PERFORMANCE TO AGE 22 YEARS OF 49 EUCALYPTS IN THE WAIRARAPA DISTRICT, NEW ZEALAND, AND REVIEW OF RESULTS FROM OTHER TRIALS

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ABSTRACT

Trials of 49 eucalypt species were established in 1979 in the Wairarapa district at Kahuiti and Pakaraka, originally to test species for their potential to stabilise erodable land for pastoral use. Trials were planted in a randomised complete block design with five replications of four-tree row plots of each seedlot (paired rows of four trees of species with only a single seedlot). The species included *Corymbia maculata* (Hook.)K.D.Hill & L.A.S.Johnson, *E. cladocalyx* F.Muell., four stringybarks (including *E. muelleriana* A.W.Howitt and *E. globoidea* Blakely), nine ashes (including *E. fastigata* Deane & Maiden, *E. regnans* F.Muell., and *E. obliqua* L'Herit), seven peppermints, and 18 gums (including *E. nitens* (Deane & Maiden) Maiden). Because of heavy thinning at Pakaraka, the Kahuiti trial only was assessed at age 22 years on production forestry criteria — diameter at breast height (dbh), stem straightness, malformation, crown health, and number of potential 5-m sawlogs per tree

The 12 best-grown species for mean tree dbh at Kahuiti, were ranked: *E. globoidea*, *E. muelleriana* (stringybarks), *E. obliqua*, *E. fraxinoides* Deane & Maiden, *E. regnans* (ashes), *E. cordata* Labill. (gum), *E. delegatensis* R.T.Baker, *E. fastigata*, *E. sieberi* L.A.S.Johnson (ashes), *E. cinerea* Benth., *E. kartzoffiana* L.A.S.Johnson & Blaxell, and *E.nitens* (gums). The ashes, with addition of *E. nitens*, showed a combination of best diameter growth (apart from the two stringybarks), straightest stems, least malformation, good crown health, and largest number of sawlogs per tree of all groups. The peppermints were generally slower-growing and more sinuous than the ashes. Some of the gums grew well and most survived better on this adverse, eroded site than the other groups.

Superiority of *E. fastigata* and *E. obliqua* was confirmed by other trials in Hawke's Bay and the Wairarapa region. The apparent good growth and health of *E. globoidea* and *E. muelleriana* in the Wairarapa district, also reported in trials in Northland, hint at the potential of these known good sawtimber species.

Keywords: species trials; New Zealand; stringybarks; ashes; peppermints; gums; growth; straightness; health; *Eucalyptus globoidea*; *Eucalyptus muelleriana*; *Eucalyptus obliqua*; *Eucalyptus fraxinoides*; *Eucalyptus regnans*; *Eucalyptus cordata*; *Eucalyptus delegatensis*; *Eucalyptus fastigata*; *Eucalyptus sieberi*; *Eucalyptus cinerea*; *Eucalyptus kartzoffiana*; *Eucalyptus nitens*.

INTRODUCTION

A number of species trials of eucalypts*, with soil conservation objectives, were established from 1978 to 1986 in seasonally dry hill country of the Hawke's Bay and Wairarapa districts of New Zealand. This research was done by the National Plant Materials Centre (NPMC) at Palmerston North (now part of HortResearch, a Crown Research Institute). An exceptionally wet winter and spring in 1977 had resulted in extensive soil slips and earthflow in the Wairarapa hill country and this provided the impetus to establish trials of up to 56 eucalypt species, as well as some *Acacia* and *Casuarina* species. These trials were originally intended to test species for their potential to stabilise erodable land so as to retain it for pastoral use. Poplars and willows, usually used for this purpose, are not sufficiently drought-tolerant for growing on hill slopes, especially on seasonally drought-prone areas. The largest trials of this series were established in 1979 at two sites, Kahuiti Station and Pakaraka, near Masterton in the Wairarapa district (Hathaway & King 1986; Bulloch 1991). Some of the same species and seedlots were also planted at a further 10 sites of a similar nature in Hawke's Bay and Wairarapa between 1978 and 1986 (B.T.Bulloch & C.E.Stace unpubl.data).

Current research at the New Zealand Forest Research Institute (NZFRI) involves reappraising earlier trials for information about long-term performance of eucalypt species in different regions of New Zealand, which have potential for producing solid wood products and pulp (Low & Shelbourne 1999; Shelbourne, Low & Smale 2000). These Wairarapa trials were thus a valuable source of information about the production forestry potential of a large number of species for that region.

The trials at Pakaraka and Kahuiti included a few species such as *E. muelleriana*, *E.globoidea* , *E. cladocalyx*, and *E. maculata*, reputedly good for sawtimber, naturally durable, and with high wood density but which had rarely been trialled for plantation forestry, as well as well-known species such as *E. regnans*, *E. fastigata*, and *E. nitens*. Unfortunately the Pakaraka trial, which was much the better-grown at age 12 years, had recently been heavily thinned to waste, but the trial at Kahuiti was unthinned since planting, and was suitable for an assessment at age 22 years, which is the main focus of this paper.

Eucalypt Species Trials in New Zealand

Field testing and comparative evaluation of eucalypt species for plantation forestry has been undertaken in New Zealand on a variety of sites and by several organisations since 1960 (*see* Fig. 1 for site locations). A summary of published and unpublished results of these trials is included here as background for reporting the assessment of the Kahuiti trial at age 22 years.

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* Full names of all eucalypt species mentioned in this paper are listed and classified in Appendix 1.

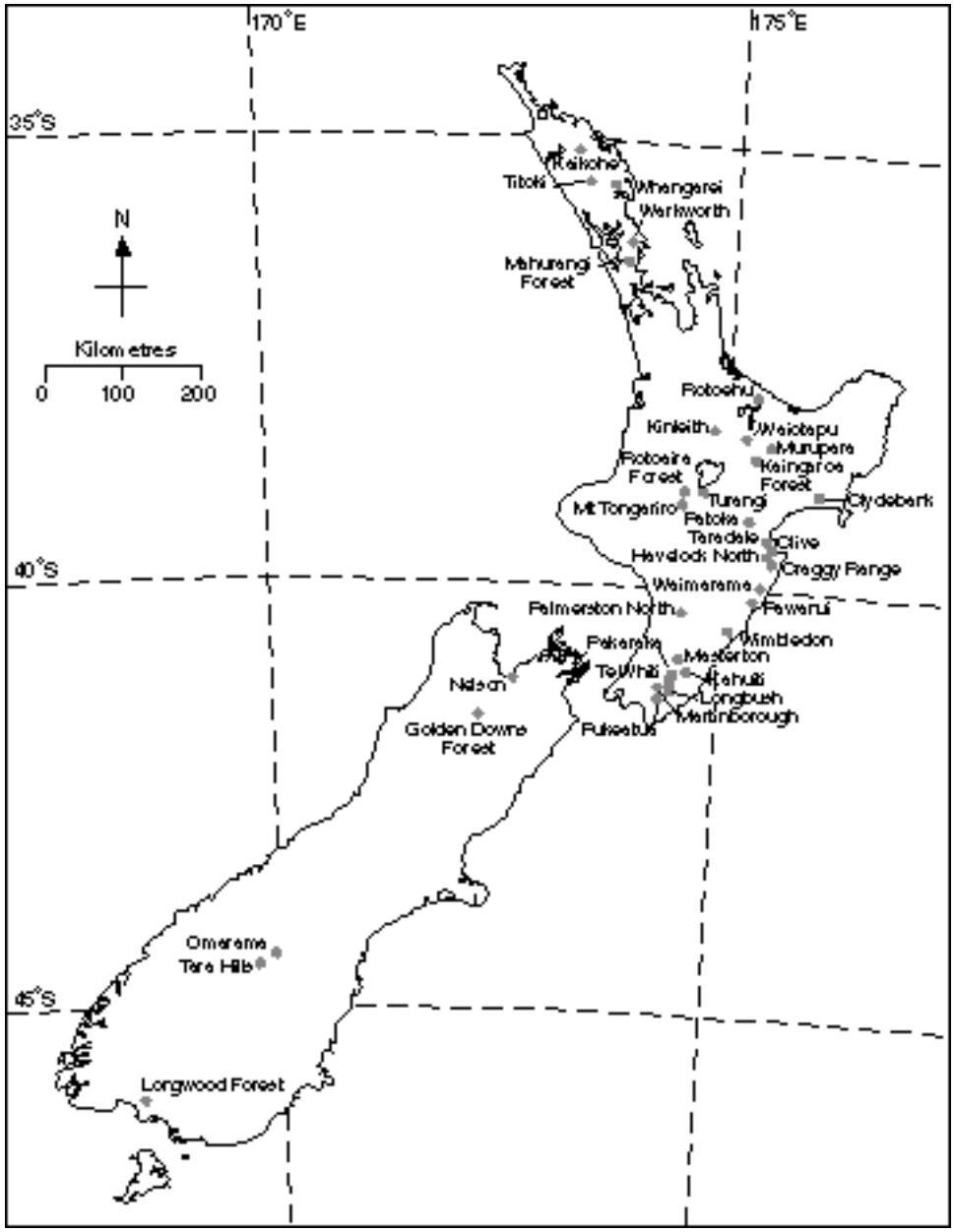

FIG. 1–Locations of the trial sites referred to in this paper.

NZFRI trials in the central North Island and Southland

One group of trials was initiated by M.D.Wilcox of the New Zealand Forest Research Institute in 1977, to compare species for growth and form, and adaptability to climate and insect and fungal pests. Successful trials resulted at two sites in the central North Island (at Rotoehu and Waiotapu), at Golden Downs Forest (near Nelson), and at Longwood Forest in Southland. The trials at Rotoehu and Waiotapu had species plots consisting of single-tree plots of different provenances, randomised within them. Species plot size at Rotoehu and Waiotapu was 25–30 trees (area 0.03 ha) and from 15 to 45 trees at Longwood (area 0.018 to 0.055 ha). The species plots lacked surrounding rows as buffers against inter-plot competition, and were too small in area and in numbers of trees at final stocking for longer-term species comparisons of volume per hectare. They involved a group of 13 ash group species, seven gums, and *E. saligna*.

At Rotoehu (altitude 70 m) in the Bay of Plenty, diameter growth and survival of ash group *E. fastigata, E. fraxinoides, E. regnans*, and *E. oreades* at age 9 years greatly exceeded those of the other species, including *E. nitens* and *E. obliqua* (Johnson & Wilcox 1989). At Waiotapu in Kaingaroa Forest (altitude 380 m), differences in dbh at age 9 years were not so marked, but *E. regnans* and *E. obliqua* were a little larger in dbh than *E. fastigata, E. nitens, E. delegatensis, E. fraxinoides*, and *E. oreades*. *Eucalyptus nitens* was particularly poor in growth and health in this trial, where today it would be expected to do well. However, *E.nitens* planted in 1979 in open-pollinated progeny tests near Murupara in Kaingaroa Forest (altitude 230 m) and at Rotoaira Forest, south of Turangi on the slopes of Mt Tongariro (altitude 700 m), grew well. Results from these tests were instrumental in the decision to continue a full-scale breeding programme with this species (Cannon & Shelbourne 1991).

In Longwood Forest in Southland (Wilcox *et al*. 1985), best growth at age 4 years was by *E. nitens*, followed by *E. fraxinoides, E. regnans*, and the *E. obliqua* × *E. regnans* hybrid. *Eucalyptus fastigata* and other species, such as *E. obliqua*, were well behind in growth rate. By age 6 years the authors were recommending *E. regnans, E. fraxinoides*, and *E.delegatensis* as best choices, and regarded *E. nitens* and *E. globulus* as too susceptible to attack by insects such as *Paropsis charybdis* Stål. History has overtaken these species selections and now *E.nitens* is the only species being planted commercially for pulpwood in Southland. *Eucalyptus delegatensis* and *E. regnans* lost favour in Southland because of low wood density, slower growth rates, and less frost tolerance than *E. nitens*. In the central North Island *E. delegatensis* and *E. regnans* were also badly affected by leaf fungi and are no longer planted for the same reasons; the main species now planted are *E. nitens* and *E. fastigata*. Most planting has been for kraft pulping, for which *E. nitens* has been favoured over *E.fastigata* . Yet the susceptibility of *E. nitens* to fungal leaf disease on lower altitude sites, and to attack by Paropsine beetles may in future offset this preference in favour of the good health and long-term high growth rates of *E. fastigata*.

NZFP trial at Kinleith

A species trial was established in 1977 in Kinleith Forest (in the central North Island) by New Zealand Forest Products Forests (NZFP) (now Carter Holt Harvey) (Poole *et al*. 1991). Up to six seedlots each of eight species were planted in one or two 28-tree plots at 3 × 2 m-spacing; species included ashes *E. delegatensis, E. fraxinoides, E. obliqua, E.oreades,*

E. regnans, and *E. sieberi*, and gums *E. nitens* and *E. glaucescens*. Results at age 11 years showed largest dbh for *E. fraxinoides*, *E. regnans*, and *E. oreades*. Growth of *E. sieberi*, *E.obliqua*, *E.delegatensis* , and *E. glaucescens* was inferior, and that of *E. nitens* was intermediate. In another provenance trial at the same site, *E. fastigata* basal area/ha at age 13 years, averaged over four provenances, exceeded that of five provenances of *E. regnans* by 25%, indicating that the growth of *E. fastigata* would have exceeded all other species on this site.

NZFP trial in Northland

Another species trial of an interesting and unusual group, chosen for good solid wood properties, was planted by NZFP in 1978 at Mahurangi Forest, north of Warkworth in Northland (altitude 60 m). This included *Corymbia maculata*, *C. citriodora*, *E. cloeziana*, *E. jacksonii*, *E. pilularis*, *E. pyrocarpa*, *E. muelleriana*, *E. laevopinea*, *E.saligna*, *E.resinifera*, *E. diversicolor*, and *E. microcorys*. Row plots of 20 trees of each species were planted in two adjacent blocks, with one or occasionally two rows of each species planted in each block. At age 9–10 years (H.M.McKenzie unpubl. data) there were on average only four or five trees surviving in each plot and best-grown species were *E.pilularis* (and related *E. pyrocarpa*), *E. muelleriana*, *E. laevopinea*, *E. regnans*, and *E.saligna* . At age 18 years the position was much the same, with good growth and health but variable form of the two stringybarks, *E. laevopinea* and *E. muelleriana*, and *E. pilularis*.

NPMC and NZFRI trials in Northland

A species trial with small row plots was planted by the National Plant Materials Centre (NPMC) near Whangarei in Northland, and this included 21 species, of which *E. blaxlandii*, *E.crenulata*, *E. microcorys*, *E. pilularis*, *E. rodwayii* , and *E. saligna* were not represented in the Wairarapa trials. At age 14 years (A.E.Hay, H.M.McKenzie, & C.B.Low unpubl. data) the best-grown four species were *E. fastigata*, *E. obliqua*, *E. regnans*, and *E. blaxlandii* (a stringybark). Lower ranked for growth were *E. botryoides*, *E. globoidea*, *E. nitens*, *E.pilularis*, *E. saligna* , and *E. sieberi*.

Stringybark species *E. muelleriana* and *E. globoidea*, along with *E. pilularis* and *E.microcory* s, were planted in a 1991 NZFRI trial of durable species at Titoki in Northland (Hay unpubl. data) and *E. muelleriana* was also planted in a nearby NZFRI provenance/ progeny trial in 1993 (Shelbourne, Low, McConnochie, & Hay 2000). Growth rates and health of *E.muelleriana*, *E. globoidea* , and *E. pilularis* have been similarly good, and growth of *E.microcorys* slower.

Pulpwood trials in Northland

A further group of species and provenance trials was established in Northland (by Paul Smale for NZFP) as a basis for a eucalypt pulpwood planting scheme, later abandoned. The trials were planted between 1988 and 1993 on four sites south of Kaikohe and involved ashes *E. fastigata* and *E. regnans*, eastern blue gums *E. saligna* and *E. grandis*, and southern blue gums *E. nitens*, *E. globulus*, and *E. maidenii*. Results at ages 8 and 11 years (Low & Shelbourne 1999; Shelbourne, Low & Smale 2000) indicated that *E. fastigata* and *E. regnans*

were the best performers for growth and health, followed by *E. maidenii*. *Eucalyptus nitens* and *E.globulus* exhibited severe attack by fungal leaf disease and high mortality, probably as a result of poor adaptation to the warm high-rainfall Northland sites. Insect attack contributed to the decline of *E. saligna*. These trials had plots of 49 and 64 trees (at 1.9–2.0 m initial spacing) with areas of 0.018 and 0.026 ha. They were thinned to 1200 stems/ha, and provided adequate estimates of volume growth on a pulpwood regime up to age 11 years, but were still adversely affected by inter-plot competition.

Central Otago trial

Early growth and frost hardiness were reported by Ledgard (1998) for a set of 18 species planted in 1981 at Tara Hills, Omarama, in central Otago; rainfall was very low, but the site was irrigated. This trial included nine of the species tested in the central North Island trial at Rotoehu (Johnson & Wilcox 1989). Annual frost events in 1982 and 1991 caused serious damage but a –19.5°C freeze in 1995 killed back all species to lower stem level. Prior to this, *E. gunnii* and *E. nitens* had survived and grown best of all species to a height of 11 m and dbh of 170 mm by age 10 years.

Fuelwood trial in Hawke's Bay

A close-spaced coppice fuelwood trial was planted near Clive in Hawke's Bay (altitude 5m, mean annual rainfall 800 mm). This included coppicing gums *E. nitens, E. globulus, E.maidenii, E. bicostata, E. ovata, E. macarthurii,* and *E. cinerea*, as well as ashes *E.fastigata, E. fraxinoides,* and *E. regnans*, mahoganies and eastern blue-gums *E. botryoides* and *E. saligna*, and red gums *E. camaldulensis* and *E. tereticornis* (Low & Shelbourne 1999). The trial was planted at 2×1 m spacing (5000 stems/ha) and designed to run for only a few years, in support of a local commercial venture on short-rotation firewood production. It was located on a riverside site with a high and fluctuating water table. Poor survival under these conditions eliminated many species, and by age 11 years the only species with reasonable survival and growth were *E. nitens, E. globulus, E. maidenii, E. bicostata, E. ovata, E.botryoides* , and *E. saligna*. Of these, *E. nitens* and *E. globulus* were well grown but in declining health from attack by fungal leaf disease, and *E. maidenii* was outstanding in health, survival, and growth. In parallel planting at Patoka (altitude 350 m), a cooler higher-rainfall site south-west of Taradale in central Hawke's Bay, growth of *E. nitens* has been extremely rapid and health was excellent. At age 11 years, *E. maidenii* and *E. bicostata*, planted adjacent, both grew well, with *E. maidenii* height of 22.5 m approaching that of *E.nitens* at 24.9 m (Low & Shelbourne 1999).

NPMC soil conservation trials

Extensive trials of altogether 56 species of eucalypts were established from 1978 to 1986 by the National Plant Materials Centre in Hawke's Bay and Wairarapa with soil conservation objectives. The trials were designed to indicate the ability of different species to thrive on eroding soils and to stabilise them so that they could continue to be used for pastoral farming. These trials are also of interest for plantation forestry. They included 13 of the 21 species planted in the central North Island trials, as well as potential sawtimber species *E.agglomerata, E. globoidea, E. macrorhyncha, E. muelleriana* (stringybarks), *C. maculata*, and *E. cladocalyx*. *Eucalyptus agglomerata, E. muelleriana, C. maculata*, and *E. cladocalyx* have been used in

plantations in Australia and are rated highly for sawn timber. Results of the two trials at Kahuiti and Pakaraka in the central Wairarapa were reported by Hathaway & King (1986) at age 5 years and then by Bulloch (1991) at age 12 years. Assessment of the Kahuiti trial at age 22 years will be reported in this paper.

Some of the same species and seedlots planted at Kahuiti and Pakaraka were planted by the National Plant Materials Centre at Kahuiti and another nine sites of a similar nature in Hawke's Bay and Wairarapa between 1978 and 1986 (Bulloch & Stace unpubl.data). Altitudes of sites varied from 70 m at Waimarama to 300 m at Pukeatua, near Martinborough in southern Wairarapa. Mean annual rainfall was generally from 1000 to 1300 mm, except at one site near Havelock North where it was 850 mm. Soils were all typical hill soils of the region, mainly from siltstone, mudstone, and argillite parent material. At most of the 10 sites a group of 10 species was planted which included ashes *E. fastigata, E. fraxinoides, E.obliqua,* and *E. regnans*, peppermints *E. nitida* and *E. pulchella*, and gums *E. rodwayi, E. cordata, E. nitens*, and *E. ovata*.

At age 12 years, adjusted site mean height and dbh varied enormously from 6.2 m and 78mm at Kahuiti (a second trial, planted in 1981) to 13.0 m and 301 mm at Pawanui. Average height growth exceeded 10 m at only four of the 10 sites — Clydebank (northern Hawke's Bay), Waimarama (central Hawke's Bay), Wimbledon (southern Hawke's Bay), and Pawanui (southern Hawke's Bay). At Kahuiti (1979 planting) mean dbh of the same group of species at age 12 years was 156 mm and at Pakaraka it was 225 mm. Corresponding mean heights were 9.1 and 10.9 m.

At the driest site (Craggy Range Road, near Havelock North), *E. pulchella* was outstanding in terms of height, dbh, and survival, followed by *E. obliqua*. At Clydebank, the highest rainfall site of all, *E. obliqua, E. pulchella,* and *E. nitens* substantially outgrew all other species. At Waimarama there was little difference in growth amongst *E. fastigata, E.fraxinoides, E. obliqua* , and *E. regnans*. At Kahuiti (1981 planting) growth was slow but *E. fastigata, E. fraxinoides*, and *E. obliqua* were best. At Whakarua Road, Longbush, the same species plus *E. pulchella* grew better. Diameter growth was good at Wimbledon though survival was often less than 40%, and *E. fastigata* outstripped *E. fraxinoides*, *E. obliqua*, and *E. pulchella*. At Pukeatua, near Martinborough, *E. fastigata, E. fraxinoides*, and *E. pulchella* performed best, with high survival.

The best-grown species overall for diameter growth, offset by survival, were *E. fastigata* and *E. obliqua*. However *E. fraxinoides, E. regnans*, and *E. pulchella* grew equally well on some sites. *Eucalyptus nitens*, at the five sites out of 10 where represented, apparently grew as well in dbh as the second-ranked ashes, and outgrew all others on two sites.

An earlier trial at Te Whiti near Masterton, assessed at age 15 years, included 35 species planted in three 12-tree-plots, which had been thinned to a total of only six trees per species (Bulloch unpubl. data). *Eucalyptus botryoides* had the biggest dbh, followed by *E. perriniana*, *E. nitens*, and *E. fastigata*, and *Eucalyptus muelleriana* ranked sixth for dbh. The top ranked 12 species out of 35 for dbh also included ashes *E. delegatensis, E. fraxinoides*, and *E.obliqua* , and peppermints *E. coccifera, E. pulchella*, and *E. tenuiramis*. Gums *E. cinerea, E. ovata*, and *E. viminalis* also ranked in the best 12 species for dbh. The rankings were quite similar to the other sites, though the gums *E. nitens* and *E. ovata* (and *E. perriniana*, not represented elsewhere) performed relatively better on this site.

MATERIALS AND METHODS

Sites

The Kahuiti site is located 28 km east of Masterton (lat. 40°56´S, long. 175°39´E) at an altitude of 150–180 m on a scarp of silt and clay loam soil over mudstone. Aspect is north-westerly, and slope is 26–35°. The higher part of the trial site is the rim of a terrace, and the site therefore receives runoff from above. When the site was planted in 1979, there were large areas of bare earth, following earthflow which is chronic on this site. Annual rainfall is 1000 mm and a nearby weather station at Waingawa recorded an average of 90 days of ground frost per year, though there were no early reports of frost damage after planting (Bulloch 1991).

The companion trial at Pakaraka (not assessed in this study in 2001 because of recent heavy thinning) is located 8 km south-east of Masterton at an altitude of 150–250 m. The site consists of a hillside of shallow loess deposits over siltstone, with a northerly aspect and slope of 21–25°. Annual rainfall is probably about 50 mm less than at Kahuiti. Most of the site had been damaged by shallow slips in 1977.

Both sites were chosen as typical of the hill soils in that region that were very susceptible to erosion, on which to test a wide range of eucalypt species for their capacity to grow and protect the sites from further soil slip.

Seedlots

A total of 104 seedlots of 49 eucalypt species were planted at Kahuiti, with an additional six species at Pakaraka. At Kahuiti there were eight species with more than three and up to eight provenance seedlots each, 12 species with two or three provenance seedlots, and 28 species with a single seedlot (Appendix 2). These species included *Corymbia maculata*, four stringybarks, nine ashes, seven peppermints, and 18 gums, as well as another eight species from various other groups.

Design and Layout

A randomised complete block design was used at both Kahuiti and Pakaraka, with row plots of four trees for seedlots of species with more than one provenance seedlot, and two parallel rows of four trees for species with only one provenance seedlot. Spacing varied somewhat between 3 and 4 m owing to visual layout and subsequent soil slip. A split-plot layout was used, in which plots of different seedlots of the same species were grouped together in each replication. Thus, for eight species with more than three provenances, the aggregated row plots in each replication originally formed an irregularly-shaped species macro-plot of 16 up to 32 trees.

The Kahuiti site was unthinned, and survival was 66% overall in 1984 (Hathaway & King 1986), 58% overall in 1991, and 66% in Replications 1–4 (Bulloch 1991). Replication 5, which was at the bottom of the slope, suffered the greatest early losses and a total of only 47 trees from 15 seedlots survived in this replication at age 22 years, compared with 238, 268, 229, and 136 trees in Replications 1–4 respectively. In practice, species with one or two seedlots had a maximum possible 32 trees (four reps) at subsequent assessments. Species with three or more provenances had more potential survivors. Areas within the experiment were not planted where topsoil had been lost through soil slippage.

Assessment in 2001

The Kahuiti trial was assessed in September 2001 at age 22 years. Trees that were suppressed individuals, well below the height of the canopy and less than half the species average dbh, were not included. The following traits were assessed :

- Diameter at breast height over bark (in mm) (Note that thick-barked species have dbh over-estimated)
- Bole straightness score (1 = very sinuous to 9 = very straight)(not assessed for trees that were very small and /or malformed, where scoring was meaningless)
- Malformation score (1 = multiple forking, no single stem; 2–3 = forked; 4 = ramicorn branches; 5 = single unforked stem)
- Crown health score (1 = badly defoliated to 9 = healthy dense crown)
- Number of possible 5-m sawlogs (0, 1, or 2)

Analysis

Analysis of variance of the Kahuiti data was carried out using PROC GLM of the SAS™ software package (SAS Institute 1989) according to the model for a randomised complete block design, with provenances nested within species. This comprehensive analysis was used for all species and provenances; the same model was also used to analyse species separately within certain taxonomic groupings in order to confine variation to within a well-defined group. The trial was laid out in a split-plot design with provenance plots of a single species, where available, grouped together within each replication. Because of the low survival in many plots and /or total absence of trees in some plots, and the imbalance that this generated, as well as the need for clear interpretation of results, the model for a randomised complete block design was used.

The equation for this model is as follows:

$$Y_{ijk} = \mu + S_i + R_j + P_k : S_i + E_{ijk}$$

where Y_{ijk} = the observation on the i^{th} species in the j^{th} rep of the k^{th} provenance
μ = the overall mean
S_i = the effect of the i^{th} species
R_j = the effect of the j^{th} replicate
$P_k : S_i$ = the effect of the k^{th} provenance within the i^{th} species
E_{ijk} = the random error associated with each tree of the k^{th} provenance in the i^{th} species in the j^{th} replicate

Species means were estimated using PROC MEANS (SAS Institute 1990) and these means were correlated with age 12 means at both the Kahuiti and Pakaraka sites using PROC CORR (SAS Institute 1990). PROC MEANS was used to provide an arithmetic mean of individual tree values for each trait, which can be interpreted in relation to number of trees and number of plots available of that seedlot/species. LS MEANS was not used as there was such extreme imbalance in survival in different replications that least squares means would have been difficult to interpret.

RESULTS AND DISCUSSION

Provenance and Species Means at Kahuiti at Age 22 Years

There were large and highly significant differences between species in diameter growth, straightness, malformation, and health in the analysis of variance over all species, and

between provenances-within-species, only for crown health and number of sawlogs (Tables1 and 2). The replication × species and replication × provenance-in-species terms reflect the amount of plot error, or failure of species and seedlots, respectively, to rank the same from replication to replication. Both were significant for dbh and crown health score, and the replication × species term was significant for malformation and number of sawlogs. Plot error was large for these traits because growth was strongly affected by varying slope, soil fertility, and wetness within each replication, of which there were only effectively four (because of very poor survival in Rep. 5). This reduced the precision of estimates of species and seedlot means, as indicated by the large least significant differences (Table 2). The other factor contributing to low precision was very small numbers of trees for many species (13 species were represented by 10 trees or less), determined partly by number of provenances of each, and even smaller numbers for each seedlot (Appendix 2).

Analyses of variance were conducted separately to remove some of the "noise" in the overall species analysis and to examine within-group differences for nine ash species and for seven peppermints. However, the within-group analyses generally showed much the same trends as in the overall analysis (Tables 3, 4, 5). In the ash group, number of provenances per species was only two for *E. oreades* and one for *E. niphophila* but averaged over five for the other species. There were significant provenance-in-species differences (Table 3) for dbh, crown health, and number of sawlogs and, in this group, numbers of trees per provenance were large enough for a few provenances to give reasonable estimates of provenance means (Appendix 2). The highly significant provenance-in-species effect for crown health underlines the importance of selecting provenances for this trait. In general, however, site variation and low number of surviving trees per seedlot were responsible for unreliable ranking of provenances within species.

The analysis of variance (Table 4) showed significant differences between species in the peppermint group for all traits except straightness but, as only two species had more than one provenance, provenance-within-species differences were unimportant (*E. stellulata* should have been included in the ash group). For the gums (Table 5), there were also significant species differences for most traits and significant provenance differences in malformation, crown health, and number of sawlogs, mainly within *E. dalrympleana*, *E. nitens*, and *E. viminalis.* Number of surviving trees exceeded 10 per provenance for only about half of the provenances of each species, resulting in low precision of provenance mean estimates.

TABLE 1–F ratios from analyses of variance of age 22 data from Kahuiti: All species

Source	Df	dbh	Df	Straight-ness	Df	Malform-ation	Crown health	No. of sawlogs
Rep	4	1.86	4	2.84*	4	3.79**	5.08**	4.05**
Species	50	2.24**	40	2.21**	49	2.76***	3.40***	1.35
Prov(Species)	52	1.17	40	1.20	52	1.09	1.55*	4.18***
Rep*Species	103	1.73*	53	1.48	92	2.14**	1.64*	1.94**
Rep*Prov(Species)	70	1.88***	38	0.85	65	1.19	4.89***	1.00
Error	640		189		543			

* significant at $p \leq 0.05$
** significant at $p \leq 0.01$
*** significant at $p \leq 0.001$

TABLE 2–Species means for diameter at breast height, straightness, malformation, and health scores at age 22 years (at Kahuiti) and age 12 (at Kahuiti and Pakaraka) (from Bulloch 1991)

Group	Species	Age 22 years Kahuiti								Age 12 years Kahuiti			Age 12 years Pakaraka		
		No. of provenances	No. trees	dbh (mm)	Straightness	Malformation	Crown health	No. of sawlogs	Survival (%)	dbh (mm)	Height (m)	Straightness	dbh (mm)	Height (m)	Straightness
Red bloodwoods	*C. maculata*	2	2	260	3.00	4.00	7.50	0.50					184	9.0	4.2
Stringybarks	*E. agglomerata*		14	214	5.64	4.54	7.08	1.23	44	95	5.9	3.2	210	7.9	3.4
	E. globoidea		9	342	5.75	3.22	7.78	0.44	28	122	4.7	2.2	244	8.6	3.0
	E. macrorhyncha		6	275	3.00	3.33	5.50	0.33	19	106	6.2	2.8	186	7.1	3.5
	E. muelleriana		10	337	6.00	3.33	6.44	0.78	31	198	8.0	2.5	210	8.7	3.5
Ashes	*E. delegatensis*	6	15	302	6.29	4.60	5.67	2.67	16	129	8.5	3.7	220	12.4	4.1
	E. fastigata	4	41	300	6.44	4.02	7.61	1.07	64	147	9.0	3.7	292	11.4	4.2
	E. fraxinoides	3	20	331	4.83	3.30	7.95	0.50	42	148	7.7	3.4	258	13.1	3.6
	E. niphophila	1	14	229	3.00	2.46	5.31	0.08	44	112	5.5	2.6	136	5.4	3.0
	E. obliqua	8	53	333	6.57	4.15	7.49	1.51	41	194	11.0	3.9	238	11.8	3.9
	E. oreades	2	6	262	5.83	4.33	7.00	1.67	19	113	5.5	3.3	196	10.0	3.5
	E. regnans	5	41	314	6.50	4.23	6.90	1.59	47	164	11.1	4.0	244	13.9	4.0
	E. sieberi	6	24	295	5.33	4.04	7.88	0.67	25	141	7.2	3.2	202	10.9	3.9
Peppermints	*E. amygdalina*		14	253	4.75	3.07	6.93	0.36	44	148	9.5	3.5	251	10.5	3.4
	E. coccifera		2	268	–	2.00	6.00	0.00	6	81	3.9	2.5	131	5.3	2.4
	E. elata	2	12	264	5.71	4.08	7.42	0.92	38	99	5.1	3.0	190	8.5	3.2
	E. nitida		3	302	5.00	3.33	2.33	0.67	9	182	9.0	2.5	192	9.1	3.4
	E. pulchella		10	270	4.00	4.30	8.00	1.10	31	184	11.3	3.3	216	12.1	3.8
	E. radiata	2	12	235	5.63	4.33	7.58	0.75	38	107	5.4	3.3	192	8.7	3.9
	E. risdonii		22	150	–	3.00	2.50	0.00	69	91	5.8	1.8	202	9.5	3.0
	E. stellulata		29	243	5.00	2.96	5.07	0.04	72	131	6.7	2.3	182	8.4	2.2
Eastern blue-gums	*E. botryoides*		16	275	5.40	3.06	5.56	0.44	50	194	8.6	3.0	268	11.7	3.6
	E. bot. x E. saligna		26	231	5.69	3.65	6.85	0.62	81	148	8.2	3.2	251	12.4	4.0
	E. deanei		20	252	5.00	2.55	6.30	0.20	50	123	6.4	2.8	176	9.4	3.4
	E. robusta		13	167	–	5.00	3.17	0.00	41	72	3.2	2.2	78	3.1	2.7
Sugar gum	*E. cladocalyx*	2	4	265	3.50	3.50	7.75	1.25	13	122	8.3	4.0	248	13.4	3.8
Red gums	*E. amplifolia*		14	149	6.00	3.50	4.00	0.17	44	55	3.8	2.7	88	5.1	3.6

TABLE 2–cont'd

Group	Species	Age 22 years Kahuiti							Age 12 years Kahuiti			Age 12 years Pakaraka		
		No. of provenances	No. trees	dbh (mm)	Straightness	Malformation	Crown health	No. of sawlogs	Survival (%)	dbh (mm)	Height (m)	Straightness	dbh (mm)	Height (m)	Straightness
Gums	*E. aggregata*		12	221	3.75	3.33	6.56	0.44	38	119	8.6	2.4	168	7.2	3.3
	E. badjensis		25	169	5.67	3.09	6.45	0.27	78	99	4.7	2.7	166	5.2	2.2
	E. barberi		6	195	–	1.50	4.00	0.00	19	89	4.9	1.6	88	4.0	2.0
	E. brookeriana	2	22	274	5.60	3.48	5.90	0.76	69	169	9.3	3.7	170	9.5	3.9
	E. camphora	2	22	215	4.33	2.65	4.50	0.20	69	122	7.0	1.9	134	5.2	2.6
	E. cinerea	2	20	287	4.25	3.00	6.65	0.20	63	153	5.3	2.3	196	5.0	3.0
	E. cordata		23	306	5.92	3.45	5.75	0.95	72	179	11.4	3.8	180	10.1	3.8
	E. cypellocarpa (E. alaticaulis)	3	15	201	4.00	2.27	3.73	0.09	31	145	5.7	2.2	176	6.6	3.0
	E. dalrympleana	5	54	247	5.40	2.81	5.13	0.25	68	135	5.5	2.6	122	4.2	2.7
	E. dunnii		5	187	4.00	3.40	2.60	0.20	16	66	3.5	2.4	132	6.6	3.0
	E. johnstonii	2	19	140	.	2.91	2.82	0.00	59	97	4.6	3.5	106	4.2	3.4
	E. kartzoffiana		22	288	4.00	3.29	5.71	0.24	69	143	7.2	2.0	105	4.0	2.2
	E. kitsoniana		20	231	5.33	3.15	6.15	0.46	63	136	8.8	2.6	171	9.3	3.0
	E. nitens	6	63	282	6.24	4.13	5.95	1.20	58	148	9.2	3.5	236	10.8	3.6
	E. ovata	2	7	143	–	3.00	5.25	0.00	22	109	6.0	3.2	206	7.9	3.2
	E. rubida	2	22	183	5.67	3.25	3.56	0.25	69	114	5.7	1.7	123	2.9	2.2
	E. smithii		17	154	–	2.55	6.18	0.00	53	77	5.2	2.2	222	8.5	2.1
	E. viminalis	6	58	228	5.07	3.35	5.43	0.65	60	134	6.5	2.6	206	7.5	3.0
Boxes & Ironbarks	*E. leucoxylon*		13	164	6.00	2.22	6.33	0.11	41	63	3.6	2.0	89	3.4	2.1
	E. melliodora		3	310	–	3.33	2.00	0.00	9	9.5	4.2	1.8	101	4.3	3.3
	E. sideroxylon		2	136	–	–	–	–	6	86	3.2	1.7	97	2.6	3.0
LSD 2 species				131	2.23	1.28	2.27	0.80							
LSD 10 species				213	3.67	2.09	3.71	1..31							
LSD 20 species				240	4.14	2.36	4.18	1.47							

TABLE 3–F ratios from analyses of variance of age 22 data from Kahuiti: Ash group (listed in Table 2)

Source	Df	dbh	Df	Straight-ness	Df	Malform-ation	Crown health	No. of sawlogs
Rep	4	0.65	4	1.92	4	1.16	2.33	0.91
Species	7	1.84	7	2.66*	7	6.83***	8.29***	3.42*
Prov(Species)	27	2.02*	24	0.89	27	0.94	4.69***	5.37***
Rep*Species	15	2.63*	13	1.31	15	0.99	3.01***	4.73***
Error	160		100		157			

* significant at p≤0.05
** significant at p≤0.01
*** significant at p≤0.001

TABLE 4–F ratios from analyses of variance of age 22 data from Kahuiti: Peppermint group (listed in Table 2)

Source	Df	dbh	Df	Straight-ness	Df	Malform-ation	Crown health	No. of sawlogs
Rep	4	0.90	3	1.83	4	3.86*	0.92	1.23
Species	7	3.14*	5	1.17	7	4.78**	17.22***	3.37*
Prov(Species)	2	1.13	2	1.14	2	0.39	1.90	6.89**
Rep*Species	13	1.59	3	1.26	11	1.58	5.01***	2.40*
Error	77		15		65			

* significant at p≤0.05
** significant at p≤0.01
*** significant at p≤0.001

TABLE 5–F ratios from analyses of variance of age 22 data from Kahuiti: Gums (listed in Table 2)

Source	Df	dbh	Df	Straight-ness	Df	Malform-ation	Crown health	No. of sawlogs
Rep	4	1.24	4	1.36	4	5.91***	2.36	4.69**
Species	17	2.05*	13	1.87	17	2.34*	2.07*	6.17***
Prov(Species)	22	1.49	13	1.70	22	1.82*	4.03***	1.80*
Rep*Species	44	4.11**	19	1.29	39	3.08***	7.76***	1.03
Error	344		78		278			

* significant at p≤0.05
** significant at p≤0.01
*** significant at p≤0.001

The main aim of the assessment was to rank the species for their ability to form a fast-grown and well-formed stand, something almost impossible to do for many species, where an initial plot of one seedlot of only eight trees represented the "stand". For those species where there were four or more provenances grouped together (initially 16 or more trees), this was more feasible. Species mean dbh need to be compared with knowledge of number of their provenances and their overall survival.

The top-ranked 12 species for dbh were, in descending order (with number of provenances in brackets); *E. globoidea* (1), *E. muelleriana* (1), *E. obliqua* (8), *E. fraxinoides* (3),

E.regnans (5), *E. cordata* (1), *E. delegatensis* (6), *E. fastigata* (4), *E. sieberi* (6), *E. cinerea*(2), *E. kartzoffiana* (1), and *E. nitens* (6). Survival of *E. globoidea, E. muelleriana, E.delegatensis* , and *E. sieberi* was only between 16% and 31%, accounting in part for their good diameter growth. *Eucalyptus fastigata, E. cinerea, E. cordata, E. kartzoffiana*, and *E. nitens* had survival of 58–72%, giving them a handicap to diameter growth from within-plot competition.

The ash species (identified in Table 2) showed the greatest diameter growth, highest bole straightness scores, least malformation (highest scores), mainly high health scores, and the largest number of possible sawlogs per tree of any group. Within the group there was considerable variation between species in these traits.

The stringybarks (Table 2) *E. globoidea* and *E. muelleriana* ranked first and second overall for mean dbh, but were each represented by only nine and 14 trees respectively. The stringybarks were of particular interest, as they are reputed to be easily sawn, with naturally durable high-density timber, and yet have rarely been planted in species trials. They suffered some malformation from recovered loss of leader, also observed elsewhere.

The peppermints (Table 2) generally showed slower growth and more sinuous stems than the ashes. *Eucalyptus pulchella* was the best-grown best-formed peppermint and had the healthiest crown, along with *E. elata* and *E. radiata* which were the straightest of the peppermints.

The gums (Table 2), a heterogeneous group of 18 species, included *E. cordata, E. cinerea, E. kartzoffiana*, and *E. nitens* with good diameter growth and very high survival, of which *E. cordata* was straight and *E. nitens* was exceptionally straight and free of forking. The good growth and health of poorly known gums *E. kartzoffiana, E. cordata*, and *E. cinerea* was remarkable but spoilt by a tendency to forking. Crown health scores varied widely within the group from 2.6 for *E. dunnii* to 6 and over for species such as *E. nitens, E. cinerea, E.badjensis* , and *E. aggregata*. With a few exceptions, survival was much higher for the gums than for the ashes and most of the peppermints.

Amongst the other groups of species, two seedlots of *C. maculata* (spotted gum), a prime sawtimber species in New South Wales and Queensland, had barely survived at this site (but grew better at Pakaraka up to age 12 years — Bulloch 1991). *Eucalyptus cladocalyx* (sugar gum) is another valuable timber species, two seedlots of which also survived poorly at Kahuiti but ranked highly for growth and form at Pakaraka at age 12 years (Bulloch 1991). The eastern blue-gums were represented only by *E. botryoides, E. deanei, E. robusta,* and a putative hybrid of *E. botryoides* × *E. saligna*. Of these, *E. botryoides* grew well initially but appeared to have declined in growth and health since age 12.

This assessment of diameter growth, stem form, and health, while important in identifying good species for plantation forestry, did not address the wood properties nor the sawing and sawn timber characteristics of these species. It is intended to investigate these at Kahuiti for *E. globoidea, E. muelleriana, E. fastigata, E. obliqua, E. regnans, E. fraxinoides, E.cladocalyx* , and *E. nitens* in a subsequent disc and short-billet sawing study.

Comparison of Results at Kahuiti at Age 22 with Those at Kahuiti and Pakaraka at Age 12 Years

Growth was much better up to age 12 years at Pakaraka than at Kahuiti, and it was frustrating not to be able to evaluate these species at age 22 years at Pakaraka. Correlations

(Table 6) between age 22 species mean performance at Kahuiti with that at age 12 were 0.75 for dbh and 0.34 for straightness, the latter perhaps indicating different scoring criteria. Correlation of species mean 12-year dbh at Kahuiti with that at Pakaraka was quite low 0.57, and similarly for 22-year dbh at Kahuiti with 12-year dbh at Pakaraka.

TABLE 6–Correlations of species mean diameter at breast height, straightness, and survival across sites and ages

Site/trait/age		Site/trait/age		Correlation coefficient
Kahuiti dbh	age 12	Pakaraka dbh	age 12	0.57***
Kahuiti dbh	age 22	Kahuiti dbh	age 12	0.75***
Kahuiti dbh	age 22	Pakaraka height	age 12	0.59***
Kahuiti dbh	age 22	Pakaraka dbh	age 12	0.58***
Kahuiti straightness	age 22	Kahuiti straightness	age 12	0.34*
Kahuiti straightness	age 22	Pakaraka straightness	age 12	0.25
Kahuiti survival	age 22	Kahuiti survival	age 12	0.69***
Kahuiti height	age 12	Pakaraka height	age 12	0.73***

* significant at p=0.05
** significant at p=0.01
*** significant at p=0.001

These correlations indicate reasonable correspondence of species growth performance between the two sites, bearing in mind the large amount of error in estimating species means at each site, the low survival at Kahuiti, and the thinning at Pakaraka to two trees per plot prior to the 12-year assessment.

Comparison of best-grown species rankings at the two sites (Table 7) shows that with the exception of *E. cordata* and *E. kartzoffiana* at Pakaraka, the other species behaved similarly to the later performance at Kahuiti. Diameter at breast height and height growth at age 12 at Pakaraka were much better than at Kahuiti (dbh 40% higher). There were some differences in ranking amongst the ashes, with *E. fastigata* outstandingly best at Pakaraka. *Eucalyptus*

TABLE 7–Ranking of best 12 species for diameter at breast height at Kahuiti at age 22, with their dbh at Kahuiti and Pakaraka at age 12

Species	Rank position for dbh (Kahuiti)	No.of trees Kahuiti age 22	dbh Kahuiti age 22	dbh Kahuiti age 12	dbh Pakaraka age 12
E. globoidea	1	9	342	122	244
E. muelleriana	2	10	337	198	210
E. obliqua	3	53	333	194	238
E. fraxinoides	4	20	331	148	258
E. regnans	5	41	314	164	244
E. cordata	6	23	306	179	180
E. delegatensis	7	15	302	129	220
E. fastigata	8	41	300	147	292
E. sieberi	9	24	295	141	202
E. cinerea	10	20	287	153	196
E. kartzoffiana	11	22	288	143	105
E. nitens	12	63	282	148	236

cladocalyx ranked tenth at Pakaraka for dbh and may have ranked better at Kahuiti if it had had better survival. *Eucalyptus botryoides* ranked second at both Pakaraka and Kahuiti for dbh at age 12, yet this species has declined in growth since age 12, ranking thirteenth at age 22. All the peppermints except *E. coccifera* had grown relatively better at Pakaraka at age 12 than at age 22 at Kahuiti.

For bole straightness at age 12 years, *E. delegatensis, E. fastigata, E. regnans, E. obliqua, E. sieberi, E. pulchella*, and the *E. botryoides*× *E. saligna* hybrid were best at Pakaraka. At Kahuiti age 22 years, the best-formed species, including straightness and freedom from forking, were *E. obliqua, E. regnans, E. fastigata, E. delegatensis*, and *E. nitens*.

CONCLUSIONS

The species trials at Kahuiti and Pakaraka were unique in including a large number of eucalypt species, covering most that had been tested elsewhere in New Zealand, as well as some stringybarks and others suitable for sawn timber. The Kahuiti trial had been planted on an eroding site with soil conservation objectives, and was situated in the Wairarapa district where no previous plantation forestry species testing had been carried out. It was old enough, at 22 years, to be predictive of long-term health, adaptability, and growth for sawlogs. The trial was also linked to trials of a smaller set of the same species at 10 other sites in the Wairarapa and Hawke's Bay districts.

The trial design at Kahuiti was not suited to long-term species comparison of volume yield because it was based on five replications of small row plots of four to eight trees, though provenance plots of a species were aggregated together in each replication. Species mean dbh, estimated in the assessment at age 22 years, need to be compared in conjunction with their respective survival and number of provenances to appreciate the reliability of estimates of species means in the face of within-species-plot competition. With this proviso, species can be ranked meaningfully for relative diameter growth and for the other traits of bole straightness, malformation, crown health, and number of potential sawlogs per tree.

The ashes *E. obliqua, E. fastigata*, and *E. regnans* were the best-grown, straightest, and amongst the healthiest species at Kahuiti, with low levels of forking. Yet the stringybarks *E.muelleriana* and *E. globoidea* had grown equally well, with good health on this adverse site, and were quite straight but showed evidence of past forking. Amongst the gums, *E. nitens* showed best stem straightness with low rates of forking, good growth, and good crown health. The growth and survival of *E. cordata, E. cinerea*, and *E. kartzoffiana* were surprisingly good, and similar to *E. nitens*. Ash group species generally improved their relative ranking for dbh from age 12 to age 22 years. The peppermints had generally fallen behind the ashes in dbh and *E.botryoides* , ranking second at age 12, had slipped to thirteenth in rank position.

Amongst species suited to solid wood products, survival of *E. cladocalyx* at Kahuiti was very low, yet its 12-year dbh and height at Pakaraka ranked with the best ash species. A recent check on the survivors of the thinning at Pakaraka have confirmed its continued good growth and health. *Corymbia maculata* grew mediocrely at Kahuiti and at Pakaraka. Two of the stringybarks, *E. muelleriana* and *E. globoidea*, were top-ranked of all species at Kahuiti for dbh at age 22, though with only one provenance of each and low survival this result is equivocal.

In similar soil conservation species trials, planted on other sites in the Hawke's Bay and Wairarapa districts, *E. fastigata* and *E. obliqua* grew better at age 12 years than *E.fraxinoides* and *E. regnans*. Peppermints *E. nitida* and *E. pulchella* grew appreciably slower in dbh, and *E. nitens* showed similar growth rates to *E. obliqua* and *E. fastigata* on the few sites it was planted. It was notable in having good crown health at these low-altitude sites, in contrast to its health on low-altitude Bay of Plenty and Northland sites, but did not grow as fast as the best ash species on these relatively low-rainfall, seasonally dry, east coast sites. The evidence from all these east coast NPMC trials indicates that *E. obliqua* and *E. fastigata* performed best of the ashes for growth, stem straightness, and crown health, in contrast to the mediocre record of *E. obliqua* in the central North Island and in Southland.

None of the eucalypt species trials in New Zealand that have been reviewed here, including the Kahuiti trial, is suitable for making species comparisons of volume per hectare at age 12 years or more, especially after thinning for sawlog production, though they have been effective in ranking species for diameter growth and form. Long-term volume per hectare species or provenance trials require plots that are large enough in area to leave a minimum of 12 trees at final stocking, and need to be separated from neighbouring plots by at least two rows of buffer trees around each plot.

The choice of species for testing in earlier trials was not made on sawing and solid wood properties, but mainly on potential adaptation and growth rate. A new national series of large-plot species trials, sown for planting in late 2002 and winter 2003, has the objective of selecting species for sawn timber production. These will include a number of stringybark eucalypts, *E. pilularis*, *E. microcorys*, *E. maidenii*, *C. maculata*, and *E. cladocalyx*, as well as *E. fastigata* as a control for North Island and *E. nitens* for South Island sites.

The "bottom line" on species selection for growth and yield in the North Island, based on all the trials reviewed and the new Kahuiti data, seems to be as follows. *Eucalyptus fastigata* is the most consistent best choice because it has high yields, adaptability to a wide range of sites, relative freedom from fungal disease and insect attack, and adequate performance for kraft pulping and sawn timber. *Eucalyptus nitens* grows exceedingly fast initially, has good form and good though not "market kraft" pulping properties, and is the most widely planted species for pulp in the Bay of Plenty and central North Island and in Southland. It is seriously affected by fungal leaf disease at lower-altitude warmer sites, and can be badly defoliated by Paropsine beetles. Its utilisation for sawtimber is more seriously affected by growth stresses and by internal checking than *E. fastigata*. From the results of the Hawke's Bay and Wairarapa NPMC trials, *E. obliqua* joins *E. fastigata* as best choice for the lower-rainfall higher-summer-temperature east coast climate. *Eucalyptus pilularis* and the stringybarks have demonstrated good growth and freedom from insect attack and fungal disease in Northland and at various other locations, including Kahuiti for *E. muelleriana* and *E. globoidea*, but are frost tender, which limits their cultivation. They are more easily sawn than most eucalypts, have high wood density and natural durability, and have been commercially marketed in limited quantities in New Zealand. The adaptive and wood properties of other stringybarks need investigating. *Eucalyptus maidenii*, characterised by high wood density, has shown promising growth and health in situations which are too warm and humid for *E. nitens*, and is good for kraft pulp on short rotations. Its wood quality and drying properties are very promising but its utilisation for sawtimber has not been fully explored.

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APPENDIX 1

CLASSIFICATION* OF EUCALYPT SPECIES MENTIONED IN TEXT

Subgenus/genus	Section/(Common name)	Species
Corymbia	(Red bloodwoods)	*C. citriodora* (Hook.) K.D.Hill & L.A.S.Johnson *C. maculata* (Hook.) K.D.Hill & L.A.S.Johnson
Symphyomyrtus	*Sejunctae* (Sugar gum)	*E. cladocalyx* F.Muell.
	Inclusae (Karri)	*E. diversicolor* F.Muell.
	Latoangulatae (Mahoganies & eastern blue-gums)	*E. botryoides* Sm. *E. botryoides* Sm. x *E. saligna* Sm. *E. deanei* Maiden *E. grandis* Maiden *E. resinifera* Sm. *E. robusta* Sm. *E. saligna* Sm.
	Exsertaria (Red gums)	*E. amplifolia* Naudin *E. camaldulensis* Dehnh. *E. tereticornis* Sm.
	Maidenaria (Gums)	*E. aggregata* Deane & Maiden *E. badjensis* de Beuzev. & Welch *E. barberi* L.A.S.Johnson & Blaxell *E. bicostata* Maiden, Blakely & Simmonds *E. brookeriana* A.M.Gray *E. camphora* R.T.Baker *E. cinerea* Benth. *E. cordata* Labill. *E. crenulata* Blakely & de Beuzev. *E. cypellocarpa* L.A.S.Johnson (incl. *E. alaticaulis* R.J.Watson & Ladiges) *E. dalrympleana* Maiden *E. dunnii* Maiden *E. glaucescens* Maiden & Blakely *E. globulus* Labill. *E. gunnii* Hook.f. *E. johnstonii* Maiden *E. kartzoffiana* L.A.S.Johnson & Blaxell *E. kitsoniana* Maiden *E. macarthurii* Deane & Maiden *E. maidenii* F.Muell. *E. nitens* (Deane & Maiden) Maiden *E. ovata* Labill. *E. perriniana* Rodway *E. rodwayi* R.T.Baker & H.G.Sm. *E. rubida* Deane & Maiden *E. smithii* R.T.Baker *E. viminalis* Labill.
	Adnataria (Ironbarks & Boxes)	*E. leucoxylon* F.Muell. *E. melliodora* A.Cunn. *E. sideroxylon* Woolls
Alveolata	(Tallowwood)	*E. microcorys* F.Muell.

APPENDIX 1–*cont*.

Subgenus/genus	Section/(Common name)	Species
Idiogenes	(Gympie messmate)	*E. cloeziana* F.Muell.
Eucalyptus	*Pseudophloius* (Blackbutts)	*E. pilularis* J.Sm. *E. pyrocarpa* L.A.S.Johnson & Blaxell
	Aromatica (Peppermints)	*E. amygdalina* Labill. *E. coccifera* Hook.f. *E. elata* Dehnh. *E. nitida* Hook.f. *E. pulchella* Desf. *E. radiata* DC. *E. risdonii* Hook.f. *E. tenuiramis* Miq.
	Capillulus (Stringybarks)	*E. agglomerata* Maiden *E. blaxlandii* Maiden & Camb. *E. globoidea* Blakely *E. laevopinea* R.T.Baker *E. macrorhyncha* Benth. *E. muelleriana* A.W.Howitt
	Eucalyptus (Green-leaved ashes)	*E. fastigata* Deane & Maiden *E. obliqua* L'Her. *E. regnans* F.Muell.
	Longitudinales (Black Sallies)	*E. stellulata* DC.
	Cineraceae (Blue-leaved ashes)	*E. delegatensis* R.T.Baker *E. fraxinoides* Deane & Maiden *E. niphophila* Maiden & Blakely *E. oreades* R.T.Baker *E. sieberi* L.A.S.Johnson
	Longistylus (Tingles)	*E. jacksonii* Maiden

* Classification based on:

Brooker, M.I.H. 1999: A new classification of the genus *Eucalyptus* L'Hĕr. (Myrtaceae). *Australian Systematic Botany 13*: 79–148.

APPENDIX 2

SEEDLOT MEANS AT KAHUITI, AGE 22 YEARS

Group	Species	Provenance	No. plots	No. trees	dbh (mm)	Straight-ness	Malform-ation	Crown health	No. of sawlogs
Red bloodwoods	*C. maculata*	Beaconsfield, VIC	1	1	160	.	4.00	7.00	0.00
	C. maculata	Beaufort, VIC	1	1	360	3.00	4.00	8.00	1.00
Stringybarks	*E. agglomerata*	Marulan, NSW	3	14	214	5.64	4.54	7.08	1.23
	E. globoidea	Mossvale Rd, NSW	2	9	342	5.75	3.22	7.78	0.44
	E. macrorhyncha	Whiskey Hill, NSW	3	6	275	3.00	3.33	5.50	0.33
	E. muelleriana	Yarram, VIC	3	10	337	6.00	3.33	6.44	0.78
Ashes	*E. delegatensis*	Patersonia, TAS	1	2	313	6.50	4.50	3.00	2.00
	E. delegatensis	Golden Downs, NZ	1	1	195	6.00	4.00	1.00	1.00
	E. delegatensis	Maggs Mtn, TAS	2	5	326	6.60	4.60	6.40	1.60
	E. delegatensis	Fingal Tier, TAS	2	5	332	6.20	4.80	7.40	5.00
	E. delegatensis	Bago SF, NSW	1	1	140	.	5.00	2.00	0.00
	E. delegatensis	Mt Skene, VIC	1	1	288	5.00	4.00	7.00	2.00
	E. fastigata	Oakura, Taranaki, NZ	4	15	359	6.57	4.07	7.87	1.53
	E. fastigata	Barrington Tops, NSW	4	10	215	6.33	4.20	7.30	0.40
	E. fastigata	Errinundra, VIC	3	11	264	6.67	4.00	7.18	1.00
	E. fastigata	Robertson, NSW	3	5	371	5.75	3.60	8.40	1.20
	E. fraxinoides	Badja mountain, NSW	3	11	301	4.67	3.36	7.82	0.45
	E. fraxinoides	S. Eden, NSW	1	3	521	4.00	2.67	8.33	0.33
	E. fraxinoides	Badja Mt, NSW	3	6	291	5.50	3.50	8.00	0.67
	E. niphophila	Mansfield, VIC	3	14	229	3.00	2.46	5.31	0.08
	E. obliqua	Forester, TAS	3	3	252	5.00	4.33	8.00	1.67
	E. obliqua		2	5	289	7.50	4.20	6.00	1.40
	E. obliqua	Mawbanna, TAS	3	11	335	6.30	4.00	7.73	1.55
	E. obliqua	Blenheim, NZ	1	4	397	7.50	4.25	6.75	1.00
	E. obliqua	Otway Ranges, VIC	4	16	323	6.67	4.31	7.81	1.56
	E. obliqua	Huon valley, TAS	1	1	610	5.00	3.00	8.00	1.00
	E. obliqua	Powelltown, VIC	2	6	315	5.60	3.67	7.17	1.50
	E. obliqua	Nietta, TAS	3	7	357	7.57	4.43	7.86	1.71
	E. oreades	Bellangry SF, NSW	2	5	270	5.80	4.40	6.80	1.60
	E. oreades	Lithgow, NSW	1	1	218	6.00	4.00	8.00	2.00
	E. regnans	Franklin, TAS	3	7	263	7.20	4.60	6.80	2.00
	E. regnans	Toolangi, VIC	3	7	303	6.17	3.57	6.71	1.14
	E. regnans	Moogara, TAS	5	13	343	6.25	4.23	7.46	1.46
	E. regnans	Rangiwahia, NZ	3	5	285	7.00	4.80	6.40	2.00
	E. regnans	Ruapuna, NZ	4	9	339	6.44	4.22	6.56	1.67
	E. sieberi	Erica, VIC	1	3	284	4.50	5.00	7.33	1.00
	E. sieberi	Pikes Saddle, NSW	3	7	295	5.33	3.43	7.86	0.43
	E. sieberi	Fingal, TAS	2	4	283	5.25	3.75	8.00	1.50
	E. sieberi	Newnes, NSW	3	7	286	6.00	4.29	8.00	0.57
	E. sieberi	Nerrigunda, NSW	1	1	425	.	4.00	8.00	0.00
	E. sieberi	Orbost, VIC	2	2	307	.	4.50	8.00	0.00
Peppermints	*E. amygdalina*	Ouse, TAS	4	14	253	4.75	3.07	6.93	0.36
	E. coccifera	Miena, TAS	1	2	268	.	2.00	6.00	0.00
	E. elata	Canberra, ACT	2	5	186	6.00	4.40	6.60	0.20
	E. elata	E. Mt Durrah, NSW	3	7	319	5.67	3.86	8.00	1.43

APPENDIX 2–*cont.*

Group	Species	Provenance	No. plots	No. trees	dbh (mm)	Straight-ness	Malform-ation	Crown health	No. of sawlogs
	E. nitida	Maydena, TAS	2	3	302	5.00	3.33	2.33	0.67
	E. pulchella	Mt Judbury, TAS	2	10	270	4.00	4.30	8.00	1.10
	E. radiata	E. Queanbeyan. NSW	3	5	257	5.25	4.40	7.80	1.00
	E. radiata	Daylesford, VIC	3	7	219	6.00	4.29	7.43	0.57
	E. risdonii	Risdonvale, TAS	4	22	150	.	3.00	2.50	0.00
	E. stellulata	Gudgenby area, ACT	5	29	243	5.00	2.96	5.07	0.04
Eastern	*E. botryoides*	Orbost, VIC	4	16	275	5.40	3.06	5.56	0.44
blue gums	*E. bot x E. salig*	W. Wandelion, NSW	4	26	231	5.69	3.65	6.85	0.62
	E. deanei	New England Tablelnds	5	20	252	5.00	2.55	6.30	0.20
	E. robusta	Bulahdelah, NSW	2	13	167	.	5.00	3.17	0.00
Sugar gum	*E. cladocalyx*	Gilgandra district, NSW	1	3	293	3.33	3.33	8.33	1.33
	E. cladocalyx	Gilgandra, NSW	1	1	181	4.00	4.00	6.00	1.00
Red gums	*E. amplifolia*	Woolombie, NSW	2	14	149	6.00	3.50	4.00	0.17
Gums	*E. aggregata*	Krawarree, NSW	4	12	221	3.75	3.33	6.56	0.44
	E. badjensis	Nimmitabel, NSW	4	25	169	5.67	3.09	6.45	0.27
	E. barberi	Cranbrook, TAS	2	6	195	.	1.50	4.00	0.00
	E. brookeriana	King Island, TAS	4	10	308	6.00	3.67	5.44	1.22
	E. brookeriana	Fingal, TAS	4	12	245	5.00	3.33	6.25	0.42
	E. camphora	Brindabella, NSW	4	11	185	4.33	2.67	4.33	0.44
	E. camphora	Uriarra Forest, ACT	4	11	244	.	2.64	4.64	0.00
	E. cinerea	Central Tablelnds, NSW	4	13	273	4.00	2.92	6.23	0.15
	E. cinerea	Majura, NSW	3	7	315	4.50	3.14	7.43	0.29
	E. cordata	Moogara, TAS	5	23	306	5.92	3.45	5.75	0.95
	E. cypellocarpa	Mt Dromedary, VIC	3	10	195	4.00	2.43	3.14	0.14
	E. cypellocarpa	Yinnar, VIC	2	2	245	.	1.00	6.00	0.00
	(*E. alaticaulis*)	Grampians, VIC	1	3	193	.	2.33	4.33	0.00
	E. dalrympleana	Steppes, TAS	2	7	247	.	2.00	3.71	0.00
	E. dalrympleana	S. Bulls Head, ACT	3	7	183	.	2.86	3.29	0.00
	E. dalrympleana	Mullion Ck, NSW	4	15	250	5.00	3.31	6.00	0.46
	E. dalrympleana	Wihareja, TAS	2	6	250	.	3.00	4.50	0.00
	E. dalrympleana	Brindabella, NSW	4	19	269	6.00	2.68	5.84	0.37
	E. dunnii	Coffs Harbour, NSW	2	5	187	4.00	3.40	2.60	0.20
	E. johnstonii	Misery plateau, TAS	2	6	156	.	3.50	2.17	0.00
	E. johnstonii	Russell Valley, TAS	2	13	132	.	2.20	3.60	0.00
	E. kartzoffiana	Braidwood, NSW	4	22	288	4.00	3.29	5.71	0.24
	E. kitsoniana	Toorongo, VIC	4	20	231	5.33	3.15	6.15	0.46
	E. nitens	Badja Mtn, NSW	3	11	330	6.50	4.11	7.67	1.67
	E. nitens	Tallaganda SF, NSW	5	14	282	5.78	3.86	5.36	0.86
	E. nitens	Blue Range, VIC	5	14	271	7.00	4.43	5.71	1.29
	E. nitens	Toorongo, VIC	2	4	297	7.67	5.00	7.25	1.50
	E. nitens	Macallister, VIC	3	12	253	5.27	4.25	5.58	1.50
	E. nitens	Errinundra, VIC	3	8	267	6.33	3.50	5.38	0.50
	E. ovata	S. Bombala, NSW	2	5	151	.	2.67	6.00	0.00
	E. ovata	Lake Sorell, TAS	1	2	125	.	4.00	3.00	0.00
	E. rubida	Bothwell, TAS	4	10	173	5.00	3.43	3.00	0.14
	E. rubida	Glendale Crossing, ACT	4	12	191	6.00	3.11	4.00	0.33
	E. smithii	S. Eden, NSW	3	17	154	.	2.55	6.18	0.00

APPENDIX 2–*cont.*

Group	Species	Provenance	No. plots	No. trees	dbh (mm)	Straight-ness	Malform-ation	Crown health	No. of sawlogs
	E. viminalis	Bruthen, VIC	4	14	271	5.57	3.50	6.00	0.71
	E. viminalis	Rotorua, NZ	4	12	194	4.60	2.60	4.20	0.50
	E. viminalis	Canberra, ACT	3	9	188	5.00	3.40	6.00	0.20
	E. viminalis	Kingston, TAS	2	4	330	5.00	3.50	6.00	1.00
	E. viminalis	Tumut, NSW	3	9	245	5.50	3.56	4.89	0.56
	E. viminalis	Cygnet, TAS	3	10	189	4.67	3.71	6.00	1.00
Boxes	*E. leucoxylon*	near Grey, SA	2	13	164	6.00	2.22	6.33	0.11
& ironbarks	*E. melliodora*	Kambah, Canberra, ACT	1	3	310	.	3.33	2.00	0.00
	E. sideroxylon	SE Gilgandra, NSW	1	2	136	.	.	.	.

Note : straightness not assessed on some very malformed/poorly grown seedlots