 (4%)	0.14 (5%)	0.19 (7%)	0.23 (8%)
(1–9)	**0.53**	**0.56**	**0.64**	**0.75**

* Family mean repeatabilities are shown in bold type

The mixed (Set D) and New Zealand (Set C) families showed the greatest family-to-family variation, partly because of the diversity of provenances represented in these sets. The least amount of family-to-family variation in all traits was shown by the families of Tasmanian origin (Set A).

Phenotypic Correlations

The phenotypic correlations among family means for all pairs of traits are shown in Table 4. Nearly all correlations were favourable to the simultaneous selection for desired traits. Particularly strong correlations in all sets occurred between branching and straightness, and between height growth and disease resistance. There was a favourable positive correlation between disease resistance and frost tolerance, but no strong evidence of an important correlation between frost tolerance and height growth. The negative correlation between frost damage and survival was testimony to the importance of frost resistance as an early selection criterion (Wilcox *et al.* 1980).

TABLE 4—Phenotypic correlations among family means in **E. regnans** at age 3 years from seed sowing

Correlation	Set A (Tas.)	Set B (Vic.)	Set C (N.Z.)	Set D (Mixed)
Height × disease	–0.53*	–0.43*	–0.57*	–0.60*
Height × frost	–0.16*	0.17†	–0.16*	0.05
Height × branching	0.22*	0.19*	0.47*	0.50*
Height × straightness	0.27*	–0.03	0.49*	0.48*
Disease × frost	0.39*	0.02	0.52*	0.26*
Disease × branching	–0.09	–0.19*	–0.46*	–0.25*
Disease × straightness	–0.23*	–0.05	–0.68*	–0.57*
Frost × branching	0.13†	0.02	–0.30*	–0.27*
Frost × straightness	0.41†	–0.01	–0.50*	–0.44*
Branching × straightness	0.50*	0.70*	0.41*	0.55*
Frost × survival	–0.07*	–0.40*	–0.62*	–0.45*

* Correlations favourable for selection

† Correlations unfavourable for selection

Selection of Families

The family means for each trait are shown in Tables 5–8, with families ranked in order of mean height. Noteworthy features of these listings are the excellent vigour of certain families from the Strzelecki Ranges, Victoria, in Set B; the good all-round performance of several families from Tokoroa, New Zealand, particularly as shown in Set D; and the very poor quality of the progeny from some of the other New Zealand populations. Provenance effects within sets were most apparent in Sets B and D.

Thirty-nine families, spread over all four sets, were selected. These are marked with an asterisk in Tables 5–8. Twenty-five are from New Zealand plus-trees and 14 are from Australian plus-trees, mostly from Tasmania. In choosing these families, emphasis was given to height ranking within sets, though notice was taken of extreme values of other traits. Furthermore, selection was biased towards New Zealand families since most parent trees were available for grafting and further seed collection.

Second-generation Selection

Individuals of excellent phenotype, including good frost-tolerance, were identified by the measurement teams during the 1980 assessment. The number of these second-generation plus-tree candidates provisionally selected in each family is listed in Tables 5–8, and totalled 125 for the four sets. Most of these plus-trees, as expected, were found in the 39 selected families. The candidates were inspected a year later and the best 50 phenotypes selected for grafting into seed orchards.

DISCUSSION

These early assessments of the family tests have revealed considerable genetic variation in the species and have demonstrated the value of such tests in the breeding programme. Because of obvious provenance effects, effects of selection, and of other problems in interpreting σ^2_f (Wilcox 1980), no attempt was made here to estimate additive genetic variance as such, or heritability, from the family variance components, though significant family effects were evident in all traits.

While provenance effects in each set were not separately analysed by estimation of a variance component, it is apparent from the family means listed in Tables 5–8 that provenance variation made an important contribution to the family variance in several instances. For example, the Strzelecki Ranges families in Set B (mean score 3.6) were much more resistant to the leaf blotch disease caused by *Mycosphaerella nubilosa* than the Narbethong families (mean score 5.0); and in Set D, the Tokoroa families (mean score 2.0) were more resistant than the Waitati families (mean score 3.8). These results are closely paralleled in companion provenance tests (Wilcox 1982). Again in Set D, the superior height growth shown by the Tokoroa provenance obviously contributed to the large family variance in this trait.

Because selection effects were confounded with provenance and set effects it was not possible to validly compare plus-tree families with unselected families and thereby measure genetic gain. Nevertheless it is tempting to attribute the excellence of the Tokoroa families in Set D at least partly to phenotypic selection, reinforced by a fortunate choice of provenance.

The total number of survivors out of 36 trees planted is listed for each family in Tables 5–8. Survival was exceptionally poor in several of the families in Set C (New Zealand). By far the worst survivors were the families of the Waitati provenance – an obvious consequence of its poor frost tolerance (Rook *et al.* 1980; Wilcox *et al.* 1980).

Eucalyptus regnans proved to be a surprisingly precocious flowerer on these sites, with more than half the individuals in some families bearing crops of flower buds (Tables 5–8). The proportion of individuals that bore buds was rather consistently correlated with the severity of Mycosphaerella attack ($r = -0.44$, Set A; -0.53, Set B;

TABLE 5—Assessment of **E. regnans** Set A families (Tasmania) at Wiltsdown in June 1980 (aged 3 years from sowing)

Rank†	Lot	N.Z. plus-tree No.	Origin‡	Height (m)	Disease§ (1–9)	Frost‖ (0–5)	BrQ (1–9)	Str (1–9)	Number of trees¶		
									Total	Buds	Plus
1	*32		Ellendale (524)	7.4	2.3	0.74	5.3	5.0	27	7	0
2	*37		Ellendale (531)	7.3	2.5	1.12	6.0	5.1	29	8	0
3	*35		Ellendale (528)	7.3	2.0	1.12	5.9	6.0	28	10	1
4	*40		Ellendale (535)	7.3	2.3	0.96	5.4	5.9	30	10	1
5	*86	877-78	Tokoroa	7.2	2.1	0.60	5.8	5.3	28	9	0
6	*88	877-80	Tokoroa	7.2	2.1	0.68	5.3	5.1	34	7	0
7	*36		Ellendale (530)	7.2	2.0	0.87	5.5	5.5	30	8	1
8	*20		Uxbridge (570)	7.2	2.4	0.93	5.8	5.3	30	12	2
9	*19		Uxbridge (569)	7.1	2.6	1.12	5.7	5.7	23	6	2
10	17		Uxbridge (567)	7.1	2.5	1.36	5.3	5.8	26	8	1
11	*39		Ellendale (534)	7.0	2.6	1.03	4.6	5.3	30	5	2
12	24		Uxbridge (574)	6.9	2.4	1.18	5.4	5.5	17	2	1
13	*84	877-76	Tokoroa	6.9	2.1	0.74	5.4	5.1	28	8	0
14	33		Ellendale (525)	6.9	2.5	1.14	4.6	5.0	25	7	0
15	14		Uxbridge (564)	6.9	2.9	1.10	5.4	5.2	17	2	0
16	43		Ellendale (596)	6.9	2.8	1.03	5.0	4.4	27	1	0
17	38		Ellendale (533)	6.9	2.4	1.30	5.0	5.1	20	6	0
18	22		Uxbridge (572)	6.8	2.6	1.32	5.5	5.8	27	7	1
19	42		Ellendale (593)	6.8	3.4	1.17	5.2	4.4	21	1	0
20	11		Uxbridge (561)	6.8	2.9	1.32	5.6	5.7	25	1	0
21	41		Ellendale (592)	6.8	2.9	1.19	5.9	5.1	25	4	0
22	*87	877-79	Tokoroa	6.7	2.5	1.39	5.2	5.1	28	6	1
23	*85	877-77	Tokoroa	6.7	2.7	0.64	5.6	5.1	28	8	0
24	21		Uxbridge (571)	6.7	3.0	1.38	5.8	5.9	17	2	0
25	*82	877-74	Tokoroa	6.7	2.8	1.68	5.3	5.7	24	3	0
26	12		Uxbridge (562)	6.7	2.6	1.13	5.1	5.1	27	8	0
27	34		Ellendale (526)	6.7	2.7	1.26	5.7	6.0	23	1	0
28	13		Uxbridge (563)	6.7	3.0	1.00	5.1	4.9	24	7	1
29	18		Uxbridge (568)	6.7	2.5	1.32	6.1	5.9	28	5	0
30	81	877-73	Tokoroa	6.7	2.8	1.53	6.0	5.9	22	7	0
31	15		Uxbridge (565)	6.6	2.5	1.21	5.1	4.7	20	4	0
32	23		Uxbridge (573)	6.5	2.3	1.02	5.4	5.4	20	2	0
33	83	877-75	Tokoroa	6.5	2.9	0.92	5.2	4.8	21	8	0
34	31		Ellendale (521)	6.5	2.9	1.26	5.3	5.7	21	5	0
35	16		Uxbridge (566)	6.5	2.5	1.08	4.8	4.9	26	4	0
36	44		Ellendale (599)	6.2	2.7	1.16	5.4	4.7	20	2	0
Mean				6.9	2.6	1.11	5.4	5.3	25	5.6	
LSD (0.05)				0.4	0.7	0.38	1.1	0.8			
F-test, families				3.8**	1.7**	2.2**	1.1ns	2.1**			

† Ranked in order of mean height. Asterisk signifies that the family and/or its parent clone has been chosen for further use in the breeding programme.

‡ A.P.M. Forests Pty Ltd's tree numbers in parentheses.

§ Infection by **Mycosphaerella nubilosa** (1 = no infection; 9 = very severe damage).

‖ Frost damage rated in August 1978 (0 = no damage; 5 = killed by frost).

¶ Total = number of crop trees surviving out of 36 planted; Buds = number of trees with flower buds; Plus = number of plus-trees provisionally selected in the family.

TABLE 6—Assessment of **E. regnans** Set B families (Victoria) at Wiltsdown in June 1980 (aged 3 years from sowing)

Rank†	Lot	Origin‡	Height (m)	Disease§ (1–9)	Frost‖ (0–5)	BrQ (1–9)	Str (1–9)	Number of trees¶		
								Total	Buds	Plus
1	*62	Strzelecki Ranges (51)	8.5	2.6	1.14	4.5	4.6	31	14	1
2	57	Strzelecki Ranges (30)	8.3	3.4	1.91	5.9	5.5	27	8	3
3	*49	Strzelecki Ranges (6)	8.2	3.1	1.09	6.2	5.9	23	8	0
4	*50	Strzelecki Ranges (7)	8.1	2.7	1.68	5.6	5.8	25	5	2
5	56	Strzelecki Ranges (28)	8.1	3.0	2.15	4.3	4.1	17	3	0
6	53	Strzelecki Ranges (13)	8.1	3.4	1.94	5.1	5.1	29	14	3
7	65	Strzelecki Ranges (90)	8.1	4.3	1.32	5.5	5.8	24	8	3
8	128	Mt Erica, 370 m (E 12)	8.0	3.7	1.88	5.1	4.8	22	3	1
9	64	Strzelecki Ranges (73)	8.0	3.8	1.36	5.1	5.4	25	16	2
10	54	Strzelecki Ranges (17)	8.0	4.2	1.73	5.6	5.2	27	6	2
11	*59	Strzelecki Ranges (36)	7.9	3.8	1.29	6.3	6.1	32	13	4
12	130	Mt Erica, 490 m (E 24)	7.8	3.0	1.55	5.2	5.1	26	5	0
13	55	Strzelecki Ranges (18)	7.8	4.6	1.17	4.8	5.3	28	2	1
14	170	Narbethong (NB 5)	7.8	4.8	1.03	5.0	5.2	30	2	2
15	175	Narbethong (NB 16)	7.7	4.7	1.85	5.6	5.7	23	1	1
16	126	Mt Erica, 370 m	7.6	4.2	2.41	5.1	5.4	21	2	0
17	176	Narbethong (NB 19)	7.6	4.9	1.45	5.0	5.3	25	3	0
18	168	Narbethong (NB 1)	7.6	4.9	1.13	5.2	4.4	27	2	0
19	187	Narbethong (NB 51)	7.6	3.9	1.45	5.2	6.0	20	2	0
20	131	Mt Erica, 490 m (E 25)	7.4	4.0	1.57	5.2	5.3	22	1	1
21	58	Strzelecki Ranges (31)	7.3	4.8	1.70	4.9	5.6	29	5	0
22	171	Narbethong (NB 6)	7.3	5.4	2.12	4.8	4.8	19	1	0
23	52	Strzelecki Ranges (12)	7.3	5.0	1.35	5.9	5.8	25	5	0
24	51	Strzelecki Ranges (9)	7.2	4.1	1.82	5.0	5.6	21	2	0
25	183	Narbethong (NB 31)	7.2	5.7	0.93	4.8	5.6	20	2	0
26	134	Mt Erica, 810 m (E 51)	7.2	3.0	1.29	5.6	6.0	28	9	1
27	181	Narbethong (NB 27)	7.1	4.7	1.68	4.7	4.8	19	1	0
28	136	Mt Erica, 990 m (E 3)	7.1	3.3	0.79	5.0	5.2	25	7	0
29	61	Strzelecki Ranges (47)	7.1	4.3	1.64	4.8	4.9	23	3	0
30	178	Narbethong (NB 24)	7.1	4.0	1.77	5.6	5.2	23	3	0
31	182	Narbethong (NB 30)	7.0	6.1	2.14	4.8	4.9	22	1	1
32	132	Mt Erica, 1100 m (E 108)	6.9	3.4	0.61	4.7	5.0	26	7	0
33	180	Narbethong (NB 26)	6.9	4.7	1.73	4.5	4.5	16	4	0
34	179	Narbethong (NB 25)	6.9	5.8	1.62	5.2	4.6	11	2	0
35	60	Strzelecki Ranges (41)	6.8	4.2	2.08	5.1	5.4	15	2	0
36	63	Strzelecki Ranges (71)	6.8	3.4	1.23	5.9	6.0	20	3	0
Mean			7.5	4.1	1.56	5.2	5.3	23	4.9	
LSD (0.05)			0.6	1.0	0.47	0.9	0.9			
F-test families			5.4**	5.4**	3.3**	2.1**	2.3**			

† Ranked in order of mean height. Asterisk signifies that the family has been chosen for further use in the breeding programme.
‡ Dr A. R. Griffin's tree numbers = (NB 5);
A.P.M. Forests Pty Ltd's tree numbers = (51);
Dr K. G. Eldridge's tree numbers = (E 12).
§ Infection by **Mycosphaerella nubilosa** (1 = no infection; 9 = very severe damage).
‖ Frost damage rated in August 1978 (0 = no damage; 5 = killed by frost).
¶ Total = number of crop trees surviving out of 36 planted; Buds = number of trees with flower buds; Plus = number of plus-trees provisionally selected in the family.

TABLE 7—Assessment of **E. regnans** Set C families (New Zealand) at Wiltsdown in June 1980 (aged 3 years from sowing)

Rank†	Lot	N.Z. plus-tree No.	Origin	Height (m)	Disease‡ (1–9)	Frost§ (0–5)	BrQ (1–9)	Str (1–9)	Number of trees‖		
									Total	Buds	Plus
1	*3	873-53	Tokoroa	7.9	1.7	0.69	6.8	6.3	30	12	4
2	*94★	877-86	Rangiwahia (ex Vic.)	7.8	1.8	0.94	5.6	6.3	30	10	3
3	*99	877-91	Lismore (ex Vic.)	7.7	2.0	0.83	6.1	6.1	27	18	3
4	92	877-84	Rangiwahia (ex Vic.)	7.6	2.5	1.32	5.1	4.8	25	11	0
5	*2	873-51	Tokoroa	7.6	2.3	0.79	6.0	6.7	28	12	4
6	*78	877-70	Rotoehu	7.5	2.4	0.48	5.8	6.9	24	12	4
7	*95	877-87	Rangiwahia (ex Vic.)	7.4	2.1	1.05	5.7	6.3	21	8	0
8	*5	873-55	Tokoroa	7.4	1.8	0.91	5.7	5.9	29	4	1
9	91	877-83	Rangiwahia (ex Vic.)	7.3	2.7	1.28	4.7	5.8	24	3	0
10	102	877-94	Lismore (ex Vic.)	7.3	3.2	1.37	5.3	6.1	27	6	2
11	*100	877-92	Lismore (ex Vic.)	7.2	2.5	1.05	6.0	5.6	18	6	0
12	*103	877-95	Lismore (ex Vic.)	7.2	2.8	1.08	5.0	5.9	26	5	2
13	93	877-85	Rangiwahia (ex Vic.)	7.2	2.4	1.41	4.9	5.6	29	8	2
14	144	877-69	Wyndham	7.1	3.6	1.00	5.3	4.8	17	1	1
15	141	877-66	Rowallan (ex Waitati)	7.1	4.1	2.28	6.1	5.1	8	0	0
16	116	877-108	Waitati	7.0	3.0	1.82	4.7	6.2	13	2	0
17	*104	877-96	Ruapuna	7.1	2.3	1.15	5.9	6.2	27	14	2
18	*1	873-50	Tokoroa	7.1	1.5	0.39	6.1	6.0	25	9	2
19	108	877-100	Ruapuna	7.1	2.3	1.25	5.5	5.7	24	11	0
20	4	873-54	Tokoroa	7.1	2.8	1.11	5.7	5.9	30	11	1
21	107	877-99	Ruapuna	6.9	2.9	1.20	4.8	5.4	19	6	0
22	97	877-89	Lismore (ex Waitati)	6.9	3.3	2.11	5.0	4.6	8	4	0
23	106★	877-98	Ruapuna	6.9	3.2	1.00	4.4	4.6	27	15	1
24	120★	877-202	Cheviot	6.9	2.8	1.37	4.9	5.6	30	7	0
25	138	877-140	Pureora	6.9	2.3	1.00	5.8	5.8	16	1	0
26	*79	877-71	Rotoehu	6.9	2.0	1.23	5.3	5.4	20	9	1
27	140	877-65	Rowallan (ex Waitati)	6.8	3.6	2.02	5.6	4.7	13	1	0
28	109	877-101	Ruapuna	6.8	3.2	1.24	4.7	5.6	21	9	0
29	115	877-107	Waitati	6.8	4.8	2.11	5.0	4.7	9	1	0
30	114	877-106	Waitati	6.7	4.2	2.00	5.7	4.5	9	1	0
31	139	877-141	Pureora	6.7	2.8	1.22	4.2	5.8	21	10	0
32	98	877-90	Lismore (ex Waitati)	6.7	3.4	2.51	5.5	5.3	17	4	0
33	143	877-68	Wyndham	6.6	2.5	1.14	5.9	5.7	19	3	1
34	105	877-97	Ruapuna	6.6	3.1	1.34	4.0	5.4	10	2	0
35	113	877-105	Waitati	6.5	4.4	1.75	5.4	4.3	7	0	0
36	142	877-67	Drummond	6.1	3.1	0.40	5.5	5.7	15	6	0
Mean				7.1	2.7	1.28	5.4	5.6	20	6.7	
LSD (0.05)				0.5	0.7	0.46	1.2	0.9			
F-test, families				5.4**	6.5**	3.4**	2.1*	2.8*			

† Ranked in order of mean height. Asterisk signifies that the family and/or its parent clone has been chosen for further use in the breeding programme. Families marked ★ occur in both Sets C and D.

‡ Infection by **Mycosphaerella nubilosa** (1 = no infection; 9 = very severe damage).

§ Frost damage rated in August 1978 (0 = no damage; 5 = killed by frost).

‖ Total = number of crop trees surviving out of 36 planted; Buds = number of trees with flower buds; Plus = number of plus-trees provisionally selected in the family.

TABLE 8—Assessment of **E. regnans** Set D families (mixed origin) at Kaingaroa in June 1980 (aged 3 years from sowing)

Rank†	Lot	N.Z. plus-tree No.	Origin‡	Height (m)	Disease§ (1–9)	Frost‖ (0–5)	BrQ (1–9)	Str (1–9)	Number of trees¶		
									Total	Buds	Plus
1	*89	877-81	Tokoroa, N.Z.	6.7	2.7	0.91	6.0	6.2	36	2	3
2	*6	873-56	Tokoroa, N.Z.	6.7	3.0	0.52	6.9	6.5	27	8	4
3	*7	873-57	Tokoroa, N.Z.	6.5	3.4	0.68	6.0	6.9	35	6	5
4	*90	877-82	Tokoroa, N.Z.	6.5	3.6	0.63	6.5	6.7	35	5	5
5	*9	873-59	Tokoroa, N.Z.	6.4	2.1	0.83	6.0	6.3	33	11	3
6	66	—	Strzelecki Ranges, Vic. (101)	6.3	3.0	1.30	5.8	6.5	35	1	2
7	*8	873-58	Tokoroa, N.Z.	6.2	2.5	0.62	5.9	6.2	34	10	3
8	67	—	Strzelecki Ranges, Vic. (108)	6.2	3.4	1.00	5.9	6.2	35	7	0
9	*94★	877-86	Rangiwahia, N.Z.	6.2	2.7	1.11	4.7	5.1	33	6	1
10	101	877-93	Lismore, N.Z.	6.1	4.1	0.65	5.1	6.0	34	3	2
11	*68	—	Silver Ck, Vic. (121)	6.1	2.0	0.83	4.6	5.6	34	10	1
12	124	—	Mt Erica, Vic. 610 m	5.8	3.2	0.83	5.5	6.2	34	5	0
13	120★	877-202	Cheviot, N.Z.	5.8	3.5	1.14	5.2	5.9	32	3	0
14	26	—	Uxbridge, Tas. (576)	5.7	4.2	0.55	5.3	4.9	27	4	0
15	127	—	Strathblane, Tas. (E 163)	5.7	5.5	2.47	5.0	5.5	20	2	0
16	29	—	Uxbridge, Tas. (579)	5.6	4.7	0.58	5.5	5.6	26	3	0
17	46	—	Ellendale, Tas. (606)	5.6	5.7	0.67	5.8	5.6	31	0	0
18	45	—	Ellendale, Tas. (602)	5.6	5.3	0.83	5.9	5.6	31	1	0
19	*80	877-72	Newstead, N.Z.	5.6	4.8	0.61	4.9	5.9	23	2	1
20	106★	877-98	Ruapuna, N.Z.	5.6	5.1	1.40	4.7	5.6	27	3	0
21	122	—	Strathblane, Tas. (E 157)	5.6	5.8	2.00	5.7	4.6	27	0	0
22	27	—	Uxbridge, Tas. (577)	5.6	3.9	0.47	5.8	6.1	29	3	2
23	*121	—	Maydena, Tas. (E 122)	5.6	2.3	0.64	6.3	6.6	30	5	4
24	30	—	Uxbridge, Tas. (588)	5.6	4.8	0.65	5.6	5.3	30	0	0
25	47	—	Ellendale, Tas. (607)	5.5	5.7	0.51	6.2	5.7	31	2	0
26	125	—	Mt Erica, Vic. 1040 m	5.5	3.7	0.54	5.6	5.6	30	6	0
27	186	—	Narbethong, Vic. (NB 34)	5.5	4.8	1.45	5.1	6.0	21	0	1
28	184	—	Narbethong, Vic. (NB 33)	5.5	2.9	0.30	5.6	6.5	30	1	1
29	48	—	Ellendale, Tas. (608)	5.5	4.4	0.88	5.7	5.6	26	3	0
30	117	877-109	Waitati, N.Z.	5.4	5.2	1.48	4.9	5.4	28	3	1
31	118	877-110	Waitati, N.Z.	5.3	5.4	2.22	4.8	4.5	21	0	0
32	28	—	Uxbridge, Tas. (578)	5.3	3.6	0.32	5.2	6.0	28	1	0
33	77	—	Lake Ahaura, N.Z. (ex Tas.)	5.3	5.1	0.13	5.7	6.0	31	2	1
34	110	877-102	Ruapuna, N.Z.	5.3	5.4	0.91	4.6	5.3	28	3	1
35	25	—	Uxbridge, Tas. (575)	5.2	5.4	0.61	5.6	5.4	25	1	0
36	76	—	Lake Ahaura, N.Z. (ex Tas.)	5.0	3.7	0.47	4.5	6.1	36	1	0
Mean				5.8	4.0	0.88	5.5	5.8	30	3.4	
LSD (0.05)				0.4	0.9	0.47	0.9	0.8			
F-test, families				10.5**	12.8**	5.7**	3.6**	4.1**			

† Ranked in order of mean height. Asterisk signifies that the family and/or its parent clone has been chosen for further use in the breeding programme. Families marked ★ occur in both Sets C and D.

‡ Dr A. R. Griffin's tree numbers = (NB 33);
A.P.M. Forests Pty Ltd's tree numbers = (578);
Dr K. G. Eldridge's tree numbers = (E 122).

§ Infection by **Mycosphaerella nubilosa** (1 = no infection; 9 = very severe damage).

‖ Frost damage rates in August 1978 (0 = no damage; 5 = killed by frost).

¶ Total = number of crop trees surviving out of 36 planted; Buds = number of trees with flower buds; Plus = number of plus-trees provisionally selected in the family.

–0.52, Set C; –0.64, Set D), suggesting that development of resistance to this disease is associated with the onset of physiological maturity. The generally more severe Mycosphaerella leaf blotch experienced in the slower-growing families is interpretable in several ways. It could be surmised that severe attacks of the disease stunted tree growth; alternatively, small trees because of their short stature and possible associated foliage peculiarities, might be more prone to infection.

Certain families deserve special comment. In Set C, the members of which are all open-pollinated families derived from seed collected from plus-trees selected in New Zealand exotic stands, Family 142 from plus-tree 877-67 on a farm in Southland was particularly slow-growing. The parent was a lone tree, and the slow growth of the progeny probably reflects inbreeding depression from selfing. In Set D, the Tokoroa families were extremely good, while the two families (76 and 77) from Lake Ahaura, which were outstandingly frost-hardy (Wilcox *et al.* 1980), proved to be very slow-growing and prone to Mycosphaerella leaf blotch (Table 8).

Several of the Australian plus-tree families in Set A (Tasmania) and Set B (Victoria) appear to be valuable acquisitions to the New Zealand breeding programme. In contrast, the 14 families from unselected mother trees of the Narbethong provenance in Victoria were extremely disappointing, being highly susceptible to Mycosphaerella *(see also* Wilcox 1982), mostly of poor stem form, and also of less than satisfactory growth rate and frost tolerance (Table 6). This provenance thus appears to be poorly adapted to central North Island sites, though it may possibly have performed better in other environments. This, and other aspects of the results from these family tests, underlines the vital importance of provenance in the domestication of a comparatively new exotic species. In these tests, selection of the best families also heavily favoured the better provenances (Wilcox 1982).

APPLICATION OF RESULTS

These preliminary results allow progress towards the breeding of genetically improved *E. regnans.* More information will be needed, particularly regarding the applicability to the South Island of the selections made. Several seed sources or "breeds" are now under development.

(1) *Clonal seed orchard*

A 0.8-ha clonal seed orchard was established at Cambridge in 1982 using 139 grafts of 42 plus-trees. Spacing was 5 × 12 m. Eight of the clones (16 grafts) were from the selected group of 25 first-generation New Zealand trees chosen using the results of the progeny tests. Grafting was unsuccessful with the 17 other superior first-generation trees (Table 9). Open-pollinated seedling progeny of each plus-tree were used as rootstock to minimise incompatibility.

Most grafts of second-generation selections in the orchard were on sibling rootstocks, and no grafts were successful with 16 of the 50 selections. Of the remaining 34 clones (123 grafts), 17 came from Australian families and 17 from New Zealand families.

The orchard is dominated by clones derived from Tasmanian provenances (60% of the clones and 73% of the grafts).

TABLE 9—Composition of clonal seed orchard of **E. regnans** planted at Cambridge in September 1982

Clone	Origin	Derivation	Native* provenance	No. of grafts
873-50	Tokoroa	Commercial seedlot	T	1
873-53	Tokoroa	Commercial seedlot	T	6
873-63	Rotorua	Mt Erica	V	1
877-72	Newstead	Unknown	?	1
877-74	Tokoroa	Commercial seedlot	T	1
877-77	Tokoroa	Commercial seedlot	T	1
877-79	Tokoroa	Commercial seedlot	T	2
877-81	Tokoroa	Commercial seedlot	T	3
881-401	Wiltsdown	Ellendale (Family 36)	T	2
881-402	Wiltsdown	Ellendale (32)	T	4
881-403	Wiltsdown	Ellendale (32)	T	4
881-404	Wiltsdown	Ellendale (35)	T	6
881-405	Wiltsdown	Uxbridge (17)	T	4
881-406	Wiltsdown	Uxbridge (19)	T	5
881-408	Wiltsdown	Narbethong (175)	V	3
881-410	Wiltsdown	Tokoroa (Family 5 ex 873-55)	T	9
881-411	Wiltsdown	Lismore (99 ex 877-91)	V	1
881-412	Wiltsdown	Rotoehu (78 ex 877-70)	?	4
881-414	Wiltsdown	Rotoehu (78 ex 877-70)	?	4
881-415	Wiltsdown	Tokoroa (4 ex 873-54)	T	5
881-416	Wiltsdown	Tokoroa (3 ex 873-53)	T	11
881-417	Wiltsdown	Lismore (103 ex 877-95)	V	4
881-418	Wiltsdown	Rangiwahia (94 ex 877-86)	V	1
881-419	Wiltsdown	Tokoroa (2 ex 873-51)	T	7
881-420	Wiltsdown	Tokoroa (3 ex 873-53)	T	5
881-422	Wiltsdown	Tokoroa (2 ex 873-51)	T	1
881-423	Wiltsdown	Strzelecki's (64)	V	1
881-424	Wiltsdown	Strzelecki's (65)	V	3
881-425	Wiltsdown	Strzelecki's (50)	V	2
881-427	Wiltsdown	Strzelecki's (54)	V	3
881-428	Wiltsdown	Mt Erica (134)	V	3
881-429	Wiltsdown	Strzelecki's (62)	V	1
881-430	Wiltsdown	Strzelecki's (53)	V	1
881-432	Kaingaroa	Uxbridge (27)	T	2
881-433	Kaingaroa	Tokoroa (90 ex 877-82)	T	2
881-434	Kaingaroa	Tokoroa (6 ex 873-56)	T	5
881-435	Kaingaroa	Tokoroa (8 ex 873-58)	T	3
881-436	Kaingaroa	Rangiwahia (94 ex 877-86)	V	1
881-438	Kaingaroa	Narbethong (184)	V	3
881-440	Kaingaroa	Tokoroa (9 ex 873-59)	T	6
881-442	Kaingaroa	Maydena (121)	T	5
881-443	Kaingaroa	Tokoroa (7 ex 873-57)	T	2

* T = Tasmania
V = Victoria

(2) *First-generation seedling seed orchard*

The family tests at Kaingaroa and Wiltsdown are due to be thinned in 1983 to remove inferior individuals. Once thinned, Set A in particular, made up entirely of families from plus-trees of interior south Tasmanian origin, may be suitable for seed collection as early as age 7 or 8 years, i.e., in 1984 or 1985.

(3) *Extensive seedling seed orchards*

Seedlings were grown in 1982 from bulked seed of 30 (23 New Zealand, 7 Australian) of the 39 selected families. The seed came from either remnant lots from the original family tests or from fresh collections from plus-trees or clonal archives.

Several small plantations have been established as future seed sources.

Until these orchards are in production, seed of good genetic quality can be collected from selected trees in certain local stands, especially those of proven, well-adapted southern Tasmanian provenances (Wilcox 1982). If further commercial seed importations are needed from Australia, emphasis should be on upland, interior, south Tasmania sources to ensure adequate frost-tolerance.

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Note added in proof: Recent studies in Victoria (Park & Keane 1982a, 1982b) indicate that the correct identity of the pathogen responsible for the common leaf blotch disease on *E. regnans* and *E. delegatensis* in New Zealand is *Mycosphaerella cryptica* (Cke) Hansf. *Mycosphaerella nubilosa* also occurs in New Zealand, but only on eucalypts of the subgenus *Symphyomyrtus* (e.g., *E. nitens* and *E. globulus*).

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