EUCALYPTS IN NEW ZEALAND: A POSITION REPORT

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ABSTRACT

The present status of eucalypts in New Zealand is described. Aspects included are the size of the resource, present and future planting, anticipated usage, species choice, establishment methods, growth and yield, and plantation management.

INTRODUCTION

Euclypts were among the first exotic tree species to be planted in New Zealand. Weston (1957) reported that over 100 species of the genus had been planted. The initial growth was so outstanding that they were widely planted for shelterbelts and general farm use. *Eucalyptus globulus* Labill, *E. macarthuri* Deane et Maiden, and *E. viminalis* Labill, were particularly favoured. *E. globulus* at an early date suffered from attack by *Gonipterus scutellatus* Gyllenhal (the gum tree weevil), and *Eriococcus coriaceus* Maskell (gum tree scale). At a later date all three species proved particularly susceptible to *Paropsis charybdis* Stal (the tortoise beetle). There was serious mortality in woodlots and shelterbelts and interest in eucalypts declined.

This lack of interest continued until the 1960s. At this time N.Z. Forest Products Ltd decided to develop a short fibre resource and State foresters began to consider something other than the ubiquitous *Pinus radiata.* The interest was reinforced by utilisation studies which showed the genus had potentiality for special purposes.

THE EXISTING RESOURCE, PRESENT AND FUTURE PLANTING

Table 1 summarises the plantation position up to 1980. Examination of the contributory figures shows:

- The trends mentioned in the Introduction — *e.g.*, 42% is less than five years old
- The insignificance of the total (11 942 ha) in comparison with the softwood plantation species (in excess of 800 000 ha)

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TABLE 1: THE EUCALYPT RESOURCE*
Stocked Areas (ha) per Lustrum

	State	Companies and Other Private	Total
1980	3087	4290	7377
1975	880	890	1770
1970	411	658	1069
1965	212	132	344
1960	57	47	104
1955	48	49	97
1950	130	63	193
1945	9	69	78
1940	93	69	162
1935	13	43	56
1930	22	175	197
1925	4	4	8
1920	0	238	238
1015	4	63	67
1910	184	—	182
Total	5152	6790	11942

*Taken from data supplied by the Director-General of Forests.

— One single owner. N.Z. Forest Products Ltd, accounts for approximately 40%.

For the immediate future, N.Z. Forest Products Ltd has announced that it will curtail its planting programme to 100-200 ha/yr, while the State in its policy statement on Exotic Special Purpose Species (Anon., 1981) has set a national target of 1290 ha/yr. This total is a combined total for State forests and the private sector, excluding the N.Z. Forest Products Ltd programme.

Thus, overall, in the immediate future, eucalypt establishment is unlikely to exceed 1400 ha/yr. At the present and for the immediate future, *P radiata* planting is anticipated to be some 40 000 ha/yr.

ANTICIPATED USAGE

The Workshop on Special Purpose Timbers (Anon., 1979) considered that eucalypt species are suitable for many aspects of furniture and joinery work. Earlier work by Kininmonth *et al.* (1974) had indicated that, for good recovery percentages of sawn timber, sawing pattern and log size would be important. Size, rather than age, is considered an important feature in reducing growth stress. Subsequent unpublished work by the Forest Research Institute has suggested that a minimum diameter of 500 mm is considered necessary and a larger breast height diameter of 750 mm preferred. These larger diameters allow quarter sawing, the preferred sawing pattern.

Satisfactory veneers have been produced by slicing and again, for this use, large size is preferred. South Africa has many years of experience with the conversion of eucalypts but Kromhout and Bosman (1982) report that no mill is consistently using eucalypt species for sliced veneer. In New Zealand conversion studies it was envisaged that suitable veneer and sawlogs would be restricted to the lower 8 or 9 m of the bole. Thus, only 45 to 55% of total tree volume would be utilised.

Eucalypts have not featured as treated poles in New Zealand, as they show considerable variation in copper-chrome-arsenate uptake and high chemical usage is required to guarantee treatment. The same difficulties are not apparent with creosote treatment. Even if eucalypt poles and posts do not appear as a commercial commodity, they will continue to be used by the small woodlot owner. For these purposes, durabilities are well known, namely:

Natural Durability in Contact with the Ground

Perishable	Non-durable	Mod. durable	Durable	V. durable
E. gunnii	*E. regnans*	*E. globulus*	*E. botryoides*	*E. cladocalyx*
E. ovata		*E. saligna*	*E. globoidea*	*E. cornuta*
		E. sieberi	*E. muellerana*	
		E. viminalis	*E. pilularis*	
			E. radiata	

The largest single resource in New Zealand, that of N.Z. Forest Products Ltd, was conceived solely as a hardwood pulp resource. For that purpose the Ash group is suitable and within that group *E. regnans* is the preferred species. It is both easy to cook and bleach. For this use wood needs determine rotation age. In recent times a rotation age of 12 to 15 years has appeared probable, but it is now more likely that crops will not be felled before age 18 to 20.

SPECIES CHOICE, PESTS AND DISEASES

Four species account for 90% of the total plantation area in New Zealand. They are *E. regnans* F. Muell, *E. fastigata* Deane et Maiden, *E. delegatensis* R. T. Baker, and *E. saligna* Sm. Of these four, three (*E. regnans, E. fastigata* and *E. saligna*) comprise 90% of current planting.

In addition to growth potential, important considerations in species choice have been susceptibility to frost and insect attack. Among the most successful of the early plantings were *E. globulus*, *E. macarthuri* and *E. viminalis*. *E. macarthuri* and *E. viminalis* showed excellent frost tolerance and *E. globulus* was an outstanding grower. All were coppicing species, an attribute valuable for the farm woodlot owner. *E. globulus* proved susceptible to the gum tree weevil (*Gonipterus scutellatus*) and the gum tree scale (*Eriococcus coriaceus*) and finally many plantations and woodlots were killed or rendered totally moribund by the eucalyptus tortoise beetle (*Paropsis charybdis*). *Eucalyptus viminalis* and *E. macarthuri* also proved highly susceptible to the tortoise beetle and suffered the same fate as *E. globulus*. A susceptibility rating of eucalypts to the tortoise beetle was prepared by Dugdale (1963), and, while this has not proved totally reliable, it has been a useful practical guide.

The Ash group is relatively immune to attacks of the tortoise beetle and for that reason recent plantings have concentrated on this group for the higher cooler sites. For the same reason attention has been concentrated on *E. saligna* at lower, warmer altitudes.

Within the Ash group there has long been recognised an increasing frost tolerance from *E. regnans* to *E. fastigata* to *E. delegatensis*. However, *E. delegatensis* has of recent years fallen into disfavour on account of its poor performance. The poor performance is attributed to infection from the leaf blotch fungus *Mycosphaerella nubilosa*. In extreme cases infection has resulted in severe die-back of the leading shoot and fine branches as well as the more familiar leaf blotching. The leaves of *E. delegatensis* by nature shorter lived than those of *E. regnans* are lost prematurely following *Mycosphaerella* infection.

For this reason formal studies on frost tolerance were begun with *E. regnans*, and have been extended to *E. fastigata*. These frost studies (Rook *et al.*, 1980; Wilcox, 1980; Wilcox *et al.*, 1980), have been carried out in the field and laboratory, and have been successful in both identifying and defining the range of tolerance between provenances and defining the seasonal differences in frost tolerance for *E. regnans*.

In the laboratory the frost tolerance level in mid-winter was —7°C (*cf. P. radiata* —12°C) with a 2.5°C variation between provenances. Temperatures of —7°C occur almost every winter on the central pumice plateau between 300 and 600 m where *E. regnans* is commonly planted. Thus, unless plantations are well sited, severe damage will be frequent; even with well-sited plantations there will be occasional failures.

Two important findings from this work with *E. regnans* were that the commonly used local source of *E. regnans* seed was among the most frost-susceptible and that another local stand displayed considerable frost resistance. Although the *E. fastigata* work has to be completed, it is expected that the species will be 1.5 to 2°C more frost-tolerant than *E. regnans* and show some variation according to provenance. The difference in tolerance is small but is nevertheless of considerable practical significance in plantation establishment.

Although the Ash group has been planted in the cooler areas of New Zealand, small plantings at lower, warmer altitudes show promise. The popular conception that the group is unsuited to lower altitudes is not necessarily correct. Of the three, *E. regnans* is the most difficult to establish, while *E. fastigata* forms an umbrageous crown early in life to rapidly occupy the site and suppress weed growth.

At lower altitudes, *E. saligna* and *E. botryoides* Sm. are the commonly planted species. *E. botryoides* has gained acceptance on account of its tolerance to flooding and salt winds. *E. saligna* is considered a better timber species but is prone to wind damage. The close relation of *E. saligna*, *E. grandis* W. Hill et Maiden has not been successful in New Zealand. It is susceptible to possum and tortoise beetle damage.

The tortoise beetle remains a major constraint to species diversification. Apart from those species (*E. viminalis*, *E. macarthuri*), which in the past have proved of value for cold areas, recent trials have given another valuable species for cold regions. This is *E. nitens* Maiden, which is easy to handle in the nursery, easy to establish in the field, and a vigorous early grower. However, it too is proving highly susceptible to tortoise beetle attack. Continuing attempts are still being made to introduce predators to control the tortoise beetle.

There are some predators of the tortoise beetle which feed on a wide range of Chrysomelids. In Australia some of these Chrysomelids are known to damage *E. regnans* and *E. saligna*. If successfully introduced now these predators could assist in the control of pests which have yet to arrive from Australia.

Other insects which, in the past, were regarded as a constraint to eucalypt planting (*e.g.*, the gum tree weevil and the gum tree scale) are no longer regarded as very important.

Incidences of fungi recorded on the foliage of eucalypts on the central plateau have increased parallel with the increase in the plantation area. The commonly recorded genera on the Ash group are *Cercospora, Septoria, Trimmatostroma* and *Aulographina.* None is yet regarded as a serious threat to production but all are being closely monitored.

Eucalypts as exotics in New Zealand must be regarded as subject to above-average disease and pest risks because of our proximity to Australia, the direction of the prevailing wind, the lack of natural enemies in New Zealand, and the volume of goods and human traffic to and from that country. This risk should be viewed in relation to the size of the existing resource and future planting.

ESTABLISHMENT METHODS

Current establishment methods have been reported by Poole and Fry (1980). The main features they stressed in the successful establishment of eucalypt crops are condensed and repeated here.

Nursery Practice

Plantations can be successfully established using naked root nursery stock. A prerequisite is that the rainfall pattern must be reliable. Important features in the growing of nursery stock are seed stratification, sowing techniques, fertiliser regime, weed control and root wrenching regime. If all are well done, satisfactory transplants *i.e.*, more than 5 mm in root collar diameter with a fibrous root system can be produced. Such plants must be lifted and handled carefully and the time from lifting in the nursery to replanting in the field kept to a minimum.

Site Selection

North-facing slopes which allow air drainage but which do not preclude tractor operations are preferred. Areas of problem weeds, those likely to require post-planting treatment, are avoided. These requirements are balanced against management considerations which favour contiguous large blocks. Small areas of eucalypts present problems, in respect of spraying operations, for *P. radiata,* the major species.

Site Preparation

The intensive site preparation practised elsewhere is not practical in New Zealand. On tractorable cut-over pine sites, cultivation is restricted to V-blading. This involves the accumulation of topsoil using a V-shaped front-mounted blade on a crawler tractor. On

TABLE 2: VOLUME PRODUCTION OF EUCALYPTUS SPECIES
Older Data

Species	Plot and Location	Age	Mean d(cm)	Mean h(m)	Stems/ha	Standing Volume m^3/ha	Basal Area m^2/ha	Total Volume Prod. m^3/ha	M.A.I. Standing V/Age	M.A.I. Total V/Age
E. regnans	Waitati	60	43.9	44.7	486	726	64.6	n.a.	12.1	n.a.
	EA 63C 628806	19	36.6	35.7	334	448.5	35.0	634.8	23.6	33.4
	BB 67C 722302	14.1	24.5	26.1	1120	550.1	52.7	553.3	37.3	39.2
	BA 67C 722302	14.1	23.5	20.4	810	323.8	35.1	325.4	22.9	23.2
E. fastigata	Kaingaroa	51	78.1	60.8	133	1092	63.86	1597*	21.4*	31.1*
E. delegatensis	Whirinaki	28.5	38.9	31.6	524	713	62.18	783.0	25.0	27.4
	Golden Downs	43.0	34.6	33.1	450	513.5	42.26	n.a.	11.9	n.a.
	Golden Downs	52.2	60.7	48.6	110	502	31.85	n.a.	9.6	n.a.
E. saligna	Waitangi	24.0	40.2	35.0	198	308	25.10	n.a.	12.8	n.a.
	Waitangi	24.0	36.6	35.4	297	384.3	31.15	n.a.	16.0	n.a.
	Waitangi	24.0	41.5	35.7	99	166.2	13.4	n.a.	6.1	n.a.
	Waipoua	10	27.3	26.1	400	231	24.4	n.a.	23.0	n.a.

*Includes 505 m^3/ha *P. radiata* extracted from mixture in 1968 areas that cannot be worked by tractor, weed control has to be obtained by burning and/or the use of chemicals. No post-planting, mechanical cultivation is possible and post-planting herbicide applications are limited to the triazines which must be applied with care. Although there are difficulties in achievement, the value of a weed-free site at planting cannot be over-emphasised.

Fertiliser

Nitrogen fertiliser is regarded as essential in the establishment year and valuable in the year following establishment. At planting, 30 g or 60 g of urea is slit applied 15 cm from each tree. The lower rate is for V-bladed areas and the higher rate for non-V-bladed areas. In the second year, 250 kg/ha of urea is applied aerially. Further responses to nitrogen fertilisation have been noted at other points in the rotation *e.g.*, at age 7 following thinning but these are not operational. No response has been detected to application of phosphorus but ex-pasture sites with a history of phosphorus fertilisation consistently perform well. This feature of enhanced growth on ex-pasture sites is also commonly observed in *P. radiata* crops.

Stand Stocking

Two spacings are used, 1450/ha for normal areas and 1100/ha for areas of exceptionally good site preparation.

Establishment Costs

Eucalypt plantations cost more to establish than *P. radiata.* Under favourable conditions these extra costs are:

- the extra cost of plants. Eucalypts cost approximately twice as much as *P. radiata* seedlings;
- the cost of fertiliser and its application in the establishment year;
- the cost of fertiliser and its application in the year following establishment.

VOLUME YIELDS AND DRY MATTER PRODUCTION

The recent State policy for the planting of eucalypts was adopted without any reference to supporting data on volume or dry matter production. The assumption was made that volume production at age 30 would be 650 m^3/ha. Although eucalypts have been recognised in New Zealand as rapid growers, the paucity of data to support this contention is surprising. There are two well-known data points relating to the Ash group. One is from a stand of

TABLE 3: VOLUME PRODUCTION OF EUCALYPTUS SPECIES
Younger Plantations: Age 9

Species	No. and Location	Age	Mean d(cm)	Mean h(m)	Stems/ha	Standing Volume m^3/ha	Basal Area m^2/ha
P. radiata	Growth model 300 m	9	16.5	12.6	1500	168	35.1
	Growth model 600 m	9	16	10.0	750	58	20.8
E. regnans	EA 63C 62806	9	13.9	13.6	1805	171	27.3
	EA 70C 427401	9	13.2	13.1	1220	106.2	16.2
	EA 70C 723902	9	23.1	22.8	1070	368.3	42.4
	BB 67 722302	8.6	15.9	14.2	830	111.7	11.8
	BB 67 722302	8.6	18.0	18.2	1220	183.7	25.6
	EA 73C 722533	8.9	16.6	20.6	1690	310.5	36.7
	EU 73C 618204	8.9	19.5	26.4	1550	455.6	46.3
	EW 73C 618204	9.0	22.4	27.6	730	271	28.9
E. fastigata	EA 72C 618603	9.0	21.7	21.3	1775	449.0	65.9
	EH 72C 618603	9.0	22.2	18.2	1025	228.2	39.6
	EC 72C 628103	9.0	21.9	17.0	1350	280.6	50.8
	ED 72C 628103	9.0	20.1	16.4	1700	308.7	53.8
	EB 72C 628703	9.0	19.3	17.3	1675	306.8	49.0
	EI 72C 628703	9.0	20.8	19.3	1500	377	51.2
E. delegatensis	ED 72C 186603	9.0	15.6	13.7	1575	191.4	30.2
	EH 72C 628103	9.0	13.3	13.3	1425	126.6	19.9
	EK 72C 628703	9.0	15.4	13.3	2000	218.5	37.2
	EH 73C 618003	9.0	12.6	13.0	1880	145.3	23.4
	Pomahaka	10.1	12.5	11.8	771	58.4	9.4
	Pomahaka	10.0	10.2	9.1	889	36.1	7.24
	Mangatu	10.0	22.8	17.7	543	169.6	22.3
E. nitens	EE 72C 618603	9.0	18.3	18.0	1550	304.2	40.8
	EB 72C 628103	9.0	18.0	18.1	1600	293.5	40.6
	ED 72C 628703	9.0	18.4	17.5	1725	326.6	45.6
E. saligna	Waipoua	9.0	24.7	23.4	400	175.3	19.1

E. regnans at Waitati (near Dunedin) and the other is the mixed stand of *E. fastigata*/*P. radiata* at Kaingaroa. There are few other historical data relating to plantation formations. These two older plots, together with other older data, are presented in Table 2.

For younger plantations there are more data. Most comes from N.Z. Forest Products Ltd and the greater proportion is under ten years old. It comes from plantations, or trials, on the central pumice plateau between 300 and 600 m above mean sea level. In addition, there are some data from State forests. The younger measurements from the State and N.Z. Forest Products Ltd are presented in Table 3 and, to facilitate comparisons between and within species, a common age, 9, is shown. Also, wherever possible, only measurements from well-stocked unthinned stands are included. Unfortunately, as far as *E. saligna* is concerned, no measurements for fully stocked stands, at this age, exist. As a reference point in Table 3, the range of performance of *P. radiata* on the central pumice plateau is shown.

The N.Z. Forest Products Ltd measurements are identified by the sample plot number and the State measurements by the name of the forest. Only one volume table is used for the N.Z. Forest Products Ltd data, one derived from measurements of *E. regnans* trees. For *E. delegatensis* and *E. nitens*, errors in using this table are not considered important. For *E. fastigata* the figures have been adjusted to take account of the thicker bark in this species. Comments on individual species relating to Tables 2 and 3 follow.

E. regnans

Many of the data presented are from establishment trials which were converted to sample plots. As trials they received more care than routine planting. However, there are sufficient sample points in the routine plantations to be confident that eucalypt plantations will exceed the volume production of *P. radiata*. A production of 300 m^3/ha by age 10 appears feasible. There are insufficient data to determine when C.A.I. and M.A.I. peak. It is, however, clear that both are delayed by poor establishment techniques.

The N.Z. Forest Products Ltd plots for *E. regnans* include examples showing the importance of various establishment factors. Prior to 1972, operational fertilisation involved a mixture of blood and bone and superphosphate. This mixture gave an equivalent of 2.6 g of nitrogen/tree. By 1973 the fertiliser application had changed to urea, giving an equivalent of 26 g of nitrogen/tree.

Plot EA 70C 427401 is in routine planting of the 1970 plantation. This site, containing bracken, was burned, with no further site preparation. The nursery stock was indifferent and the fertiliser at establishment was a mixture of blood and bone and superphosphate. In contrast, plot EU 73C 618204, at a comparable altitude, had good site preparation, better nursery stock and a higher rate of nitrogen at establishment. The respective volumes at age 9 are estimated as 106 and 455 m^3/ha.

Plot EA 70C 723902, also in the 1970 plantation of *E. regnans*, was established on a site which previously carried a lucerne crop. The survival was indifferent (1070 stems/ha) but the high fertility has given an outstanding result (368 m^3/ha at age 9).

The effect of altitude on production is shown by the two plots EU 73C 618204 and EW 73C 618204, where soils and treatments were similar. The former, at 300 m altitude, had a production at age 9 of 455 m^3/ha and the latter, at 600 m, had a production of 310 m^3/ha at the same age.

E. fastigata

The results for this species can only be described as highly satisfactory. In addition to the outstanding total production of the historical plot at Kaingaroa, the younger plots at N.Z. Forest Products Ltd have all performed well. Volumes may still be subject to slight adjustment when a volume table, for the species, is produced. The other unexpected trait in the plantings to date has been the relatively good form. In addition to its high volume production, it is almost immune to *Paropsis* attack and shows few foliar fungal infections.

E. delegatensis

The very few volume figures available are not impressive. Although this species is still recommended as a special-purpose species, no outstanding plantations are known to the writer.

E. nitens

The figures, at age 9, do not adequately reflect the performance of the species. These measurement plots are isolated small areas of a *Paropsis*-prone species and infestation took some time to develop. Before the *Paropsis* infestation developed, the *E. nitens* plots were noted for their rapid occupancy of the site and rapid height and diameter growth. Today, although the volume growth appears satisfactory, the crowns are severely affected by *Paropsis* attack and an understorey is reappearing. In other larger areas of *E. nitens* where infestation has occurred earlier, and developed more rapidly, growth effects have been more severe. In one line-by-line mixture with *E. regnans, E. nitens* clearly out-performed *E. regnans* for three years. It was then that *Paropsis* attack began to increase so that by the end of the fifth year the *E. nitens* was moribund, showing mortality, and the *E. regnans* had become dominant.

E. saligna

As with *E. delegatensis,* data for fully stocked stands are scarce, yet it still appears as a strongly recommended species. Although data are lacking, the performance of woodlots and shelterbelts is visually very promising.

As far as the Ash group and *E. saligna* are concerned, what data exist do suggest that the target volume of 650 m^3/ha, at age 30, will be attainable from well-established plantations.

D. Frederick and H. Madgwick (pers. comm.) completed a study involving *Eucalyptus* biomass production in 1981. The study compared the dry matter production at age 8 of three species, *Eucalyptus regnans, Acacia dealbata* and *Pinus radiata* on adjacent sites. The summarised results are in Table 4. All three species have high dry matter production and the *A. dealbata* figure is exceptional, particularly as it comes from a stand established directly from seed.

Density studies have been carried out on several eucalypt species by Harris and Young (1980). They clearly show an increase in density moving upward in the stem for wood of the same cambial age as well as an increase in density moving outward from the pith. The Ash group generally are low density hardwoods (0.390 to 0.500 g/cc) and *E. saligna* a medium density wood (0.420 to 0.560 g/cc).

TABLE 4: STAND CHARACTERISTICS AND DRY MATTER PRODUCTION OF 8-YEAR-OLD *ACACIA DEALBATA, EUCALYPTUS REGANS* AND *PINUS RADIATA*

	A. dealbata	*E. regnans*	*P. radiata*
Stocking (stems/ha)	2875	2150	1775
Basal area (m^2/ha)	47.9	39.1	32.9
Av. diameter (cm)	13.4	14.5	14.7
Av. height (m)	15.6	17.6	12.3
Stem mass dry matter (tonnes/ha)	137	121.8	61
Total, above ground dry matter (tonnes/ha)	191.3	171.2	104.2

THE MANAGEMENT OR EUCALYPTUS CROPS

There has been little documented detail of the management of *Eucalyptus* crops. Some of the plantations in State forests are mixtures, rows of eucalypts, approximately 10 m apart, having been interplanted with pines. In these mixtures the objective is to remove the rows of pines to leave a final crop of eucalypts. The larger area of pure plantations controlled by N.Z. Forest Products Ltd is for pulpwood and minimum management is proposed. The Forest Research Institute is studying spatial relationships in a Nelder design, but at 3 years old it is too early to comment on this. Auckland Conservancy has one formal thinning trial with *E. saligna* and N.Z. Forest Products Ltd has a thinning trial with *E. regnans*. Both trials have four treatments. It is perhaps noteworthy that the most conservative treatment in the Auckland Conservancy trial just overlaps with the most severe treatment in the N.Z. Forest Products Ltd trial (Table 5). All treatments are severe by commonly accepted standards and aim to produce large piece size in the shortest time.

The objectives of the Auckland Conservancy trial were to study crop development at what are regarded by the Forest Service as normal (200 stems/ha) and extreme (100 stems/ha) final stockings. The three-year age difference in achieving the final stocking was to give the opportunity to examine lower costs against later, more certain, selection. All treatments are severe but are consistent with the commonly accepted goal of achieving diameter on crop trees in the shortest time.

TABLE 5: THINNING TRIAL TREATMENTS

Owner	*Species*	*Treatments*	*Age*		*Stems/ha*
State	*E. saligna*	1.	5	thinned to	760
	2135 stems/ha		7	,,	200
	at planting	2.	5	,,	760
			7	,,	100
		3.	5	,,	760
			7	,,	400
			10	,,	100
		4.	5	,,	760
			7	,,	400
			10	,,	200
NZFP	*E. regnans*	A.	Unthinned		
	1500 stems/ha	B.	4	thinned to	800
	at planting	C.	4	,,	400
		D.	9	,,	400

The considerations in the N.Z. Forest Products Limited trial were:

(a) *Unthinned:* Least cost to grower. High cost to harvester. Good material for pulp production, probably the best volume yield up to 20 years of age.

(b) *Thinned 800 st/ha age 4:* Higher cost to grower. Lesser cost to harvester. Little or no volume loss. More flexible clear-felling age. Opportunity for later thinning and a final timber crop.

(c) *Thinned 400 st/ha age 4:* Similar objectives to (b), but a substantial volume loss and unacceptable branch development expected.

(d) *Thinned to 400 st/ha age 7:* Earliest opportunity for a production thinning which need not damage residuals. (Australian workers stress the susceptibility of the Ash group to rot resulting from mechanical damage.) Thinning would not lead to instability and would give the same opportunities as treatments (b) and (c).

The summary measurements for the two trials are given in Table 6.

Comments made by Williamson (1981) on the Auckland Conservancy trial included:

— There was a loss of height growth with the most severe thinning treatment.

— There was a difference in diameter between the plots thinned to 100 stems/ha at age 7 and those thinned to the same stocking at age 10, the respective mean diameters being 34.3 and 29.3 cm.

— There was no difference detected between those plots thinned to 200 stems/ha at age 7 and those thinned to 200 stems/ha at age 10.

— The enhanced diameter achieved in the plots thinned to 100 stems/ha had been at the expense of branch control and at the risk of suffering volume loss through breakage. (*E. saligna* is regarded as brittle and susceptible to wind damage.)

The present interpretations of the N.Z. Forest Products Ltd trial are:

— There is volume loss with the most severe treatment (thinning to 400 stems/ha at age 4). Other thinning treatments show little or no volume loss.

TABLE 6: RESULTS OF TWO THINNING TRIALS

Treatment	*Age (yr)*	*Mean Diameter (cm)*	*Mean Height (m)*	*Stems/ ha*	*Volume (m^3/ha)*	*Basal Area (m^2/ha)*	*Total V Production (m^3/ha)*	*Diam. Crop Trees Top 250*	*Diam. Crop Trees Top 100*
(1) N.Z. Forest Products Trial with *E. regnans* (Mean of four replications of each treatment)									
Unthinned	8.9	19.5	24.7	1341	388.9	40.2	404	26.2	28.2
Thinned age 4 to 400	8.9	27.0	26.3	428	279	29.3	330	31.8	33.7
Thinned age 4 to 800	8.9	24.1	25.8	801	346.9	36.4	382.8	28.1	30.2
Thinned age 7 to 400	8.9	25.9	26.1	403	202.4	21.4	396.7	27.3	28.9
(2) Auckland Conservancy Trial with *E. saligna* (Mean of two replications of each treatment)* All plots thinned to 760 st/ha age 5, then:									
	8.6	26.1	23.9	200	84.6	10.8	N.R.	—	—
Thinned age 7 to 200/ha	9.8	29.3	25.6	200	113.6	13.7	N.R.	—	32
	8.6	30.6	23.1	100	54.6	7.4	N.R.	—	—
Thinned age 7 to 100/ha	9.8	34.3	24.9	100	71.1	8.9	N.R.	—	34.3
Thinned age 7 to 400	9.8	27.3	26.5	400	205.3	23.9	N.R.	—	—
Thinned age 10 to 100	9.8	29.3	26.5	100	71.8	6.8	N.R.	—	29.3
Thinned age 7 to 400	9.8	26.7	27.2	400	200.5	22.9	N.R.	—	—
Thinned age 10 to 200	9.8	28.5	27.2	200	111.9	12.8	N.R.	—	31.2

* Refer Table 5.

— There is increased branch size with the most severe thinning (400 stems/ha at age 4).
— Delaying thinning to age 7 does give a pulpwood yield at high cost. Such a thinning need not damage residual trees.
— Diameter effects are apparent both in the mean tree diameter and the diameter of the crop trees — *i.e.*, top 250 or 100/ha.
— Mortality has started in the unthinned plots.
— The crop trees, top 250 stems/ha, have by age 9 developed substantial differences at the treatment extremes. In the unthinned plots the mean diameter is 28.2 cm, while in those thinned to 400 stems/ha at age 4, the mean diameter is 33.7 cm, a difference of 5.5 cm.

Both trials are consistent in showing positive benefits, in diameter growth for early stocking manipulation. A crop diameter of 700 mm at age 40 appears as a realistic objective for both *E. saligna* and *E. regnans*. However, as previously emphasised, these growth rates can only be achieved if full attention has been given in the establishment phase. It is also inevitable in the extreme regimes that branch control, through self-pruning, will be ineffective. The alternative of green pruning has given cause for concern as the wounds produced have allowed entry of insects and soft rot fungi, the effects of which have still to be quantified. A further result of the free-grown regimes is the production of a considerable volume (*ca* 35-40% of total volume) of low-grade industrial wood or fuel wood.

The management of eucalypts in mixtures with pine has waned. The original concept was that the eucalypts would in time dominate the pines, which would be removed and sold as thinnings. Until that event the pine would control branch size and assist in the self-pruning mechanism. In practice, the mixture has hardly ever worked satisfactorily. On occasions the eucalypt has so dominated the pine that the pine has failed to fulfil its purpose. On other occasions, delaying of planting of the eucalypts has resulted in their suppression by vigorous weeds.

Of some concern in the management of *E. regnans* crops is the frequency of double- and multi-leadered trees. Examination of thirty sample plots involving 2947 trees reveals an overall incidence of 26% of double- or multi-leaders occurring below the normal breast height measurement point. The range in frequency is considerable, from less than 1% to 56%. The reasons for this failure for apical dominance to be asserted are not completely understood.

There is a strong suggestion that the less satisfactory crops in respect of early growth show the lowest incidence of this defect. If the cause is uncertain, management is required to remove the effects. An early form pruning — *i.e.*, reducing trees to a single leader at age one — has been used and, more latterly, it is proposed to waste thin crops at age three to approximately 800 stems/ha. This would remove the multi-leaders and give advantages for future operation — *e.g.*, larger piece size. Both of these management options create opportunities for the entry of soft rot fungi.

CONCLUSIONS

Eucalypts in New Zealand are viewed as a minor component of total wood supply. They will fill special niches in sawnwood, roundwood and pulpwood industries. They will also continue to be used as fuel wood and for temporary buildings in rural areas. There should be no difficulty in acquiring suitable land for this scale of operation.

The industrial needs can be well satisfied by a few species. All of these species are obvious high volume producers, but present knowledge is insufficient to define yield potential and management options. The present indication is that the production of suitable sawlog sizes can be achieved in 35 to 40 years. The probable cost of such management is a large proportion, *ca.* 40%, of the total volume only being suitable for fuel or pulpwood.

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REFERENCES

Anon., 1979. Workshop on Special Purpose Species. N.Z. Forest Service.

Anon., 1981. State Policy on Exotic Special Purpose Species. N.Z. Forest Service.

Dugdale, J. A., 1963. *Paropsis charybdis* in New Zealand. Communication to Chief of Research. Files of Forest Research Institute, Rotorua.

Harris, J. M.; Young, C. D., 1980. Wood Properties of Some New Zealand Grown Eucalypts. Paper to A.N.Z.I.F. Conference, Rotorua.

Kininmonth, I. A.; Revell, D. H.; Williams, D., 1974. New Zealand grown eucalypts for sawn timber and veneer, *N.Z. Jl For., 19*(2): 246.

Kromhout, C. P.; Bosman, D. L., 1982. The influence of short rotation forestry on wood production for sawn wood and veneer. *S.A. Jl For.*, March: p. 11.

Poole, B. R.; Fry, G., 1980. The Establishment of Eucalypts on the Central North Island Plateau. Paper to A.N.Z.I.F. Conference, Rotorua.

Rook, D. A.; Wilcox, M. D.; Holden, D. G.; Warrington, J., 1980. Provenance variation in frost tolerance of *Eucalyptus regnans* (F. Muell). *Aust. For. Res., 10* (3): 21.

Weston, G. C., 1957. Exotic forest trees in New Zealand. *N.Z. For. Serv. Bull. No. 13.*

Wilcox, M. D., 1980. Genetic improvement of eucalypts in New Zealand. *N.Z. Jl For. Sci., 10:* 343-59.

Wilcox, M. D.; Faulds, T.; Vincent, T. G.; Poole, B. R., 1980. Genetic variation in frost tolerance among open pollinated families of *Eucalyptus regnans* F. Muell. *Aust. For Res., 10* (2).

Wilcox, M. D.; Rook, D. A.; Holden, D. G., 1980. Provenance variation in frost resistance of *Eucalyptus fastigata* Deane and Maid. I.U.F.R.O. Symposium and Workshop, "Genetic Improvement and Productivity of Fast Growing Species."

Williamson, M. J., 1981. Growth of *Eucalyptus saligna* in a thinning trial at Waipoua. *N.Z. Jl For., 26* (2): 243.