

Management of *Eucalyptus grandis* coppice regeneration of seedling parent stock in Zululand, South Africa

Keith M. Little and Ben du Toit

Institute for Commercial Forestry Research, PO Box 100281, Scottsville, Pietermaritzburg 3209, South Africa.
Email: keith@icfr.unp.ac.za

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Summary

In 1992, a trial was initiated in Zululand on *Eucalyptus grandis* to investigate the effects of an early thinning or reduction (at a dominant height of 1.5 m as opposed to the standard operational height of 4 m) of first coppice, of chemical control of secondary coppice regrowth (with glyphosate or paraquat), and of fertiliser or weed control on final yield. No significant treatment differences were detected for any of the tree growth parameters measured (height, diameter at breast height, basal area, volume and stocking) when the trees were felled at 8 y. The non-significant results obtained nonetheless indicate the possibility for alternative coppice management practices. The silvicultural practices of weed control and fertiliser application were shown to be of no benefit in stands managed for coppice. First coppice can be reduced at an early stage without a loss in final yield. Secondary coppice regrowth can be sprayed with glyphosate at 0.6% as an alternative to manual removal using hand-held implements.

Keywords: coppice; thinning; herbicides; glyphosate; fertilisers; shoot growth; yields; *Eucalyptus grandis*

Introduction

Plantation forestry carried out in the Zululand region is of great importance as it contributes 18% of the total eucalypts grown for hardwood pulpwood in South Africa (Directorate Forest Policy 2000). One of the notable attributes of *Eucalyptus* species is their ability to survive and produce new growth following adverse environmental conditions (Florence 1996). This is largely a function of the bud systems of the genus. Although four types of buds are recognised in eucalypts, coppice regrowth in *Eucalyptus grandis* following felling is confined to development from epicormic buds, which are situated in the live bark, or cambium, at the base of the tree (Penfold and Willis 1961). This survival mechanism is exploited in commercial plantations for re-establishment following felling. For *E. grandis* the coppice shoots can be selectively thinned over time and managed as a coppice stand for the production of pulpwood (MacLennan and Schönau 1991; Little 2000).

Previous research on coppice management in South Africa focused primarily on the effects of the number of stems remaining on the

stump, and on the effects of frequency and timing of coppice reduction (thinning of the shoots) on timber volume and properties. This produced recommendations which are still used today (Schönau 1980, 1990; Stubbings and Schönau 1980; Bredekamp 1991).

In terms of the timing of reduction operations, these recommendations state that coppice should be reduced in two operations: first to two or three stems per stump when the dominant shoot height is 4 m, and later to the original stocking when the dominant shoot height is 8 m. However, an experiment on the reduction of coppice of *E. grandis* in Zululand indicated that first coppice could be reduced to two shoots per stump when the shoots were under 3 m in height (Bredekamp 1991). That study also questioned the value of fertiliser application and weed control in managed coppice stands, and the potential to apply herbicide instead of manually removing secondary coppice regrowth using axes.

The present trial has been undertaken to investigate the effects of early reduction of first coppice, chemical control of secondary coppice regrowth, fertiliser application and weed control on final yield.

Materials and methods

The trial was located in Southern Area, Zululand, on a SAPPI plantation at 28°40'S and 32°03'E. The climate is sub-tropical, with mean annual precipitation of 1089 mm and temperature of 21.6°C. There is good rainfall distribution, 35–40% occurring in winter, and this combined with mild winters allows trees to grow throughout the year (Schulze 1997). The trial was situated at an altitude of 50 m on a deep Fernwood 1210 soil (using the taxonomic system for South Africa, Soil Classification Working Group 1991). The parent material of the soil (as for most of the Zululand region) is aeolian in origin, and as such contains little organic carbon (<0.5%) or clay (<6%). The growth rate of *E. grandis* for this region of Zululand is considered to be good, with mean annual increments of up to 55 m³ ha⁻¹ being recorded when optimum planting densities are coupled with fertiliser application and weeding during establishment (Coetzee *et al.* 1996). The site had been planted to *E. grandis* for pulpwood and

Table 1. Coppice management treatments implemented on *Eucalyptus grandis* in Zululand, South Africa

Treat. No.	Height of coppice when reduced ¹	Silvicultural input + method of secondary coppice regrowth control
1 (control)	4 m + 8 m	Manual removal of secondary coppice regrowth when 0.75 m high
2	1.5 m + 8 m	Manual removal of secondary coppice regrowth when 0.75 m high
3	4 m + 8 m	Secondary coppice regrowth sprayed with glyphosate @ 0.6% when 0.75 m high
4	4 m + 8 m	Secondary coppice regrowth sprayed with paraquat @ 0.4 % when 0.75 m high
5	4 m + 8 m	Broadcast application of 321 kg ha ⁻¹ of fertiliser as 4:1:1 (N:P:K) This equates to 94 kg N ha ⁻¹ , 23 kg P ha ⁻¹ and 23 kg K ha ⁻¹ Manual removal of secondary coppice regrowth when 0.75 m high
6	4 m + 8 m	Chemical control of all vegetation with glyphosate @ 4 L ha ⁻¹ Manual removal of secondary coppice regrowth when 0.75 m high

¹ The coppice was reduced in a stepwise manner: the first reduction (when 1.5 or 4 m high) was to two stems per stump and the second (when 8 m high) to the original stocking.

Table 2. The initiation and timing of events for the various coppice management treatments

Treatments affected ¹	Date of event (months after felling)	Action taken
	June 1992	Trees felled
2	October 1992 (4 mo)	1st coppice reduction to 2 stems per stump
1, 3, 4, 5 and 6	January 1993 (7 mo)	1st coppice reduction to 2 stems per stump
5	January 1993 (7 mo)	Broadcast application of fertiliser to the inner 6 × 5 trees
All treatments	February 1994 (20 mo)	2nd coppice reduction to original stems ha ⁻¹
6	January + April 1993; March 1994 (7, 10 and 21 mo)	Complete weed control through the broadcast application of glyphosate
1, 2, 5 and 6	February, June, October 1993; March 1994 (8, 12, 16 and 21 mo)	Secondary coppice regrowth manually removed when 0.75 m high
3	February and June 1993 (8 and 12 mo)	Secondary coppice regrowth sprayed with glyphosate when 0.75 m high
4	February, June, October 1993; March 1994 (8, 12, 16 and 21 mo)	Secondary coppice regrowth sprayed with paraquat when 0.75 m high
All treatments	June 2000 (96 mo/8 y)	Last measurement before trees felled

¹ Refer to Table 1 for treatment description.

was felled in June 1992. The trees had been planted at 2.9 m × 2.9 m spacing, resulting in a stocking of about 1185 stems ha⁻¹.

Six treatments (Table 1), replicated eight times, were laid out in a randomised complete block design. Each treatment plot consisted of 7 × 8 trees, of which only the inner 3 × 4 trees were measured. The initiation and timing of events for the different treatments are listed in Table 2. Weed growth in the weed-free treatment (Treatment 6 in Table 2) was controlled on three occasions with glyphosate sprayed at 4 L ha⁻¹. Weed control beyond 21 mo was not necessary due to the effect of shading following canopy closure, which reduced the growth of competing vegetation. Initial weed growth in the remainder of the treatments was dominated by *Panicum maximum* Jacq., and as for Treatment 6, weed growth following canopy closure was negligible. The foliage of the secondary coppice regrowth (Treatments 3 and 4 in Tables 1 and 2) was sprayed with the appropriate herbicides until runoff, using a

solid-cone nozzle. Care was taken not to spray the foliage of the selected coppice stems.

Coppice height was measured regularly during the first 20 months after felling in order to determine the timing for reduction operations, and then again just before the trees were felled (8 y). Diameter at breast height was first measured at 7 mo after felling and then on an annual basis. These diameter measurements, together with the number of stems per treatment plot, were used to calculate basal area on a treatment plot basis. As a suitable volume equation for *E. grandis* coppice could not be found, the merchantable volume per tree was first calculated using Bredenkamp's (2000) tree volume equation for *E. grandis*, before merchantable volume on a hectare basis was determined. Merchantable volume refers to the underbark volume to a small-end diameter of 7.5 cm. Analysis of variance, appropriate for a randomised complete block design, was used to test for treatment

Table 3. Summary of data when the trees were felled at 8 y of age

Data	Initial stocking (stumps ha ⁻¹)	Final stocking (stems ha ⁻¹)	Basal area (m ² ha ⁻¹)	Merchantable volume (m ³ ha ⁻¹)
Grand mean	885	1140	30	276.3
Unit coefficient of variation (%)	15.6	18.4	19.5	20.9
Standard error of the difference	69	105	2.9	28.9
Bartlett's Test for homogeneity of variance ($P < 0.05$)	0.849 ^{ns}	0.235 ^{ns}	0.706 ^{ns}	0.784 ^{ns}

Note: ns denotes non-significance at $P < 0.05$.

effects. Prior to all analyses, Bartlett's Test (Snedecor and Cochran 1956) was used to test for homogeneity of variance, an assumption which must be met for a valid analysis of variance. Assessments of the weed growth were scheduled to be carried out when coppice growth responses to competition were detected. No significant differences were detected between treatments, so no vegetation assessments were carried out for the duration of the trial.

Results and discussion

Although the site had been selected to include only that part of the compartment within which there was good tree stocking, high mortality after felling resulted in the survival of only 885 coppice-bearing stumps ha⁻¹. Similar stump mortality after felling (30%) was recorded by Bredenkamp (1991) for *E. grandis* in Zululand. To reach the original stocking of about 1185 stems ha⁻¹, two stems were left on certain stumps to compensate for those that were missing. This resulted in a mean stocking of 1247 stems ha⁻¹ after the final reduction (at a height of 8 m) at 20 mo. Further stem mortality over time left a final stocking of 1140 stems ha⁻¹, a 4% reduction from the original stocking (Table 3).

No significant differences were detected for any of the variates measured, either for the duration of the trial or at the last measurement. The mean height for the trial at eight years was 21.3 m, the mean diameter at breast height 18.6 cm, the mean basal area 30 m² ha⁻¹ and the merchantable volume 276 m³ ha⁻¹. Bearing in mind that these results are based on the data of one trial only and are particular to the conditions under which the trial was conducted, the non-significant results obtained nonetheless indicate the possibility for alternative coppice management practices as outlined in the objectives.

Neither weeding nor fertiliser application produced any benefit in terms of coppice growth when compared to the control. The application of fertiliser to seedlings immediately following planting (60 kg N ha⁻¹) has yielded significant gains on similar sites in the same region (du Toit 1995), a response attributed to enhanced nutrient supply during the period before tree roots thoroughly colonise the site. In another study on a similar site, however, an application of fertiliser (70–140 kg N ha⁻¹) to seedling crops, three to six months after establishment, yielded no significant response (Noble 1992). Post-establishment applications of fertiliser (80 kg N ha⁻¹) have been beneficial on only the most infertile sites of the coastal plain, which had been burned and tilled extensively under previous shifting agricultural use (du Toit *et al.* 2001). In two *E. grandis* coppice trials conducted on sites

where tree performance is enhanced through the application of phosphorus, Schönau *et al.* (1981) were able to show that coppice growth responded positively to the application of fertiliser, but the subsequent high cost of weeding and fertiliser at the rates applied made this operation a doubtful proposition.

In the present trial the lack of response to the fertiliser applied (94 kg N ha⁻¹) or weed control may be in part attributed to the use of the existing and well-established root system of the stump by the coppice shoots (Tschaplinski and Blake 1989). Young coppice shoots may be able to obtain necessary nutrients and moisture from a larger soil resource than that available to newly-planted seedlings. In addition, some of the necessary nutrients and water may come from resources already existing in the stumps and associated roots (Bamber and Humphreys 1965). An additional reason for the lack of response to fertiliser could be that the first coppice reduction treatment, immediately prior to fertiliser application, decreased the size of the sink that existed for nutrient uptake in the above-ground biomass. The rapid initial growth of the coppice shoots when compared to seedlings (Blake 1980; Taylor *et al.* 1982), combined with their slightly elevated position on the stumps, may also have contributed to the lack of weed competition detected. This lack of response to weed control has been confirmed in a subsequent *Eucalyptus* coppice trial (Little 1998), and in a *Eucalyptus* hybrid post-establishment weed control trial (Little and Rolando 2002). It is recommended, though, that woody and invasive weeds be controlled. This will help to reduce under-canopy fuel loads and risks of uncontrolled fires, reduce the seed bank of unwanted vegetation and prevent its re-establishment, and improve access for silvicultural operations (Denny and Schumann 1993).

There was no significant difference in yield between carrying out an early reduction of first coppice at a height of 1.5 m, and the control (reduction of first coppice to two stems at a height of 4 m). The rationale for early reduction includes the potential saving of labour required to carry out the reduction operation due to the smaller size of the stems, and a possible growth benefit resulting from the channelling of plant resources into the selected stems at an earlier age. The lack of significant differences between these two treatments may in part be explained by selective thinning, at 8 m in height, to the original stocking, by removing the smaller of the two stems per stump. Apart from the potential benefits (which did not materialise in this trial), disadvantages may include an increase in the incidence of windthrow due to the poor attachments of the coppice shoots to the stump, the inability to accurately select shoots of suitable stem form when they are

only 1.5 m in height, and the production of more secondary coppice regrowth following reduction.

No increased incidence of windthrow following an early reduction was detected in this trial, as indicated by the lack of significant treatment differences obtained for the final stocking. The nature of the trial design might not have lent itself to the detection of differences in windthrow between treatments due to the sheltering effect of adjacent treatments. Much larger plots should be used in any test of susceptibility to windthrow. The reduction to two stems per stump when the coppice was 1.5 m high was not based on the selection of dominant shoots, as most of the shoots were of equal size. In subsequent trials, the early reduction of coppice has been delayed until the shoots have a dominant top height of 2 m to minimise this problem (Little 1997, 1998). Although it was not tested in this trial, data from subsequent trials have shown that the early reduction of first coppice leads to increased regrowth of secondary coppice requiring more frequent control in order to avoid a loss of growth (Little 1997, 1998). The timing of the first reduction operation in the selected management regime will depend on economic benefits arising from the timing, number and cost associated with each operation, rather than benefits from improved growth.

Regrowth of secondary coppice following the initial coppice reduction treatments was controlled either by manually removing it with a bushknife or by spraying it with herbicides (glyphosate at 0.6% or paraquat at 0.4%). Of the two herbicides tested, glyphosate gave far better control (sprayed on two occasions) than either manual removal or spraying with paraquat (removed or sprayed on four occasions). Glyphosate, a systemic herbicide, resulted in the death of the coppice regrowth following translocation of the active ingredient without negatively affecting the performance of the remaining coppice stems. This result has been confirmed in a subsequent trial carried out on *E. grandis* × *E. camaldulensis* hybrid clones in Zululand (Little 1998). In contrast, paraquat, a contact herbicide, resulted only in the desiccation of the sprayed foliage, leaving the epicormic buds to re-sprout. As there was no significant difference in coppice volume between these methods of controlling secondary regrowth and the control, spraying with glyphosate would seem the logical choice. Besides the economic benefits, damage to the remaining stems or bark through manual control will also be alleviated.

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