SELECTION OF EUCALYPTUS SPECIES FOR SOIL CONSERVATION PLANTING IN SEASONALLY DRY HILL COUNTRY

R. L. HATHAWAY
Soil Conservation Centre, Aokautere, Ministry of Works and Development, Private Bag, Palmerston North, New Zealand

and M. KING
Wairarapa Catchment Board, P.O. Box 41, Masterton, New Zealand

(Received for publication 16 September 1985; revision 24 June 1986)

ABSTRACT

The performance of 56 **Eucalyptus** species (119 provenances) at two exposed, seasonally dry, hill country sites in the Wairarapa district was assessed at age 5 years. There were significant differences among species in height and diameter growth, Eucalyptus tortoise beetle (**Paropsis charybdis** Stal) and leafroller caterpillar (**Strepsicrates macropetana** Meyrick) damage, wind damage, stem straightness, crown width, crown density, and branch size. **Eucalyptus cordata** Labill., **E. fastigata** Deane et Maid., **E. fraxinoides** Deane et Maid., **E. obliqua** L'Herit., **E. pulchella** Desf., and **E. regnans** F. Muell. ranked highly for most traits at both sites and are considered to be the most suitable of those species tested.

Keywords: soil conservation; hill country; Wairarapa; **Eucalyptus**.

INTRODUCTION

Eucalyptus species are becoming increasingly used for soil conservation planting in hill country regions of New Zealand, particularly in those areas prone to summer drought such as Hawke's Bay, Wairarapa, and North Canterbury. The need for suitable trees with the ability to establish on and stabilise seasonally dry upper slopes has been recognised for many years. Barr (1980) and Cutten (1964) have reviewed the suitability of the more commonly grown eucalypts for the eastern areas of New Zealand, primarily for timber production and shelter purposes, but, prior to the establishment of the experiments reported here, no detailed investigation of species' suitability for soil conservation planting has been conducted. Species selection has generally been based on the performance of trees in older farm plantings in each local district. A genetic improvement programme for seven *Eucalyptus* species has recently been initiated by the Forest Research Institute, New Zealand Forest Service, with the aim of identifying reliable provenances for timber production (Wilcox 1980).

Particularly severe erosion of upper slopes in the Wairarapa district during winter 1977 prompted the commencement of a project to test a wide range of *Eucalyptus* species for slope stabilisation planting on such sites. The type of tree required for this situation should be evergreen but with a reasonably narrow crown to avoid dense shading of pasture, be tolerant of strong desiccating winds in the spring, be able to withstand summer drought, and have rapid development of an extensive root system. Poplars and willows, the traditional species used for erosion control planting in grazed hill country, have proved completely unsuitable for planting on exposed upper slopes. *Pinus radiata* D. Don is known to grow satisfactorily, but is not favoured because of the dense shading of pasture if not tended regularly. The *Eucalyptus* genus was considered likely to contain suitable species and emphasis was given to testing a wide range of species of *Eucalyptus* on several sites. Because timber production was not a major consideration a number of species not promoted in New Zealand for their timber quality were included in the trial plantings.

The performance of the *Eucalyptus* species in the two largest trials (which are located in the Wairarapa district) 5 years after planting, is reported here.

MATERIALS AND METHODS

Species and Provenances

Details of the *Eucalyptus* seedlots used in the trials are available from the authors. Included were 119 provenances from 56 species or subspecies. Most seedlots were from collections made in New South Wales, Victoria, and Tasmania, and seven were from collections made in New Zealand. CSIRO supplied 63 seedlots, which were selected after inspection of natural stands, and the Forestry Commission, Victoria, supplied five seedlots. The Forest Research Institute, New Zealand Forest Service, supplied 49 seedlots from FRI collections and Forest Service commercial stocks.

Planting Stock

All plants were raised at the Soil Conservation Centre, Aokautere, nursery. Seed of most seedlots was stratified for 3–5 weeks (*Eucalyptus delegatensis* R.T. Bak. 9 weeks). Seed of *Eucalyptus botryoides* Sm., *E. botryoides* × *saligna* Sm., *E. camaldulensis* Dehnh., *E. leucoxylon* F. Muell., and *E. robusta* Sm. was not stratified. All seed was sown between 21 December 1978 and 29 January 1979. Seedlings were pricked out at the cotyledon stage into 8 × 8-cm peat pots containing a mixture of 5 parts peat : 2 parts pumice : 2 parts perlite : 1 part sterilised loam, to which had been added 3 kg dolomite, 1.5 kg 3–4 month Osmocote(R) (NPK = 15 : 5.2 : 12.5), 1.5 kg superphosphate, and 100 g fritted trace elements per cubic metre. The seedlings were moved out of the greenhouse 3 weeks after pricking out, hardened off, and grown in the open until planting in early June 1979. At this stage, the plants were 15–30 cm tall.

Site Details

Planting was carried out at two sites.

Pakaraka: Latitude 41° 00′ S; longitude 175° 42′ E; altitude 150–250 m; aspect north; slope 21–35°; soil type shallow deposits of loess over siltstone (Pirinoa hill soils and Taueru silt loam); severe soil slip erosion over much of site; located on Pakaraka Station, 8 km south of Masterton.

Kahuiti: Latitude 40° 57′ S; longitude 175° 52′ E; altitude 150–180 m; aspect north-west; slope 26–35°; soil type silt and clay loam over mudstone (Taihape steepland soils); earthflow and soil slip erosion over much of site, with large areas of subsoil exposed; located on Kahuiti Station, 28 km east of Masterton.

Both trial sites were hard-grazed 2 weeks before planting, and then retired from grazing until February 1983. Wire netting was fitted to boundary fences to exclude hares and rabbits.

Climate 1979–84

Average rainfall recorded at Waingawa, 4 km south-east of Masterton, for the years 1979–84 was 1014 mm (range 725–1247 mm), with the wettest months generally being May to October and the driest months January and February. Rainfall in 1979–81 was approximately 40% higher than in 1982–84.

Frost records are not available for the trial sites. However, frost damage was not observed on even the most frost-tender species, and it can be assumed that frost levels were quite low.

Establishment

One week before planting, establishment sites were sprayed with paraquat at 1.2 kg a.i./ha and simazine at 1.5 kg a.i./ha to a diameter of 1.2 m. The soil was spade-cultivated to 25 cm deep, and 20 g Magamp(R) (NPKMg = 7 : 14 : 5 : 13) was incorporated at planting. The bottom of each peat pot was cut off prior to planting. Spacing between trees was 4 × 4 m.

Experimental Design

Each trial was a nested design, with provenances randomised within species plots. Where a species was represented by only one provenance, eight-tree plots were used. Where more than one provenance of a species was present, four-tree plots were used. Thus species plots contained a minimum of eight trees, and up to 28 trees where seven provenances were included. Species plots were randomised within five replicates at the Pakaraka site, and four replicates at the Kahuiti site.

Assessment Method

The following were assessed:

March 1980: Height, survival

April 1982: Height, stem diameter, survival

February 1984: Height, stem diameter, *Paropsis charybdis* damage, leafroller (*Strepsicrates macropetana*) damage, wind damage, stem straightness, crown width, crown density, branch size, survival.

There was little change in survival between the 1980 and 1984 assessments, and only the latter is reported here.

All trees were measured individually for height (m) and stem diameter (cm at 1.4 m above ground-level). Other scores were assessed as follows on a provenance plot basis, with a single mean rating allocated to each plot for each character.

Resistance to *P. charybdis* damage: scored on a scale of 0 (complete defoliation by larvae or adult beetle) to 5 (no damage).

Resistance to leafroller damage: scored on a scale of 0 (very severe damage) to 5 (no damage).

Resistance to wind damage: scored on a scale of 0 (severe damage) to 5 (no damage); wind damage included crown and branch breakage, and lack of shoot or branch growth on the side of the tree most exposed to the prevailing wind.

Stem straightness: scored on a scale of 0 (very wavy) to 5 (very straight).

Crown width: scored on a scale of 0 (very spreading) to 5 (very narrow).

Crown density: scored on a scale of 0 (very open crown) to 5 (very dense crown).

Branch size: scored on a scale of 0 (very heavy branches) to 5 (very small diameter, light branches).

Root system development is important in the selection of suitable tree species for soil conservation planting. However, owing to the difficulty in excavating root systems of such a large number of trees, monitoring of root system development was not attempted. It has been assumed that root growth is likely to be proportional to above-ground growth, although it is recognised that variation in root system morphology is likely to be significant. It is intended to excavate the root systems of representative trees at a later date.

Data Analysis

Data from each site were analysed separately. Species means were estimated by the method of least squares. Provenance variation within species was analysed separately for each species at each site. F-tests and least significant differences were used to compare differences among species and among provenances within species.

RESULTS AND DISCUSSION

Species Performance

Species means for the February 1984 assessment (almost five growing seasons after planting) are given in Table 1 (Pakaraka site) and Table 2 (Kahuiti site). Statistically significant differences among species were detected for all the characters assessed at both sites. Growth and survival in almost all species were greater at Pakaraka than at Kahuiti. Species means for height ranged from 1.77 m to 6.21 m at Pakaraka and 1.20 m to 5.31 m at Kahuiti. Mean survival was 81% at Pakaraka and 66% at Kahuiti. The ranking for height for the top 15 species at each site is shown in Table 3.

Subgenus Monocalyptus

Several species from the ash group (series OBLIQUAE of Pryor & Johnson 1971) performed well at both sites. *Eucalyptus regnans* was significantly taller than any other species at Pakaraka, and at Kahuiti was among the tallest group of species. In addition it scored favourably for all other traits. The tallest individuals of *E. regnans* at Pakaraka were 9.5 m at the time of assessment. *Eucalyptus fastigata, E. fraxinoides,* and *E. obliqua* ranked highly at both sites for height growth, and were satisfactory in all other characters scored.

All three species were slightly damaged by *P. charybdis,* but the level of damage was not considered to be serious. *Eucalyptus obliqua,* as expected, appeared to be more tolerant of excessively dry microsites on upper slopes than *E. fastigata* or *E. fraxinoides. Eucalyptus sieberi* L. Johnson grew well at Pakaraka with only slight *P. charybdis* damage and was of good form, but survival was considerably lower than other ash group species. At Kahuiti survival was very low. *Eucalyptus delegatensis* survived well and showed reasonable growth rates at the Pakaraka site, while at Kahuiti survival was poor (48%) and growth rates considerably lower.

Two species of the peppermint group (series PIPERITAE of Pryor & Johnson 1971), *E. nitida* Hook f. and *E. pulchella,* performed well at both Pakaraka and Kahuiti, particularly on the drier areas of each site. In some trees of *E. pulchella,* young leaves were somewhat prone to infestation with leafroller caterpillars. Stem straightness in these species was inferior to that of the ash group species, but still acceptable for soil conservation planting. At the Pakaraka site *E. amygdalina* Labill. and *E. risdonii* Hook f. (also of the peppermint group) ranked highly for height growth and other characteristics, although *E. amygdalina* was moderately damaged by leafroller caterpillars. These three species generally had wavy stems.

Subgenus Symphyomyrtus

Of the species belonging to this subgenus, *E. botryoides, E. brookerana* A.M. Gray, *E. cordata,* and *E. nitens* (Deane et Maid.) Maid. ranked within the top 15 species at both sites for height growth.

Eucalyptus botryoides grew rapidly and incurred little insect damage, but in very exposed situations there was some branch breakage in the crown. Also, this species already has a wide crown 5 years after planting, and is likely to develop into a wide-spreading tree on these sites.

Eucalyptus brookerana performed very well at both sites and, despite being quite susceptible to damage by *P. charybdis,* was one of the fastest growing species. Other characteristics were also scored high, and survival was almost 100%.

Eucalyptus cordata, although only a moderately sized tree in Australia, showed impressive growth rates and favourable characteristics in both trials. It has the added advantage of being completely resistant to attack by *P. charybdis.*

Eucalyptus nitens grew very rapidly on the moister lower slopes, but less well on the very dry areas on these sites. Although *P. charybdis* damage was moderate, growth rates were still favourable.

A number of species grew particularly well at one of the sites but not at the other. These were *E. botryoides* × *saligna, E. cladocaylx* F. Muell., *E. amygdalina, E. kartzoffiana* L. Johnson et D. Blaxell, *E. deanei* Maid., and *E. kitsoniana* Maid. (The seedlot of *E. kartzoffiana* in these trials proved to be very similar in morphology to *E. viminalis* Labill., and may not be typical of *E. kartzoffiana* as described by Cole & Hall 1975).

The Symphyomyrtus species were more severely damaged by *P. charybdis* than the Monocalyptus species at both sites. Damage was more severe at Pakaraka (Monocalyptus rating 0.80, Symphyomyrtus 2.13) than at Kahuiti (Monocalyptus 0.43, Symphyomyrtus

TABLE 2—Assessment of **Eucalyptus** species in Kahuiti trial, February 1984

Species	No. of provenances	Ht (m)	Ranking for height	dbh (cm)	Resistance to: **Paropsis charybdis** (0–5)	Resistance to: Leaf-roller (0–5)	Resistance to: Wind (0–5)	Stem straightness (0–5)	Crown width (0–5)	Crown density (0–5)	Branch size (0–5)	Survival (%)
Subgenus Corymbia												
E. maculata	2	2.6	33	3.3	4.0	5.0	5.0	2.0	1.0	2.0	2.0	8
Subgenus Monocalyptus												
E. agglomerata	1	1.8	50	1.6	5.0	4.7	4.5	2.5	2.0	2.0	2.0	75
E. amygdalina	1	2.9	27	3.3	4.7	3.7	5.0	3.0	3.0	2.3	3.0	69
E. blaxlandii	1	1.5	55	1.6	5.0	5.0	5.0	2.5	2.0	2.5	2.0	31
E. coccifera	2	1.5	53	0.9	4.8	4.8	5.0	1.5	2.2	2.2	2.2	32
E. delegatensis	7	2.6	34	2.2	4.5	4.8	5.0	3.2	2.5	2.2	2.5	48
E. elata	2	2.0	47	1.4	4.6	3.4	5.0	1.7	1.7	2.6	2.3	60
E. fastigata	4	3.5	14	3.4	4.3	5.0	4.9	3.5	2.1	2.5	2.3	70
E. fraxinoides	3	3.9	6	3.7	4.0	5.0	4.9	3.7	2.6	2.9	2.6	61
E. globoidea	1	2.3	38	2.8	4.6	4.4	4.8	2.4	1.4	3.0	2.0	63
E. kybeanensis	1	1.2	57	1.4	5.0	4.0	5.0	2.3	2.0	3.0	2.0	50
E. macrorhyncha	1	2.1	40	2.7	4.8	4.8	4.6	2.8	2.4	2.6	2.4	56
E. muellerana	1	2.9	28	3.4	4.3	5.0	5.0	2.7	1.7	2.7	2.0	50
E. niphophila	1	2.0	45	2.0	3.7	4.2	5.0	2.3	2.5	2.8	2.5	81
E. nitida	1	3.2	19	3.9	4.3	4.3	5.0	2.7	2.0	3.0	2.3	71
E. obliqua	7	3.9	8	4.5	4.3	5.0	4.7	3.3	2.5	2.5	2.4	65
E. oreades	2	2.3	37	2.3	4.2	5.0	5.0	3.0	2.0	2.3	2.5	41
E. pauciflora	2	1.5	54	0.6	4.5	4.0	5.0	1.0	2.0	3.0	2.0	50
E. pulchella	1	3.9	10	3.6	5.0	4.3	5.0	3.0	2.3	2.3	2.3	53
E. radiata	2	2.0	44	1.8	4.9	4.4	4.5	1.6	1.9	1.9	2.4	55
E. regnans	5	4.0	5	3.6	4.4	4.4	4.4	4.3	2.8	2.2	2.9	80
E. risdonii	1	2.1	42	1.7	5.0	4.5	4.0	1.5	2.0	1.8	2.0	84
E. sieberi	7	3.0	26	3.2	4.4	4.1	4.6	2.8	2.4	2.1	2.4	29
E. stellulata	1	3.0	24	3.4	4.2	4.5	5.0	2.3	2.7	1.8	2.2	78
Subgenus Symphyomyrtus												
E. aggregata	1	2.1	[illegible]	2.6	4.0	5.0	5.0	2.3	1.7	2.5	1.7	[illegible]

TABLE 1—Assessment of **Eucalyptus** species in Pakaraka trial, February 1984

Species	No. of provenances	Ht (m)	Ranking for height	dbh (cm)	Resistance to Paropsis charybdis (0–5)	Resistance to Leaf-roller (0–5)	Resistance to Wind (0–5)	Stem straightness (0–5)	Crown width (0–5)	Crown density (0–5)	Branch size (0–5)	Survival (%)
Subgenus Corymbia												
E. maculata	2	3.2	31	3.2	4.0	4.3	4.9	2.7	1.9	2.6	2.2	79
Subgenus Monocalyptus												
E. agglomerata	1	3.3	28	4.3	5.0	4.7	5.0	3.0	1.5	2.8	1.7	68
E. amygdalina	1	4.0	10	5.3	4.0	3.0	5.0	3.4	3.0	2.8	2.6	79
E. blaxlandii	1	3.1	32	2.9	4.8	4.6	5.0	3.0	1.4	3.0	1.8	65
E. coccifera	2	2.1	50	2.0	4.4	3.2	5.0	1.0	1.7	2.9	2.1	63
E. delegatensis	7	3.6	22	3.9	4.4	4.6	5.0	3.6	2.3	2.4	2.1	79
E. elata	2	3.3	26	3.8	4.3	2.9	5.0	2.3	1.8	3.2	2.1	78
E. fastigata	4	5.2	2	6.6	4.2	4.7	5.0	4.3	2.2	3.1	1.9	85
E. fraxinoides	3	5.1	4	6.5	3.4	4.1	4.9	3.8	2.2	2.8	2.2	85
E. globoidea	1	3.2	30	4.7	4.2	4.2	5.0	3.3	2.0	3.3	1.7	88
E. kybeanensis	1	2.4	46	2.7	5.0	3.5	5.0	2.5	2.2	3.0	2.7	88
E. macrorhyncha	1	2.8	40	3.7	4.6	4.6	5.0	2.4	2.0	2.4	2.2	85
E. muellerana	1	4.0	11	5.2	3.5	4.0	5.0	3.5	2.0	3.0	2.2	50
E. nitida	1	3.9	14	4.4	4.2	3.8	5.0	3.4	2.2	3.0	1.8	83
E. obliqua	7	3.9	13	4.2	3.7	4.5	4.9	3.0	2.1	2.9	2.1	85
E. oreades	2	3.7	20	3.9	3.4	4.3	5.0	3.7	1.7	2.9	1.7	72
E. pauciflora subsp. **niphophila**	1	2.1	49	1.5	3.8	3.0	5.0	1.6	2.2	2.4	2.2	88
E. pauciflora subsp. **pauciflora**	2	1.9	55	1.6	4.0	2.7	5.0	0.8	2.0	3.0	2.2	88
E. pulchella	1	4.8	6	5.8	4.8	3.8	5.0	2.0	1.8	2.6	2.6	70
E. radiata	2	2.4	33	3.7	3.9	3.4	5.0	2.5	2.1	2.6	2.1	88
E. regnans	5	6.2	1	7.2	4.8	5.0	5.0	4.7	2.7	2.6	2.2	73
E. risdonii	1	3.8	16	4.2	5.0	4.0	5.0	2.3	1.7	2.7	2.0	72
E. sieberi	7	3.8	17	4.3	3.7	4.4	5.0	3.3	2.0	2.5	2.1	67
E. stellulata	1	3.8	15	5.0	3.2	4.8	5.0	1.6	1.8	2.8	2.2	93
Subgenus Symphyomyrtus												
E. aggregata	1	3.7	19	4.7	3.4	4.2	5.0	1.8	1.4	2.6	2.0	67
E. amplifolia	1	1.9	54	2.1	3.2	3.6	5.0	1.4	1.4	2.4	1.6	85
E. badjensis	1	2.8	37	4.0	2.8	2.0	5.0	2.0	1.2	3.6	1.8	93
E. barberi	1	3.0	35	3.0	1.2	3.6	5.0	1.4	1.6	1.6	2.0	93
E. botryoides	1	4.4	7	4.8	4.2	4.7	5.0	3.0	1.3	2.8	1.7	90
E. botryoides × saligna	1	5.1	3	7.1	4.0	5.0	4.8	4.0	1.0	3.6	1.0	100
E. brookerana	2	4.3	8	6.1	2.1	4.1	5.0	2.9	1.4	3.1	2.3	98
E. camaldulensis	2	2.0	52	1.8	1.1	2.6	5.0	1.1	2.6	1.3	2.6	73
E. camphora	2	2.9	36	3.5	3.0	4.2	5.0	1.2	1.4	2.6	1.4	80
E. cinerea	2	3.4	25	6.3	5.0	3.6	3.6	1.9	1.6	2.6	1.7	75
E. cladocalyx	2	4.9	5	6.6	5.0	5.0	5.0	3.1	1.7	2.9	1.9	88
E. cordata	1	4.0	12	5.3	5.0	3.6	5.0	3.0	2.4	3.0	2.2	88
E. cypellocarpa	3	3.2	29	3.8	2.5	3.7	4.8	1.7	1.7	2.4	1.8	75
E. dalrympleana	5	2.6	45	3.1	1.4	2.6	5.0	1.6	1.9	2.0	2.0	96
E. deanei	1	3.0	34	4.3	3.7	3.5	5.0	3.0	1.4	2.8	2.0	98
E. dunnii	2	2.7	43	6.6	4.2	4.7	5.0	4.3	2.1	2.5	1.8	93
E. gunnii	3	2.0	53	1.6	0.1	2.4	5.0	1.3	2.0	0.9	2.4	65
E. johnstonii	2	2.8	38	3.7	2.1	3.4	5.0	2.7	2.7	3.0	1.9	92
E. kartzoffiana	1	2.8	41	3.7	2.4	2.8	4.4	1.6	1.6	2.6	2.0	90
E. kitsoniana	1	3.4	24	3.7	2.0	4.0	5.0	2.0	1.8	3.3	2.0	88
E. leucoxylon subsp. **megalocarpa**	1	1.8	56	2.8	2.5	4.0	5.0	1.5	2.0	3.0	2.0	88
E. leucoxylon subsp. **pruinosa**	1	1.8	57	1.5	1.2	3.2	4.5	0.3	1.5	2.0	2.2	63
E. mannifera	1	3.3	27	4.6	3.4	3.8	5.0	2.0	2.0	2.4	2.0	83
E. melliodora	1	2.3	48	2.8	4.0	4.0	5.0	1.7	1.3	3.3	2.0	43
E. nitens	6	4.2	9	5.3	3.1	3.9	5.0	3.3	1.1	2.7	2.2	91
E. ovata	3	3.7	21	4.9	2.9	4.1	5.0	2.4	1.7	3.0	1.8	80
E. polyanthemos	1	2.8	42	3.1	4.8	4.4	5.0	1.2	1.2	2.2	2.2	93
E. robusta	1	2.0	51	2.0	2.6	3.2	4.8	2.2	1.4	2.2	1.6	98
E. rubida	2	2.8	39	3.4	4.1	3.2	4.7	1.3	1.5	2.1	2.1	78
E. sideroxylon	1	2.4	47	1.7	2.6	3.4	5.0	1.0	1.4	2.2	2.0	88
E. smithii	1	3.8	18	6.0	2.0	3.0	5.0	2.0	1.2	2.8	1.4	93
E. urnigera	1	2.6	44	2.3	0.3	3.7	5.0	0.7	2.3	1.0	2.7	66
E. viminalis	6	3.6	23	4.8	2.4	3.3	5.0	2.4	1.8	2.6	2.0	85
Mean		3.3		4.0	3.4	3.8	4.9	2.4	1.8	2.6	2.0	81
LSD (5%)		1.1		2.0	0.8	0.6	0.3	0.9	0.6	0.6	0.5	
F-test (species)		10.9**		6.9**	26.7**	17.4**	5.5**	15.7**	7.1**	8.2**	4.7**	

TABLE 2—Assessment of **Eucalyptus** species in Kahuiti trial, February 1984

Species	No. of provenances	Ht (m)	Ranking for height	dbh (cm)	Resistance to **Paropsis charybdis** (0–5)	Resistance to Leaf-roller (0–5)	Resistance to Wind (0–5)	Stem straightness (0–5)	Crown width (0–5)	Crown density (0–5)	Branch size (0–5)	Survival (%)
Subgenus Corymbia												
E. maculata	2	2.6	33	3.3	4.0	5.0	5.0	2.0	1.0	2.0	2.0	8
Subgenus Monocalyptus												
E. agglomerata	1	1.8	50	1.6	5.0	4.7	4.5	2.5	2.0	2.0	2.0	75
E. amygdalina	1	2.9	27	3.3	4.7	3.7	5.0	3.0	3.0	2.3	3.0	69
E. blaxlandii	1	1.5	55	1.6	5.0	5.0	5.0	2.5	2.0	2.5	2.0	31
E. coccifera	2	1.5	53	0.9	4.8	4.8	5.0	1.5	2.2	2.2	2.2	32
E. delegatensis	7	2.6	34	2.2	4.5	4.8	5.0	3.2	2.5	2.2	2.5	48
E. elata	2	2.0	47	1.4	4.6	3.4	5.0	1.7	1.7	2.6	2.3	60
E. fastigata	4	3.5	14	3.4	4.3	5.0	4.9	3.5	2.1	2.5	2.3	70
E. fraxinoides	3	3.9	6	3.7	4.0	5.0	4.9	3.7	2.6	2.9	2.6	61
E. globoidea	1	2.3	38	2.8	4.6	4.4	4.8	2.4	1.4	3.0	2.0	63
E. kybeanensis	1	1.2	57	1.4	5.0	4.0	5.0	2.3	2.0	3.0	2.0	50
E. macrorhyncha	1	2.1	40	2.7	4.8	4.8	4.6	2.8	2.4	2.6	2.4	56
E. muellerana	1	2.9	28	3.4	4.3	5.0	5.0	2.7	1.7	2.7	2.0	50
E. niphophila	1	2.0	45	2.0	3.7	4.2	5.0	2.3	2.5	2.8	2.5	81
E. nitida	1	3.2	19	3.9	4.3	4.3	5.0	2.7	2.0	3.0	2.3	71
E. obliqua	7	3.9	8	4.5	4.3	5.0	4.7	3.3	2.5	2.5	2.4	65
E. oreades	2	2.3	37	2.3	4.2	5.0	5.0	3.0	2.0	2.3	2.5	41
E. pauciflora	2	1.5	54	0.6	4.5	4.0	5.0	1.0	2.0	3.0	2.0	50
E. pulchella	1	3.9	10	3.6	5.0	4.3	5.0	3.0	2.3	2.3	2.3	53
E. radiata	2	2.0	44	1.8	4.9	4.4	4.5	1.6	1.9	1.9	2.4	55
E. regnans	5	4.0	5	3.6	4.4	4.4	4.4	4.3	2.8	2.2	2.9	80
E. risdonii	1	2.1	42	1.7	5.0	4.5	4.0	1.5	2.0	1.8	2.0	84
E. sieberi	7	3.0	26	3.2	4.4	4.1	4.6	2.8	2.4	2.1	2.4	29
E. stellulata	1	3.0	24	3.4	4.2	4.5	5.0	2.3	2.7	1.8	2.2	78
Subgenus Symphyomyrtus												
E. aggregata	1	3.1	22	3.6	4.0	5.0	5.0	2.3	1.7	2.5	1.7	72
E. amplifolia	1	1.8	49	1.4	3.5	4.7	5.0	1.3	1.5	2.3	2.0	81
E. badjensis	1	2.7	30	3.3	3.0	3.0	4.5	2.5	1.7	2.3	2.0	97
E. barberi	1	2.7	31	4.0	2.7	4.7	3.0	1.5	2.0	1.5	2.0	84
E. botryoides	1	3.9	7	5.8	4.7	5.0	4.5	3.0	1.5	3.0	1.5	81
E. botryoides × saligna	1	3.4	17	4.2	4.7	5.0	4.8	3.0	1.5	3.3	1.5	97
E. brookerana	2	5.3	1	6.7	2.6	4.9	5.0	3.4	2.6	2.3	2.4	97
E. camaldulensis	2	2.4	36	1.4	3.5	4.7	3.2	1.2	1.7	1.5	1.8	63
E. camphora	2	3.6	11	3.9	3.2	4.4	4.7	1.9	1.9	2.1	2.2	78
E. cinerea	2	3.1	23	3.9	5.0	4.7	4.0	2.3	1.7	2.1	2.0	69
E. cladocalyx	2	2.8	29	2.6	4.8	5.0	4.4	2.8	2.0	2.6	2.0	20
E. cordata	1	4.0	4	5.2	5.0	4.2	4.3	3.5	2.0	3.3	2.0	72
E. cypellocarpa	3	3.3	18	3.9	3.0	4.7	4.5	1.8	1.3	2.6	1.5	60
E. dalrympleana	5	3.5	15	4.6	3.0	4.6	4.5	2.6	2.2	2.0	2.0	91
E. deanei	1	4.4	3	4.0	4.2	4.5	4.5	2.8	1.5	2.8	2.0	94
E. dunnii	2	2.1	41	1.9	5.0	4.6	4.6	1.9	1.3	2.3	2.3	63
E. gunnii	3	2.0	43	1.6	2.8	3.7	3.9	1.3	2.5	1.2	2.5	31
E. johnstonii	2	2.6	32	3.8	2.3	4.1	5.0	3.0	2.9	2.7	2.7	89
E. kartzoffiana	1	4.5	2	6.6	2.5	3.7	3.3	2.5	1.7	1.8	2.0	88
E. kitsoniana	1	3.9	9	4.6	3.0	5.0	5.0	2.8	1.5	3.0	2.0	94
E. leucoxylon subsp. **macrocarpa**	1	2.0	46	1.5	4.0	5.0	5.0	1.8	1.7	2.5	2.0	84
E. leucoxylon subsp. **pauperita**	1	1.2	56	0.0	4.5	5.0	5.0	1.0	1.0	2.5	1.5	22
E. mannifera	1	1.6	52	2.3	4.0	5.0	5.0	2.3	2.7	1.3	2.7	76
E. melliodora	1	3.1	20	3.6	5.0	5.0	4.5	2.0	1.0	3.0	2.0	28
E. nitens	6	3.5	13	3.9	3.6	4.8	4.5	3.3	1.5	2.4	1.8	72
E. ovata	3	3.0	25	3.3	2.8	5.0	4.6	2.7	2.1	2.1	2.3	85
E. polyanthemos	1	1.7	51	1.7	5.0	4.7	4.5	1.3	1.2	2.3	1.7	88
E. robusta	1	1.9	48	1.7	4.0	5.0	4.5	1.8	1.2	3.0	1.5	88
E. rubida	2	3.4	16	3.9	3.9	4.7	4.0	1.9	2.0	2.0	2.2	100
E. sideroxylon	1	2.2	39	1.6	4.0	5.0	5.0	1.0	1.0	2.5	1.5	48
E. smithii	1	3.1	21	4.0	2.7	3.7	3.5	2.8	1.5	1.8	2.0	88
E. urnigera	1	2.4	35	2.8	2.7	4.0	4.0	1.0	2.2	1.3	2.5	43
E. viminalis	6	3.5	12	4.3	2.8	4.0	4.2	2.8	1.9	2.3	2.0	79
Mean		2.9		3.1	4.0	4.6	4.4	2.4	1.9	2.3	2.1	66
LSD (5%)		2.4		1.4	0.8	0.6	0.7	0.9	0.7	0.7	0.6	
F-test (species)		4.2**		3.7	18.4**	6.8**	4.7**	8.8**	6.5**	4.8**	4.5**	

TABLE 3—Ranking for height of top 15 species (mean of all provenances per species) at each site

Pakaraka			Kahuiti		
Species	Height (m)	Survival (%)	Species	Height (m)	Survival (%)
E. regnans*	6.2	73	E. brookerana*	5.3	97
E. fastigata*	5.2	85	E. kartzoffiana	4.5	88
E. botryoides × saligna	5.1	100	E. deanei	4.4	94
E. fraxinoides*	5.1	85	E. cordata*	4.0	72
E. cladocalyx	4.9	88	E. regnans*	4.0	80
E. pulchella*	4.8	70	E. fraxinoides*	3.9	61
E. botryoides*	4.4	90	E. botryoides*	3.9	81
E. brookerana*	4.3	98	E. obliqua*	3.9	65
E. nitens*	4.2	91	E. kitsoniana	3.9	94
E. amygdalina	4.0	79	E. pulchella*	3.9	53
E. muellerana	4.0	50	E. camphora	3.6	78
E. cordata*	4.0	88	E. viminalis	3.5	79
E. obliqua*	3.9	85	E. nitens*	3.5	72
E. nitida	3.9	83	E. fastigata*	3.5	70
E. stellulata	3.8	93	E. dalrympleana	3.5	91
LSD (0.05%)	1.5			1.3	

* Ranked in top 15 at both sites

1.38), and it was noticed that damage at Pakaraka began when the trees were younger. The greater susceptibility of the Symphyomyrtus species to damage by *P. charybdis* is reflected in the growth rates of many of the species from this group. Although the assessment method did not differentiate between damage to juvenile and to adult foliage, or whether damage was predominantly caused by the larval or the adult forms, it was noticed that trees of some species were more or less susceptible to damage depending on the presence or absence of adult foliage – e.g., only the adult foliage of *E. nitens* was attacked, and trees which retained juvenile foliage longer were less damaged. Conversely, the juvenile foliage of *E. gunnii* Hook. f. was severely attacked, so much so that a number of trees were killed. (It is possible that possum damage may have contributed to the defoliation of *E. gunnii,* but the evidence was not conclusive.) Species such as *E. ovata* Labill. and *E. brookerana,* which do not have such major differences between juvenile and adult foliage, were attacked at both stages.

Provenance Variation within Species

The experimental layout was designed primarily to compare species performance and, although some species were represented by up to seven provenances, insufficient numbers of trees of individual provenances were available to accurately assess provenance variation within species. In addition, the variability of the sites, particularly Kahuiti, made comparisons of small numbers of trees less sensitive. For these reasons, and also because of the bulk of the data, individual provenance means for the traits assessed are not presented. Nevertheless, interesting trends and some significant differences were apparent in several species, and are worthy of comment.

At Pakaraka, statistically significant differences among provenances in height growth were detected in *E. delegatensis, E. fastigata, E. radiata* Sieb. ex DC., *E. rubida* Deane et Maid., and at Kahuiti in *E. camaldulensis*. Several other species exhibited provenance variation that could be of practical significance – e.g., *E. nitens* and *E. obliqua*. There was very little difference in height growth among provenances of *E. fraxinoides, E. regnans, E. gunnii, E. sieberi,* and *E. viminalis*.

Several of the top-ranking species for height growth showed significant provenance variation in other traits – e.g., *E. nitens* varied substantially in crown width, with the Badja Mt, Tallaganda, and Blue Range provenances having considerably wider crowns than the other provenances. The Huon Valley provenance of *E. obliqua* also had a consistently wider crown than the other provenances of this species.

Paropsis charybdis and leafroller caterpillar damage showed significant variation among provenances of several species. *Eucalyptus camaldulensis, E. dalrympleana* Maid., *E. delegatensis, E. dunnii* Maid., *E. gunnii, E. johnstonii* Maid., and *E. sieberi* all showed significant variation among provenances in damage caused by *P. charybdis*. The same species, with the exception of *E. dalrympleana* and *E. delegatensis,* also varied significantly among provenances in damage by leafroller caterpillars. The two provenances of *E. radiata* varied significantly in their susceptibility to damage by leafroller caterpillars but not to *P. charybdis*.

APPLICATION OF RESULTS

The results of these trials indicate that a range of *Eucalyptus* species can be grown successfully on seasonally dry sites in the Wairarapa district. Survival percentages and growth rates of several species were very high, and are considered satisfactory for the establishment of trees for soil conservation on these sites. Favourable growing conditions during the summer after planting, with higher than mean monthly rainfall for all months except February, may have contributed to the high survival rates obtained. However, equally high survival rates have been obtained in subsequent trial plantings on similar sites when rainfall has been less than the mean (unpubl. data).

Provided that correct establishment techniques are adhered to, the following species are considered to be suitable for establishing on seasonally dry sites in the Wairarapa, and other similar districts: *E. cordata, E. fastigata, E. fraxinoides, E. obliqua, E. pulchella, E. regnans*. These species ranked highly for most traits assessed at both sites. *Eucalyptus botryoides* also performed well in these trials but, as it is known to be prone to wind damage under exposed conditions, it cannot be recommended for all sites. *Eucalyptus brookerana* and *E. nitens* may also be suitable but require caution with regard to their susceptibility to *P. charybdis* at ages greater than 5 years.

The limited number of provenances tested of each species prohibits recommending specific seed sources. Nevertheless, until further studies are carried out, those provenances which have consistently performed well in these trials could be used.

Most of the species which have given good results in these trials grow into large trees in suitable environments, and this is particularly so with *E. botryoides, E. nitens,* and the ash group species listed (*E. fastigata, E. fraxinoides, E. obliqua, E. regnans*). Wide-spaced trees of these species are likely to develop heavy spreading crowns as maturity approaches. Where slope stabilisation is the primary reason for planting, rapid growth rates are of major benefit in obtaining maximum slope-stabilising effect in the shortest possible time. However, it is not difficult to envisage a situation where these species may grow to a size which is disadvantageous to stability because of excessive loading on the slope from wind forces, and the shading effects on surface cover vegetation. Such problems would probably apply only to the more favourable sites for tree growth on lower less exposed slopes, and should not be of concern on upper exposed slopes where growth rates are slower and expected maximum size of trees is somewhat smaller. On critical lower slopes, therefore, it may be prudent to consider planting only those recommended species with a smaller maximum size, such as *E. brookerana, E. cordata,* and *E. pulchella.* Other species which for this reason are currently under further investigation, include the Tasmanian species *E. amygdalina, E. nitida, E. tenuiramis* Miq. (peppermints), and *E. rodwayi* R.T. Bak. et H.G. Sm. *Eucalyptus nicholii* Maid. et Blakely, also a smaller tree, could likewise be worth considering for these situations.

Where the production of timber is either a primary or a secondary objective, these trials indicate that the ash group species are likely to be the most useful, as has been found in most other districts of New Zealand. *Eucalyptus regnans* in particular has grown exceptionally well on lower slopes and should be capable of yielding useful timber. Whether or not the production of quality timber from soil conservation plantings on the types of sites under consideration in the present study is economically feasible is a question for further study.

ACKNOWLEDGMENTS

The assistance of S. Blakemore, P. Cameron, M. Vine, C. Stace, and P. Yalden is gratefully acknowledged. Thanks are also due to Professor L. D. Pryor for initial discussions on species suitability and to Dr M. D. Wilcox, Forest Research Institute, Rotorua, and J. Doran, CSIRO, Canberra, for supplying seed of many of the species tested. Dr M. D. Wilcox also provided helpful comments on the manuscript.

REFERENCES

BARR, N. 1980: Eucalypts for Hawke's Bay and other east coast districts. **New Zealand Tree Grower 1(3):** 12–4.

COLE, E. G.; HALL, N. 1975: Araluen gum **Eucalyptus kartzoffiana** L. Johnson et D. Blaxell. **Forestry and Timber Bureau, Forest Tree Series No. 186.**

CUTTEN, E. Y. 1964: Eucalypts for Canterbury. **Farm Forestry 6(1):** 3–19.

PRYOR, L. D.; JOHNSON, L. A. S. 1971: "A Classification of the Eucalypts". Australian National University, Canberra. 102 p.

WILCOX, M. D. 1980: Genetic improvement of eucalypts in New Zealand. **New Zealand Journal of Forestry Science 10:** 343–59.