An Assessment of Growth and Form for Pruning to Six Metres in *Eucalyptus nitens* Plantations

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Abstract

Seven plantations of Eucalyptus nitens *which had been managed for high growth rates were investigated for their suitability for pruning to 6 m and conversion to sawlog plantations. All the young plantations (three) had been established at 1430 stems/ha and one, at Creekton Road, had received two levels of nitrogen fertiliser during the first three years of growth. Four plantations established at 2500 stems/ha were assessed at age 10 years. It was shown that at least 400 trees/ha of acceptable form should be available for pruning to 6 m and that green pruning to a first lift of 3 m could be done at age three years. Nitrogen fertiliser increased the incidence of poor form but did not prevent conversion of these plantations to a clearwood regime. Establishment of* E. nitens *at high altitude also increased the incidence of poor form and considerably reduced the proportion of prunable trees. Application of nitrogen and phosphorus fertilisers may be necessary at some sites to ensure that minimum heights for first-lift pruning at age three years are achieved.*

Introduction

Native forest has supplied most eucalypt sawn timber and veneer produced in Tasmania. However, its capacity to maintain the current levels of production is not anticipated to last more than a few decades (FFIC 1990). This situation was brought more sharply into focus recently by the removal of large parts of the Southern and Lemonthyme forests from the production forest zone (Helsham *et al.* 1988).

Two alternatives present themselves to ensure a potential supply of sawlogs and veneer in the future. The first involves a transition from oldgrowth forest to regeneration forest, with thinning at some point after regeneration in some areas to advance the rotation and select the final crop. The second is to use plantations.

One option for establishing plantations for sawlogs is to plant at high densities and thin and prune during the rotation. Experiments with *Eucalyptus grandis* point to the desirability of early pruning in fast-growing eucalypts to increase the availability of clearwood timber later in the rotation (Lückoff 1967; Bredenkamp *et al.* 1980). Green pruning can be done during the vigorous phase of growth, thus ensuring rapid occlusion of stubs. In addition, the knotty core is kept as small as possible and the incidence of loose knots is reduced (Shepherd 1986). Timely pruning should result in rates of recovery such that there are no long-term effects on subsequent height and diameter growth. Results with *E. grandis* suggest there are no such effects with up to 50% removal of the live crown (Bredenkamp *et al.* 1980).

The selection of the appropriate numbers of trees of the correct form for pruning is the initial task for plantation managers who wish to establish a clearwood. This study investigates the growth and form of *E. nitens* in several plantations established at high stockings for pulpwood. The objective for these plantations is their conversion to a final stocking for sawn timber of 250 stems/ha, with each tree having a pruned length of 6 m; that is, sufficient to produce two 2.7 m veneer logs, in two 3 m lifts. *Eucalyptus nitens* is the most widely planted eucalypt in Tasmania, has the highest growth rates over a range of sites compared to other species (Turnbull *et al.* 1993) and is presently considered the most suitable for conversion to sawlog plantations. Over the last three years (1991/93), over 3000 ha of *E. nitens* have been established specifically for sawlog production through the Intensive Forest Management Program of the Forests and Forest Industry Council.

Methods

The plantations

Seven plantations were considered and all were located within the Esperance Municipality (Table 1). Three were measured at age three or four years, the others at age 10 years. In each case, the area was planted to the Upper Toorongo provenance of *E. nitens.*

Three/four-year-old plantations. The Creekton plantation was established in 1989 on a cleared, ex-native forest site (*Raminea* 4820: 929005, Tasmania 1:25000 Series Map). The others were established in 1990. Gould's plantation (*Dover* 5020: 002065) was primarily on improved or partially improved pasture and Reid's (*Geeveston* 4822: 905228) was primarily on cleared land which had reverted to scrub. Both blocks carried some residual forest which was harvested before site preparation.

The planting lines were 3.5 m apart and prepared using a bulldozer with heavy offset discs and a winged-ripper cultivating to a nominal depth of 0.7 m. Seedlings (1430/ha) were planted on the riplines, with 2 m between plants within rows. Pre- and post-planting weed control was used at all sites to minimise competition from woody weeds (Creekton), grass (Gould's) and scrub vegetation, primarily bracken (Reid's).

Phosphorus (P) was broadcast aerially and once only pre-planting as 600 kg/ha triple superphosphate or 120 kg/ha P. Nitrogen (N) was applied post-planting as single applications of urea equivalent to 100 kg/ha N. This was repeated once only at Gould's and twice at Reid's to give total applications of 200 and 300 kg/ha respectively during the first three years of growth. The area at Creekton had been divided into four 20-hectare blocks for clearing (see Turnbull *et al.* 1992). Each was subdivided into 10-hectare blocks and one allocated to each level of the N treatments. Half the plots received one application only at the start of the second year of growth; the other half received three applications as at Reid's.

Ten-year-old plantations. The four plantations were located at 60, 240, 440 and 650 m a.s.l. in the Esperance Valley (*Raminea* 4820: 935054 and 894074, and *Waterloo* 4821: 859122 and 863186, respectively). All were established in 1983 on cleared native forest sites, with plants at 2 m x 2 m spacing. Total weed control was maintained to age four years and fertiliser equivalent to 410:180:150 kg/ha NPK was applied to each plantation over the same period (see Turnbull *et al.* 1993).

Growth

For the young plantations, height and diameter over bark at breast height (DBHob) were measured in a series of 30-tree plots. The measurements were made at age three (all plantations) and four years (Creekton only). Ten plots were located at Gould's and Reid's. Each of the N treatments at Creekton was represented by 20 growth plots, five per 10-hectare block. In the 10-year-old plantations, a single measurement of both variables was made in a 60-tree plot at each site at age 10 years.

Table 1. Characteristics of the plantation sites and the seedlots of Eucalyptus nitens *(Upper Toorongo provenance) used for planting.*

Site	Site index*	Soil type	CSIRO seedlot	Source of seedlot
Creekton	37	Yellow podzolic on dolerite	unknown	unknown
Gould's	-	Podzolic on sandstone	S16905/16915	Erica/Erica Township
Reid's	-	Podzolic on sandstone and dolerite	S16905/16915	Erica/Erica Township
Esperance/60m	38	Yellow podzolic on mudstone	S13611	Penny Saddle
Esperance/240m	50	Krasnozem on dolerite	S13611	Penny Saddle
Esperance/440m	50	Kraznozem on dolerite	S13611	Penny Saddle
Esperance/650m	55	Lithosol on dolerite	S13611	Penny Saddle

* based on Lawrence (1981)

Form for pruning

The following criteria were used to define trees suitable for pruning.

1. Single stemmed and free of secondary leaders. Where double leaders are present above 6 m, the tree may be accepted.
2. Straight stem with no stem deformations from the vertical of more than 5 cm.
3. Stems free of wounds or splits below 6 m.
4. Branches less than 3 cm in diameter at their junction with the stem and not making an acute angle with the stem.
5. Butt sweep limited to the bottom 0.3 m of the stem.

Analysis of data

All variables except height (m) and diameter (cm) were expressed as the proportion of surviving trees in each plantation or treatment. Prunable trees (PR) are those which meet the above criteria. Non-prunable trees (PF) are those with problems of form (i.e. stem deformation) other than competing leaders. Competing leaders were expressed in terms of double leaders (DL), multiple leaders (more than two, ML) or competing limbs (CL, usually a competing leader which had become suppressed). Variance of mean height, diameter, PR, PF, DL, ML and CL were analysed for each age at Creekton. Percentages were first transformed as the arcsine of their square root. Trees which were less than 6 m (TS) but otherwise of good form were not included in the analysis.

Results

Three/four-year-old plantations

Mean height and diameter at age three years varied between 5.7 and 7.3 m, and 6.1 and 8.3 cm respectively across the plantations (Table 2). At the Creekton plantation, differences in both years were larger for diameter than for height between the two fertiliser treatments. These differences were significant ($P < 0.05$) for diameter but not for height, also in both years.

At all plantations, at least one-third of all trees were of suitable form for pruning at age three years (PR in Table 2). At Creekton, the blocks which had received 300 kg N/ha had 44% of trees of prunable form compared to 33% in the blocks which had received 100 kg N/ha. There was little difference between the treatments, 54% and 51% respectively, at age four years. However, the incidence of trees with double leaders and stem deformations was higher in the blocks receiving the higher levels of N. These differences were significant for double leaders ($P < 0.05$) at age four years. The incidence of multiple leaders was low at all sites.

The numbers of double leaders decreased whereas those of competing limbs increased

Table 2. Mean height, diameter and form for pruning at age three, four and 10 years. Abbreviations are percentages of prunable trees (PR), non-prunable trees with stem deformations (PF) or competing leaders (double leaders, DL, multiple leaders, ML, or competing limbs, CL), and trees < 6 m but otherwise of good form (TS).

Site	Age (yr)	Height (m)	Diameter (cm)	Form (%)					
				PR	PF	DL	ML	CL	TS
Gould's	3	7.3	8.3	41	16	9	0	8	26
Reid's	3	5.7	6.1	36	9	7	0	9	39
Creekton/100 kg/ha N	3	5.8	6.1	33	6	15	2	2	42
	4	7.9	8.4	54	9	12	2	5	18
Creekton/300 kg/ha N	3	7.1	7.8	44	11	24	2	1	18
	4	9.4	10.3	51	16	19	3	7	4
Esperance/60 m	10	14.3	14.1	42	24	24	0	10	0
Esperance/240 m	10	14.3	13.7	57	17	11	0	15	0
Esperance/440 m	10	11.5	13.5	53	29	14	2	2	0
Esperance/650 m	10	13.4	15.7	26	34	19	0	21	0

within each treatment at Creekton between ages three and four years (Table 2).

Ten-year-old plantations

The mean heights were larger than 11.5 m and mean diameters larger than 13.5 cm across sites (Table 2). Prunable form was greater than 40% at the three lower sites but only 26% at the 650 m site. At the 650 m site, the incidence of trees with stem deformations and competing limbs was higher than at the other sites. The incidence of multiple leaders was again low at all sites; double leaders varied between 11% and 24%.

Prunable stems at age three years

To assess the suitability of the three-year-old plantations for conversion to clearwoods, the growth and total number of prunable stems only were considered. There were at least 400 prunable stems/ha in the four plantations investigated (Table 3). The mean heights of these trees were ≥ 7.0 m and the mean diameters varied between 8.1 and 9.9 cm.

Discussion

Plantation managers are presently faced with the decision as to which and how many trees they can choose for pruning at an early age to ensure the successful conversion of eucalypt plantations to clearwoods which provide the required number of sawlogs and veneer logs at the end of the rotation. An assessment of the growth and form of young stands of *E. nitens* established at 1430 stems/ha for pulpwood and managed for high growth rates has shown that at least 400 stems/ha should be available for selection for pruning to 6 m.

Experiments with *E. grandis* in South Africa point to removal of up to 50% of the length of the living crown as having no significant effect on height and diameter growth in the long term (Bredenkamp *et al.* 1980). Crown lengths of the prunable trees in the three-year-old plantations (Table 3) were approximately equal to their height as canopy closure had not yet occurred. A first pruning lift to 3 m in these stands at age three years would therefore result in the removal, on average, of between 35% (Gould's) and 43% (Reid's) of the length of crown. The 6 m criterion for selection for pruning would, of course, result in the removal of 50% of crown length from the shortest prunable trees.

Pruning at age three years also coincides with the period of maximum diameter increment in stands of *E. nitens* growing at similar rates to those in Table 3 (Turnbull *et al.* 1993). Added to the potential advantage of green pruning (i.e. minimising the knotty core and

Table 3. The number of prunable stems/ha and their mean height and diameter at age three years in the Gould's, Reid's and Creekton plantations.

Site	Height (m)	Diameter (cm)	Planting density (stems/ha)	Survival (%)	Prunable stems (stems/ha)
Gould's	8.5	9.9	1430	91	530
Reid's	7.0	7.8	1430	87	450
Creekton/100 kg/ha N	7.3	8.1	1430	88	420
Creekton/300 kg/ha N	7.8	8.8	1430	86	550

reducing the incidence of loose knots (Shepherd 1986)) would be rapid occlusion of stubs at this age. In both fertiliser treatments at Creekton, canopy closure had occurred by age four years, with substantial lifting of the canopy and death of branches. Pruning to 3 m at this stage of growth is anticipated to be less satisfactory than before canopy closure.

There was a significant response in diameter growth at ages three and four years to the application of 300 compared to 100 kg N/ha during the first three years of growth (Table 2). At Gould's block, there was no corresponding response at age two years to the application of up to 480 kg N/ha during the first two years of growth (Turnbull *et al.* 1994). Height growth at Creekton was also faster at the higher levels of N application (Table 2) but these differences were only significant at the 10% level ($P < 0.1$). The greater effect of fertiliser on diameter than height growth has been noted previously in *Pinus radiata* (Will and Hodgkiss 1977). Applications of N and P fertilisers at sites similar to Creekton where variables such as available water and temperature are not limiting growth should ensure that minimum heights for pruning to 3 m are achieved by age three years.

The application of fertiliser to trees or their planting on soils of high fertility may lead to significant changes in criteria used to describe form (Table 2; Hopmans and Flinn 1991; Turnbull *et al.* 1994). At Creekton, the only significant response to the higher levels of N was an increased incidence of double leaders: some of these double leaders had become competing limbs at age four years. Stem deformations (PF) were also higher at 300 compared to 100 kg N/ha at Creekton and high levels of fertility and fertiliser at Gould's, possibly through induced copper deficiency, may have contributed to the high numbers of PF trees at age three years (Turnbull *et al.* 1994). The severity of these changes was not sufficient to prejudice the first pruning lift in these young plantations.

The planting of *E. nitens* at 650 m resulted in a much higher percentage of trees with poor form, and care should be taken that stockings are such that sufficient trees are available for conversion to clearwoods on sites at high altitudes. Otherwise, the plantings at higher densities in the Esperance Valley (2500 stems/ha compared to 1430 stems/ha in the younger plantations) resulted in a similar range of prunable trees.

The viability of sawlog plantations is dependent on minimising costs of silviculture as well as achieving high growth rates (Gerrand *et al.* 1993). It should be noted that costs of pruning in two lifts to 6 m are in the order of \$600–\$700/ha (A. Gerrand, pers. comm.) and additional costs will be incurred in thinning the stand to establish the final crop. Stand densities should therefore be adjusted to allow sufficient choice for selecting trees for pruning while minimising costs of thinning. Based on the current work, lower stand densities than used here (> 1000 stems/ha) should still be adequate for conversion of *E. nitens* to a clearwood regime of 250 stems/ha.

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