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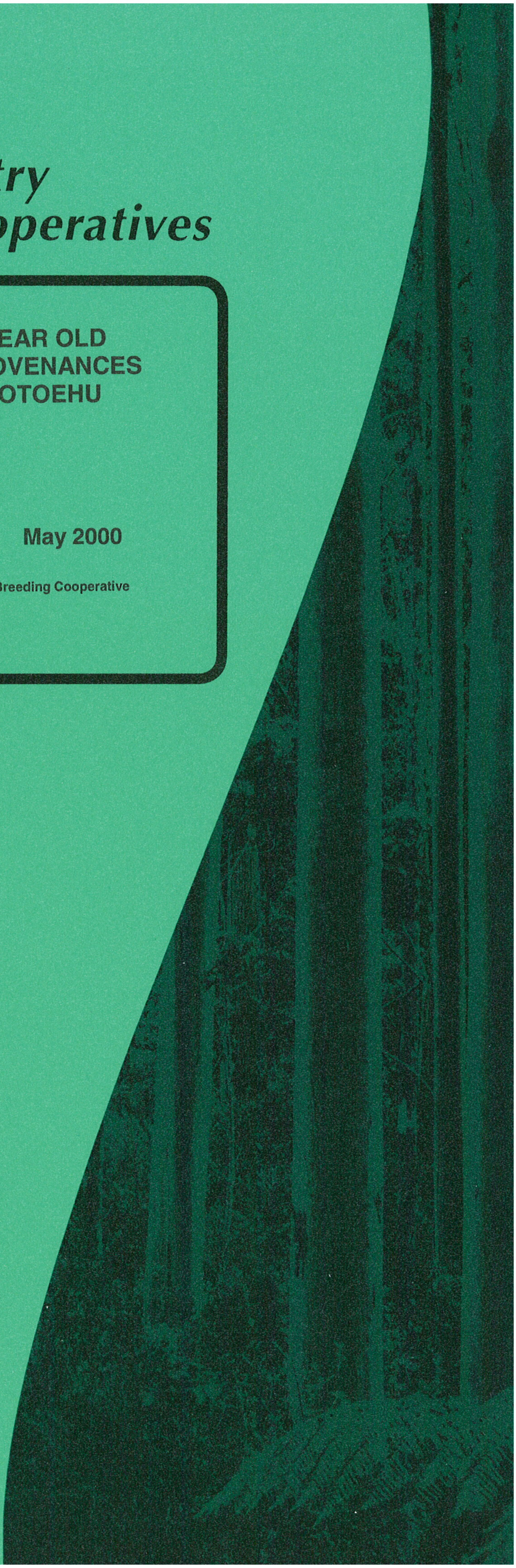

forest research

PERORMANCE OF 7 YEAR OLD EUCALYPTUS NITENS PROVENANCES ON A WARM SITE AT ROTOEHU FOREST

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Keywords: *Eucalyptus nitens*, provenance, growth, form, health

ABSTRACT

Eucalyptus nitens is being planted on a large scale in New Zealand, now that a major pest, the eucalyptus tortoise beetle (*Paropsis charybdis*), has been biologically controlled by a parasitic wasp. Early trials planted in 1978 of *E. nitens* from mainly Victorian provenances showed good tolerance to frost and fast early growth and these provenances became the preferred seed source and basis of the breeding programme. Reports that provenances from New South Wales (NSW) could have advantages in climates with mild winters, prompted a further series of trials to evaluate a wider range of NSW provenances. Seed from selected provenances and progenies was used to plant progeny trials and a provenance trial.

This report presents the results of two assessments of the provenance trial planted in 1992, on a low altitude, sheltered site at Rotoehu Forest in the coastal Bay of Plenty (North Island). There are large differences between provenance seedlots in growth rate and health on this warm site. The Victorian seedlots grew very well for the first four years, but crown health became depressed by age seven and growth of unhealthy seedlots is likely to slow down more in future years. Seedlots from Ebor (northern NSW) and Nimmitabel (southern NSW) enjoy comparatively good crown health and should be considered for sites with warm winters and significant summer rainfall. However, contrary to experience in Northland (Low and Shelbourne, 1999), several of the southern NSW provenances, such as the three from the Tallaganda region were demonstrating low health scores. The northernmost Ebor (Majors Point, NSW) seedlot is represented, nationally, only on this trial and has grown particularly well.

Ten of the best individuals of NSW origin were selected from the trial and a further nine from the surrounding bulked NSW progeny planting. These selections have now been grafted to form the basis of a seed orchard. Three individuals were selected from the Nimmitabel seedlot and either one or two from the NSW seedlots from Ebor, Badja, Barren Mountain, Mt. Anembo and Kaingaroa cpt 905 (originally from Nimmitabel). This orchard should produce *E. nitens* with good adaptation to warm sites as in the coastal Bay of Plenty, which are well suited to fast-grown, short rotation eucalypt crops.

INTRODUCTION

Eucalyptus nitens occurs naturally over scattered and isolated areas in the coastal mountain ranges of eastern Victoria and southern New South Wales (NSW) with isolated occurrences in northern NSW, from latitudes 30° to 38°. The climate varies considerably from mainly summer rainfall around the northernmost location at Ebor NSW, through year-round rain in southern NSW, to mainly winter rainfall in Victoria. As *E. nitens* grows at altitudes of between 600 and 1600 metres above sea level, winter frosts and snow are common throughout the range.

E. nitens begins its growth with juvenile foliage which is relatively resistant to frosts, making a transition to adult foliage of longer, slimmer and pendant leaves between the ages of one and five years. Pederick (1979) studied the performance of the two contrasting foliage types and concluded that the juvenile foliage provided more leaf area, better interception of the sun's rays and faster growth. He also found that Victorian provenances tended to stay in juvenile foliage longer (as did high altitude provenances), while northern NSW provenances made a faster transition to adult foliage, with a noticeable reduction in early growth.

Other studies in summer rainfall areas of South Africa (Purnell and Lindquist, 1986) have shown that juvenile foliage is attacked by *Mycosphaerella* leaf-spotting fungi, making the northern NSW provenances the preferred seed source there. The degree of adaptation of native provenances to climates varying from winter to summer rainfall means that provenance differentiation may play a large part in determining the health and growth of *E. nitens* plantations.

Early New Zealand trials of *E. nitens* from mainly Victorian provenances, planted in 1978, showed good tolerance to frost and fast early growth and these provenances became the preferred seed source (King and Wilcox, 1988) and the basis of the New Zealand breeding programme. In 1978, most sites available for planting were at high altitude and/or in the South Island and these favoured the Victorian provenances. *E. nitens* is now being planted on a large scale in New Zealand, now that a major pest, a leaf-chewing beetle, *Paropsis charybdis*, has been biologically controlled by the parasitic wasp *Ennogera nassaui*.

Trials planted at three sites in Northland in 1988-90 compared NSW and Victorian provenances of *E. nitens* with provenances of *E. fastigata*, *E. regnans*, *E. saligna*, *E. grandis*, *E. globulus* and *E. maidenii*. Results of assessments at ages 9-11 years (Low and Shelbourne, 1999; Shelbourne, Low and Smale, 2000) showed deteriorating health of *E. nitens* at these ages, although early growth had been superior to all other species. *E. fastigata* and *E. regnans* eventually overtook *E. nitens*, even though the health of NSW provenances was better than Victorian. Health in these stands is largely determined by amount of infection or defoliation by *Mycosphaerella* spp. and *Kirramyces eucalypti* (*Septoria*) (Ian Hood pers. comm.).

Trials of *E. nitens* provenances were planted in November 1992 featuring ten NSW seedlots, two seedlots from seed collected in Victoria and one second generation Victorian seedlot collected from the 1978 trial in New Zealand. *E. fastigata*, *E. regnans* and *E. muelleriana* were also included as single seedlot controls. The trials were planted on four sites; two frosty sites in the central plateau, Poronui station and the Waireka flats in Kaingaroa Forest, a warm, low altitude site in Rotoehu Forest, with a further cold site at Lillburn in Southland. A series of unusually harsh climatic events (a frost on the 25th of December on the central plateau and a weeklong freeze-up in Southland) caused the abandonment of all except the Rotoehu site.

Most of the seedlots were also incorporated in a 1991 species and provenance trial at Knudsen Road near Kaikohe in Northland, where results at age seven have been recently reported (Low and Shelbourne, 1999). The trial at Rotoehu was assessed in March 1996 and again in September 1999 at age seven and the results of those assessments are reported here.

MATERIALS AND METHODS

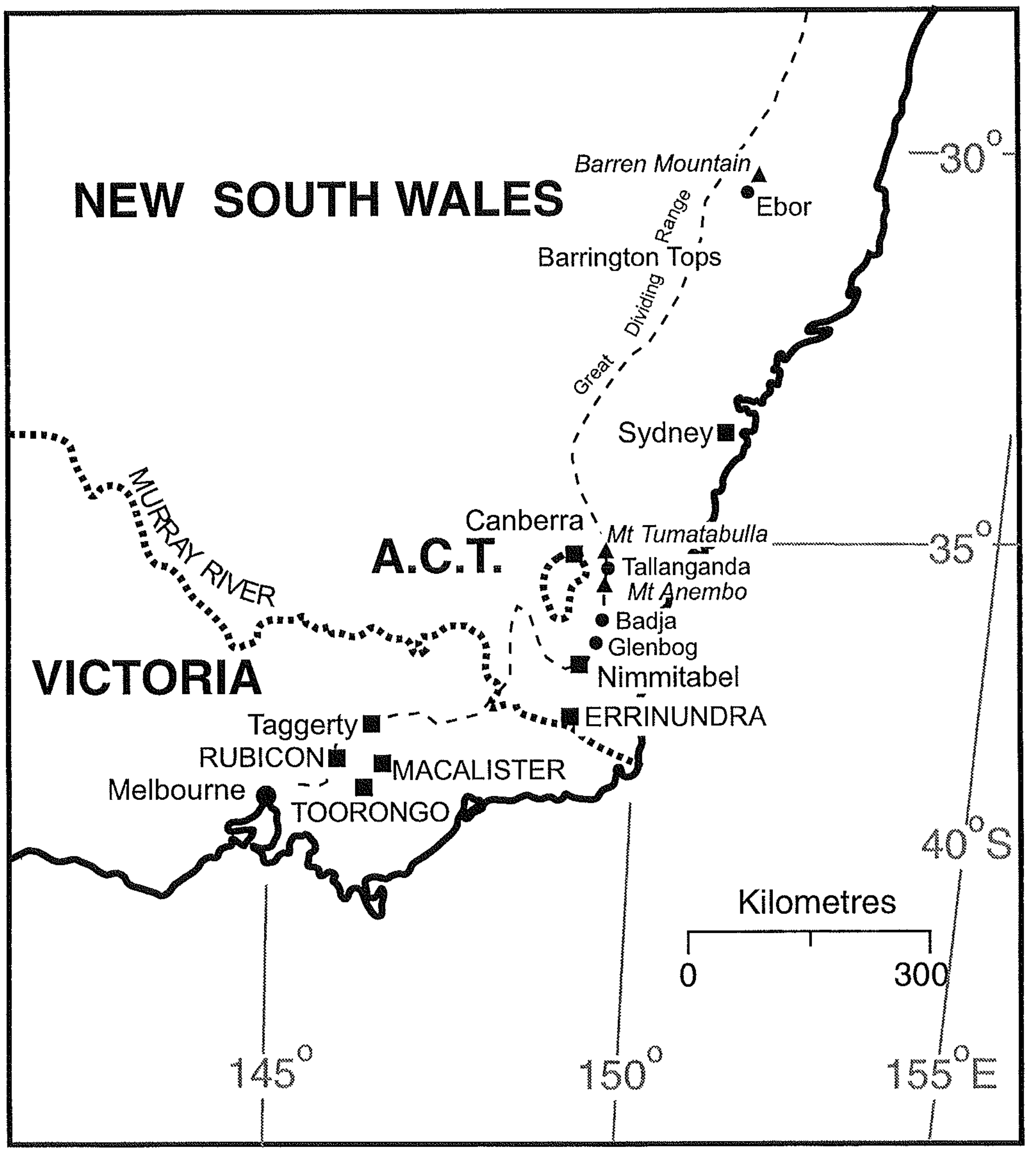
The trial at Rotoehu originally included ten replicates of six-tree row plots, but five replicates suffered from animal browsing and were abandoned soon after planting. Spacing was 3.5 metres between rows and 3.0 metres between trees within a row, creating a stocking of 950 stems per hectare. There were 13 seedlots of *E. nitens* included in the trial (Table 1.) The location of Australian seedlots is shown in Figure 1.

Table 1. Seedlot Details

Code	Species	Provenance	Latitude	Longitude	Seedlot Number or Origin	# of Parents
1*	*E. nitens*	Central VIC - Toorongo	37° 36'	146° 10'	CSIRO 16869	16
2	*E. nitens*	Majors point mix NNSW	30° 25'	152° 21'	CSIRO 16636	10
3*	*E. nitens*	Brown Mtn, SNSW	36° 31'	149° 17'	CSIRO 16307	9
4*	*E. nitens*	Tallaganda S.F. SNSW	35° 48'	149° 31'	CSIRO 15137/16619 Kylisa 92/17	40
5	*E. nitens*	Glenbog S.F. SNSW	36° 36'	149° 25'	CSIRO 14439 / 15134	29
6	*E. nitens*	Barren Mtn, NNSW	30° 24'	152° 30'	CSIRO 16840	5
7	*E. nitens*	Badja, SNSW	36° 10'	149° 31'	CSIRO 15135 / Kylisa 91/28	30
8	*E. nitens*	Mt Anembo, SNSW	35° 52'	149° 30'	CSIRO 15139	14
9	*E. nitens*	Mt Tumatbulla, SNSW	35° 44'	149° 31'	CSIRO 15136	7
10*	*E. nitens*	Central VIC Ex Rotoaira			FRI Collection	10
11	*E. nitens*	Southern NSW			90/8 ex Kaingaroa cpt 905	
12	*E. regnans*				Tas. For. Comm. 88/166	
13	*E. fastigata*				CSIRO 9/0/86/207	
18*	*E. nitens*	Rubicon Mix, VIC	37° 25'	145° 45'	Kylisa 16868 / 18075	28
19	*E. nitens*	NSW Mix			CSIRO, Kylisa Seeds mixture	168
20	*E. muellerian a*				Australian Tree Centre	1

* denotes that this seedlot was present in the Eucalyptus species trial at Knudsen Road

Figure 1. Map of Southeastern Australia showing seedlot location



TRAITS ASSESSED

The following traits were assessed in March 1996 and in September 1999 at the Rotoehu site: -

Age 4 Diameter – measured by tape at 1.4 metres above ground level
Age 4 Straightness – 1 to 5 scale, where 1 = most sinuous to 5 = perfectly straight
Age 4 Form – 1 to 5 scale, where 1 = amorphous crown to 5 = light, regular branching
Age 4 Malformation – 1 to 5 scale, where 1 = multiple forking to 5 = no malformation
Age 7 Diameter – same as age 4
Age 7 Straightness – 1 to 9 scale, where 1 = very sinuous and 9 = perfectly straight
Age 7 Malformation – same as age 4
Age 7 Health – 1 to 9 scale where 1 = almost leafless to 9 = long dense crown of undamaged leaves
Age 7 Status (of trees which were not measured) -1 = dead, -2 = crown smashed out, –3 = too small

ANALYSIS

Tree identity was kept, so that data from the age seven assessment could be merged with the age four data on an individual tree basis. All analyses were performed on the *E. nitens* seedlots only, as the row plot layout suppressed the other species, which initially grow more slowly.

Analysis of variance was carried out on all traits except for "status" using PROC GLM of the SAS software package. The model considered seedlots as fixed, with replicate and the replicate times seedlot interaction terms as random.

The equation for the model of a randomised complete block design is as follows:-

$$Y_{ij} = \mu + \tau_i + \beta_j + \beta\tau_{ij} + \varepsilon_{ij}$$

Where:

Y_{ij} = the response of seedlot (or treatment) i in replication (or block) j
μ = the overall mean
τ_i = seedlot effect of the ith seedlot
β_j = replication effect of the jth replication
$\beta\tau_{ij}$ = a replication x seedlot interaction effect or plot error
ε_{ij} = experimental error

Provenance means were calculated using an option of PROC GLM, and Tukey's multiple range test was used to show significant differences between seedlot means. Means for *E. regnans*, *E. fastigata* and *E. muelleriana* were calculated by PROC MEANS for comparative purposes only.

Phenotypic correlation coefficients between traits were calculated using SAS's PROC CORR on individual tree data. The means for diameter were ranked at age four and at age seven and these ranks were plotted using SAS's PROC GPLOT to illustrate rank changes over time.

Percentage of surviving trees at age seven was calculated using the number of trees which were assessed per seedlot as well as those suppressed trees (which were not measured) with a status score of –3. Basal areas were calculated per tree, with suppressed trees awarded a diameter of 120 mm, as this was a typical diameter for such trees. Basal areas were then totaled for each seedlot and expressed as basal area per hectare.

RESULTS AND DISCUSSION

Growth rate on this low altitude Bay of Plenty site is good, and wide variation was expressed for most traits. Basic statistics are shown in Table 2.

Table 2. Basic Statistics for All *E. nitens* Trees Assessed

Variable	N	Mean	Standard Deviation	Minimum	Maximum
DBH4	330	124.30	23.97	77	188
STR4	330	3.07	1.00	1	5
FRM4	330	3.26	0.85	1	5
MAL4	330	7.32	2.63	1	9
DBH7	326	192.82	44.68	89	323
DBHINC	307	68.94	29.42	13	151
STR7	326	6.34	1.37	2	9
MAL7	326	4.63	0.72	2	5
HLT7	326	4.80	2.04	1	9

The F tests from the analysis of variance are shown in Table 3 for the age four assessment and in Table 4 for the age seven assessment. Significant seedlot differences were found for all traits except malformation, which had unusually large replicate differences. Seedlot means are shown in Tables 5 and 6.

Table 3. F Tests From Analysis of Variance: Age Four Traits

Source	Degrees of Freedom	Diameter	Straightness	Form	Malformation
Rep	4	4.81**	4.32**	4.38**	3.69*
Seedlot	12	4.31***	4.14***	3.89***	1.64
Rep x Seedlot	46	1.24	1.68**	1.23	0.78
Error	267				

Table 4. F Tests From Analysis of Variance: Age Seven Traits

Source	Degrees of Freedom	Diameter	Diameter Increment	Straightness	Malformation	Health
Rep	4	1.18	2.06	4.14**	8.10***	0.99
Seedlot	12	3.00***	5.16***	2.83**	1.16	4.97***
Rep x Seedlot	46	1.33	0.93	1.64**	0.80	1.19
Error	263					

There were significant differences between seedlots for diameter at both age four and age seven, but ranking of seedlots did not remain the same. The Central Victorian seedlot from Rotoaira was top-ranked at age four, but was overtaken at age seven by the Nimmitabel provenance from southern NSW and the Ebor provenance from northern NSW. Diameter increment from age four to age seven also shows the same trend; six NSW seedlots had equal or better increment than the best Victorian provenance from Rotoaira. Seedlot mean diameter and diameter increment were, however, quite variable within both NSW and Victorian groups.

Basal area reflects not only the diameter growth of the trees, but also the numbers of surviving trees. Only one seedlot, code 4 from Tallaganda, suffered from poor survival and consequently has very small basal area. NSW seedlots generally had better survival than Victorian seedlots although the small numbers of trees per seedlot mean that such comparisons are imprecise.

There were large differences between provenances in crown health, scored at age seven, which were apparently affecting growth rate, and it is likely that these effects will become increasingly marked in future. Some of the NSW provenances, i.e. Nimmitabel, Ebor and Badja, showed comparatively good crown health and would be the seedlots of choice for similar sites.

E. nitens has generally good bole straightness, light branching and good apical dominance, so form is not an important selection trait. The differences shown between seedlots for straightness and form are significant but largely academic, as the general standards were high, with even the poorest seedlots being within acceptable limits.

Differences between seedlots in malformation score were not significant at either age and the incidence of forking was generally very low. Significant replicate effects for malformation show the strong environmental component involved in this trait, probably related to damage caused by opossums in particular replicates.

Table 5. Seedlot Means for Age Four Traits

Code	Seedlot	Diameter	Straightness	Form	Malformation
2	Majors Point mix, Ebor	123 abcd	3.38 abc	3.21 abcd	7.63
3	Brown Mtn, Nimmitabel	137 ab	3.15 abcd	3,15 abcd	6.74
6	Barren Mtn	109 d	2.35 d	3.35abcd	8.42
7	Badja	130 abc	2.80 cd	3.20 abcd	7.80
8	Tallaganda, Mt Anembo	115 cd	2.54 d	3.23 abcd	7.54
9	Tallaganda, Mt Tumatbulla	110 cd	2.87 bcd	2.87 cd	6.73
4	Tallaganda S.F. SNSW	118 bcd	2.96 abcd	2.96 cd	6.63
5	Glenbog S.F. SNSW	109 d	3.15 abcd	3.00 bcd	7.10
11	Southern NSW	125 abcd	2.81 bcd	3.30 abcd	7.63
19	NSW Mix	125 abcd	2.88 bcd	2.73 d	6.38
10	Central VIC Ex Rotoaira	141 a	3.77 a	3.70 ab	7.33
1	Central VIC – Toorongo Plateau	129 abcd	3.63 ab	3.83 a	7.38
18	Rubicon Mix, VIC	129 abcd	3.57 abc	3.64 abc	7.50
12	*E. regnans*	99	2.86	2.57	5.07
13	*E. fastigata*	112	3.50	2.83	8.67
20	*E. muelleriana*	82	2.33	2.00	4.33

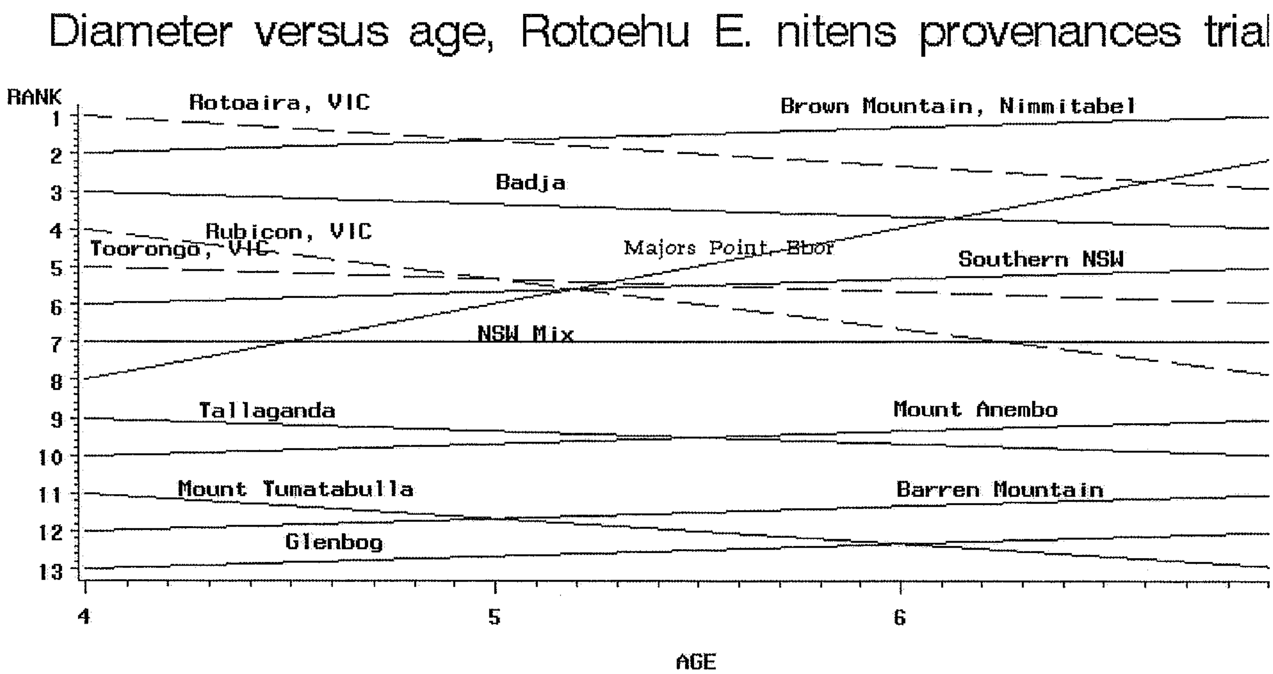
Letters following seedlot mean scores were generated by Tukey's multiple range test. Means not sharing a letter are considered to be significantly different.

Table 6. Seedlot Means for Age Seven Traits

Code	Seedlot	Survival %	Diameter	Diameter Increment	Basal Area	Straight-ness	Malform-ation	Health
2	Majors Point mix, Ebor	80	215 a	92 a	29	7.00 ab	4.58	6.42 a
3	Brown Mtn, Nimmitabel	100	217 a	87 ab	37	6.50 abcd	4.60	6.20 ab
6	Barren Mtn	100	174 bc	71 abcd	23	5.53 d	4.63	5.20 abc
7	Badja	89	207 ab	78 abc	30	5.97 bcd	4.63	5.16 abc
8	Tallaganda, Mt Anembo	90	181 abc	70 abcd	23	5.93 bcd	4.48	4.52 bcd
9	Tallaganda, Mt Tumatbulla	90	182 abc	48 d	24	6.45 abcd	4.55	3.27 d
4	Tallaganda S.F. SNSW	46	164 c	64 bcd	12	6.11 abcd	4.56	4.30 cd
5	Glenbog S.F. SNSW	71	170 bc	57 cd	16	6.24 abcd	4.71	3.94 cd
11	Southern NSW	97	199 abc	71 abcd	30	6.62 abcd	4.79	4.90 abcd
19	NSW Mix	83	188 abc	61 bcd	24	5.64 cd	4.40	4.68 abcd
10	Central VIC Ex Rotoaira	81	209 ab	72 abcd	28	6.90 ab	4.62	4.69 abcd
1	Central VIC – Toorongo Plateau	70	188 abc	55 cd	19	6.71 abc	4.90	4.38 bcd
18	Rubicon Mix, VIC	80	183 abc	52 cd	21	7.17 a	4.79	3.13 d
12	*E. regnans*	50	124	32	7	6.67	4.40	3.20
13	*E. fastigata*	53	151	83	13	6.69	4.56	4.88
20	**E. muelleriana**	27	94	35	4	5.00	3.50	5.50

Changes in seedlot mean rankings for diameter from age four to age seven are shown in Figure 2. Victorian seedlots appear less well ranked at age seven than at age four and that the northernmost seedlot from Ebor has improved its ranking dramatically.

Figure 2.



Phenotypic correlation coefficients (for individual trees) are shown in Table 7. These show that there are significant correlations between the form traits and strong correlations between age seven growth rate and health. The correlation with health and diameter increment is greatest, closely followed by health and age seven diameter, with a much weaker correlation between age seven health and age four diameter, when health was not scored.

Table 7. Phenotypic Correlation Coefficients Between Traits

	DBH4	STR4	FRM4	MAL4	DBH7	DBH-INC	STR7	MAL7
DBH4	1.00							
STR4	0.14*	1.00						
FRM4	-0.08	0.54***	1.00					
MAL4	0.01	0.17**	0.35***	1.00				
DBH7	0.78***	0.17**	0.01	0.12*	1.00			
DBH-INC	0.37***	0.13*	0.09	0.20***	0.87***	1.00		
STR7	0.17**	0.57***	0.42***	0.24***	0.28***	0.26***	1.00	
MAL7	0.03	0.25***	0.33***	0.48***	0.12*	0.20***	0.47***	1.00
HLT7	0.46***	0.13*	0.00	0.16**	0.73***	0.73***	0.21***	0.14*

*** = a significant correlation at P<= 0.001
** = a significant correlation at P<= 0.01
* = a significant correlation at P<= 0.05

CONCLUSIONS AND FURTHER DEVELOPMENTS

There are large differences between provenance seedlots in growth rate and health on this warm site. The Victorian seedlots grew very well for the first four years, but their crown health became depressed by age seven and growth of unhealthy seedlots is likely to slow down more in future years. Seedlots from Ebor (northern NSW) and Nimmitabel (southern NSW) enjoy comparatively good crown health and should be considered for sites with warm winters and significant summer rainfall. However, contrary to experience in a seven year old trial in Northland (Low and Shelbourne, 1999), several of the southern NSW provenances, such as the three from the Tallaganda were demonstrating low health scores. The northern NSW Ebor (Majors Point) seedlot is represented, nationally, only on this trial and has grown particularly well.

Ten of the best individuals were selected from the trial and a further nine from the surrounding bulked progeny planting of NSW *E. nitens*. These selections have now been grafted to form the basis of a seed orchard. Three individuals were selected from the Nimmitabel seedlot and either one or two from Ebor, Badja, Barren Mountain, Mt. Anembo and Kaingaroa cpt 905 (originally from Nimmitabel).This orchard should produce *E. nitens* with good adaptation to warm sites such as the coastal Bay of Plenty sites which are well suited to fast-grown, short rotation eucalypt crops.

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