E. globulus Coppice Study at Malcolm's Site in the Wellington Reservoir Catchment: A Progress Report

by P. Ritson and N. E. Pettit

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ABSTRACT

Despite coppicing being a common technique used to manage commercial eucalypt plantations overseas little information is available on how best to apply this technique to eucalypt plantations in the south west of Western Australia.

A small (2.2 ha) plantation of eight year old *E. globulus* ssp *globulus* was divided into three blocks and within each block the trees felled at three different times of the year (March, August and December). Three rates of fertiliser (0, 300, and 1000 kg/ha) were applied to the stumps during the first year after felling and the coppice growth was thinned to one or two stems per stump 21 months after felling.

The month in which the trees were felled strongly influenced stump survival with March having best survival (95%) and December the worst (81%). There was no significant effect of fertiliser application on stump survival or coppice growth. Thinning to one stem per stump caused a 25-28% reduction in crown volume index (CVI) and basal area, however recovery to pre-thinning levels was fairly rapid. It is intended to continue monitoring all treatments over the full length of the first coppice rotation (expected to be around 8 years for pulpwood production).

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INTRODUCTION

Coppicing is a common means of regeneration used in the estimated 8 million hectares of eucalypt plantations around the world. The system relies on dormant buds in the stumps of felled trees to produce new shoots (coppice) once the inhibiting effect of the crown (through auxin production) is removed. These shoots, which may be thinned to one, or just a few, become the stems of the next crop. They also have the advantage of growing from an established root system.

Despite the common use of coppice systems overseas for eucalypt regeneration it seems likely that second rotation (2R) *E. globulus*[1] in the south-west of Western Australia will be established by replanting rather than from coppice. This would be to take advantage of tree improvement (selection/breeding) programmes. Nearly all the *E. globulus* planted so far has come from wild seed. However, based on overseas experience with eucalypt plantations, increases in yield of 50-100%, or even more, can be expected with genetically improved stock. To replace the old crop with genetically improved stock the stumps would have to be killed, e.g. by poisoning any coppice soon after

[1] E. globulus spp globulus

clearfelling, and a new crop planted. This raises a valid question: Why experiment with coppicing techniques if 2R *E. globulus* may be established by other means? One reason is that we need to compare the costs and yields of establishing the 2R by coppicing with that of replanting with genetically improved stock. It remains to be seen whether the 2R from coppice will out-yield the 1R from seedlings due to starting from an established root stock. This is found with *E. globulus* overseas (Wattle Research Institute (WRI) 1972). A second important reason for experimenting with coppicing techniques is that, even if the 2R is established by replanting, the 3R or subsequent rotations may be established by coppicing. This is because a law of diminishing returns is likely to apply to any tree breeding programme. Large gains may be expected in yield in the change over to the 2R, but additional gains with later rotations will be progressively smaller.

Several aspects of coppicing *E. globulus* meriting consideration are discussed below.

Felling

Specifications for managing eucalypts as coppice crops are given in Food and Agriculture Organization (FAO) (1979). Stumps should be no more than 12 cm high and cut at an angle to facilitate water runoff and thus reduce fungal attack. Care should be taken to leave bark intact on the stumps so coppice production is not reduced. Debris must be removed from stumps or it will cause deformities of coppice growing through it (FAO 1979, Stubbings and Schönau 1980, Geary *et al*. 1983). The debris, spread over the areas between stumps, will act as a mulch on the soil, increasing soil moisture retention and providing some nutrients (WRI, 1972). However both WRI (1972) and FAO (1979) suggest that, as the debris will impede access and becomes a fire hazard, it is best piled between every third or fourth row and burnt on a damp windless day. In contrast, Stubbings and Schönau (1980) suggest that burning the debris increases stump mortality while cultivation of the debris reduces stump mortality.

The timing of felling may have important effects on coppice success. FAO (1979) state that periods of heavy frosts or sharp dry periods may be unfavorable for eucalypt coppice. However, they also state that there is rarely a need to interrupt employment or production because of the danger of failure of eucalypt coppice. Pereira *et al*. (1984), working with *E. globulus* in Portugal found that, on a site prone to waterlogging, stump mortality was highest when trees were felled during the cold rainy season. On a non-waterlogging site there was, however, no significant difference between seasons of felling. Other authors, who have worked with various eucalypt species (not *E. globulus*) report either that there were important seasonal effects of felling (Stubbings and Schönau 1980, Webley *et al*. 1986, Zohar *et al*. 1978) or no effect (Jacobs 1950).

In our experiments we consider the effect of three felling times (March, August and December) on stump survival and coppice growth rates.

Fertilising

It is possible that fertilising *E. globulus* coppice could stimulate growth of coppice rotations. However, WRI (1982) do not recommend fertilising eucalypt coppice in South Africa. They found fertilising seedlings was often warranted but that any responses of coppice were negligible. The only other references to fertilising coppice crops that we could find relate to non-eucalypt species. Blake (1981) cites references relating mainly to poplars (*Poplus* spp) to point out the apparent contradictions in the literature as to whether or not fertilising stimulates coppice growth. He felt the different responses may have been due to variation in initial soil nutrient levels.

Our experiments test the effect of fertilising the coppice crop in the first year after felling.

Coppice thinning

The coppice shoots are usually thinned to one, two, or three stems per stump depending on the management objectives of the plantation. According to FAO (1979) this is best done by the time the coppice shoots are 18 months of age though WRI (1972) suggest leaving thinning until 2 years after felling.

Fewer shoots per stump should produce bigger stems of better form due to less butt sweep (WRI 1972) and more selection at the thinning stage. More stems per stump should produce slightly more merchantable volume per hectare at the end of the rotation especially on short rotations but with a smaller average log size (Poynton 1965, WRI 1972) .

In our experiments we compare thinning to one stem per stump with thinning to two stems per stump.

METHODS

Site description

The study site was on Water Authority land (ex-Malcolm's farm) in the Wellington Reservoir Catchment (Fig. 1). An area of approximately 2.2 ha of *E. globulus* plantation within a much larger area of mixed *Eucalyptus* species plantation was used. The plantation was established in 1980 with seedlings planted at a nominal spacing of 4 x 3 m (833 trees/ha).

By 1987 the average stocking of *E. globulus* on the study site was 534 trees/ha with an average basal area of 18.3 m^2/ha. Mean annual increment was estimated to range from from around 11 m^3/ha/yr near the western end to around 19 m^3/ha/yr over the eastern half (average 15.6 m^3/ha/yr).

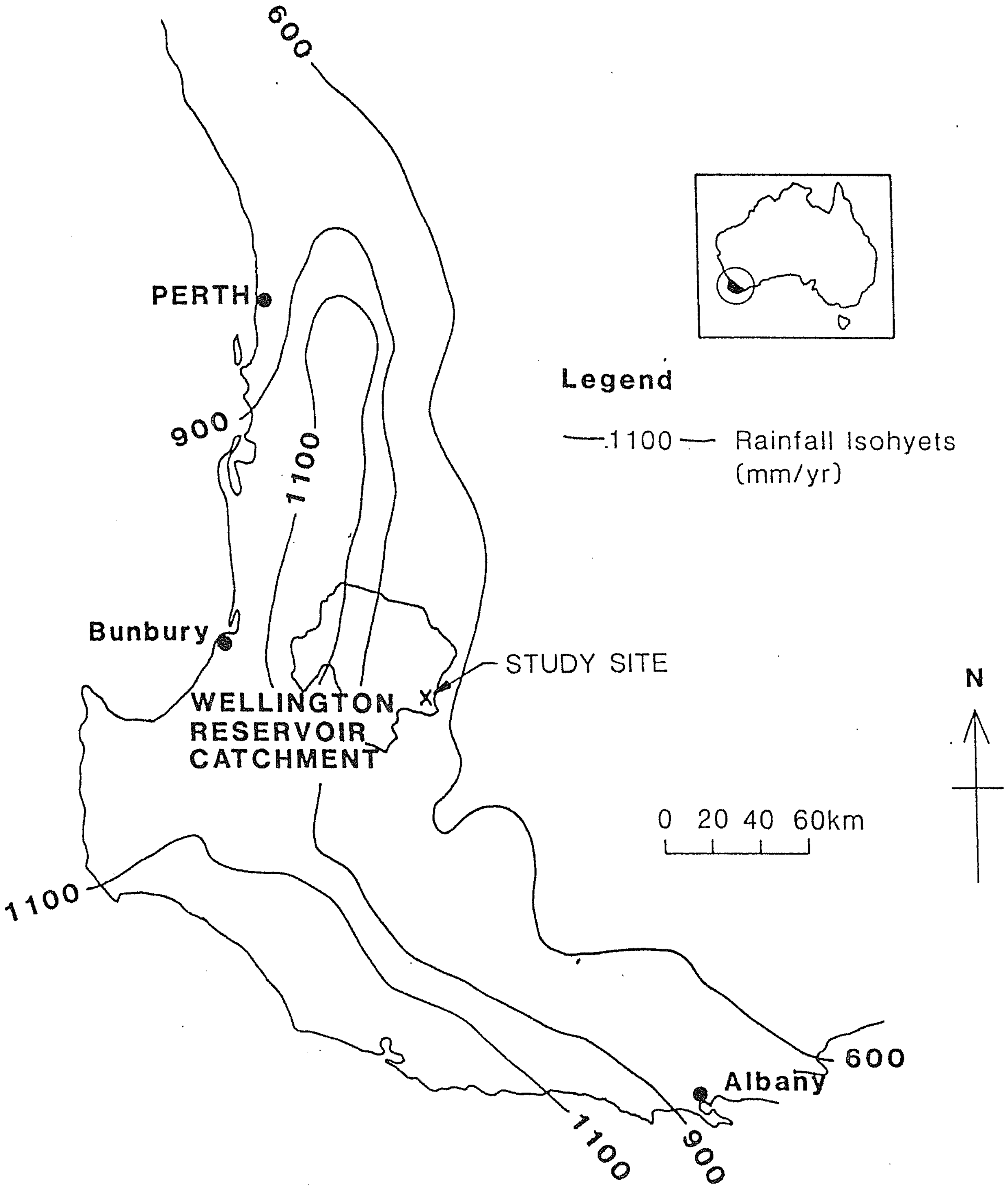

Figure 1. Location of the study site in the Wellington Reservoir Catchment, and rainfall isohyets.

Soil pits in the study area revealed lateritic gravel soils with the matrix ranging in texture from sandy loam to clay loam.

Long term average rainfall is around 650 mm/yr, 80% falling in the six months from May to October. Temperature and evaporation also show strong seasonal variation, being highest in summer and least in winter. There are an average of 22 frosts each year.

Treatments

Treatments consisted of all combinations of 3 felling times x 3 fertiliser levels x 2 coppice thinning levels i.e. 18 treatment combinations.

(a) Felling times

The three felling times were :

- December 1987
- March 1988
- August 1988.

Thus the plantation ages at felling ranged from 7 years 5 months to 8 years 2 months.

The December felling was started with a Bell Infield Logger. However, due to mechanical problems this machine was only used for about a quarter of the area, the remainder being felled with chainsaws. All logs were de-limbed with chainsaws but removed to a log landing with the Bell Infield Logger.

The March and August fellings were done with an Ösa Tree Harvester. This machine also delimbed the logs, knocking an estimated 70% of the bark off the logs in the process. An Ösa forwarder was used to remove logs to the landing.

Neither the Bell Infield Logger nor the Ösa Tree Harvester could leave stumps cut at an angle so this was not done. Average stump height (measured after December '87 felling only) was 0.10 m. Logging debris was removed from the stumps and spread reasonably evenly over the areas between the stumps in each felling operation.

(b) Fertilising

Soil and leaf samples for nutrient analyses were collected prior to implementing any fertiliser treatment. All samples were analysed for nitrogen (N), phosphorus (P) and potassium (K) content (Table 1).

Table 1a. Soil nutrient levels.

	N[a] (%)		P[b] (mg/kg)		P[c] (mg/kg)		K[b] (me %)	
	X	SD	X	SD	X	SD	X	SD
Soil samples[d] :								
0-10 cm	0.13	0.03	124	55	6.1	2.4	0.41	0.22
10-20 cm	0.08	0.03	80	55	3.9	1.7	0.38	0.24

(a) total nitrogen (by weight)

(b) HCl extraction

(c) HCO_3^- extraction

(d) Data are means and standard deviations from sampling at five locations throughout the study site.

Table 1b Leaf nutrient levels

	N[e] (%)		P[f] (%)		K[f] (%)	
	X	SD	X	SD	X	SD
leaf samples[g]	1.30	0.11	0.11	0.02	0.96	0.42

(e) Kjeldahl method

(f) Tri-acid method

(g) Data are means and standard deviations from bulk samples of the growing tips of leaves from ten trees throughout the study site.

note: N/P ratio in leaves = 11.8

The three fertiliser levels applied were :

- control (no fertiliser)
- 300 kg/ha NPK Blue Special
- 1000 kg/ha NPK Blue Special.

NPK Blue Special is a fertiliser, manufactured by CSBP and Farmers Ltd, with 12% N, 6% P, 16% K and trace elements (0.05% copper, 0.05% zinc, 0.13% manganese and 1.0% magnesium). The total fertiliser dose for each plot was applied in four lots at three month intervals after felling. This avoided applying the fertiliser in different seasons according to felling time as would have been done if it was applied in a single dose a set time after felling. The time of year for application of nitrogen fertiliser, in particular, has been found to have important effects on tree growth (J. McGrath, Department of Conservation and Land Management, pers. comm. 1987).

(c) Coppice Thinning

Alternative coppice thinning treatments tested were to thin the coppice on the stumps back to either

- one stem/stump, or
- two stems/stump.

This was done 21 months after felling according to guidelines developed from WRI (1972), FAO (1979) and Stubbings and Schönau (1980) i.e.

1. Choose dominant shoots, of good form, with the firmest attachment as low down on the stump as possible.

2. If only one stem is left it should preferably be on the windward side i.e. the north-west or west at the Malcolm's site.

3. If >1 stem is retained on a stump select shoots of similar height and diameter, spaced as widely apart as possible.

4. Cut the shoots at an angle below the level of the stump.

Nearly all stumps produced new coppice after thinning which has required removal.

Field layout

The 18 treatment combinations (plots) were replicated 3 times into 3 blocks across the study site (Figure 2). This was done to allow for variations in site conditions within the study area.

Each plot was 20 m long x 5 rows (~20 m) wide. Measurements were only made in core areas within these plots though treatments were applied to the whole plots. Core areas were 3 rows wide x a variable length calculated to make each core area 130 m^2. This left buffer strips ~4 m wide around the core areas within the plots. The average number of trees per core area of all plots was 6.9 with a standard deviation of 1.6.

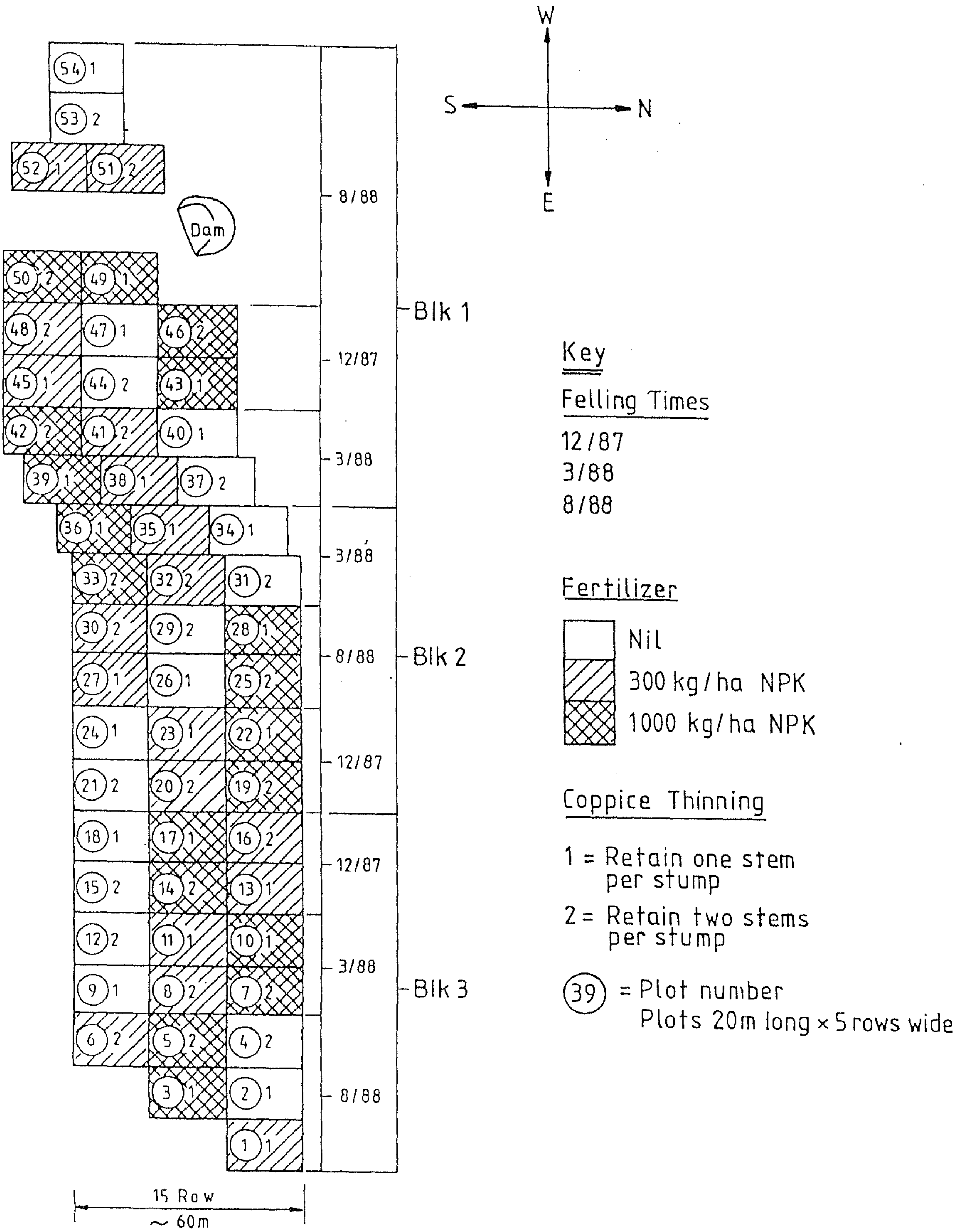

Figure 2. Field layout of the experiment.

Measurements

Stump survival and coppice growth was recorded in the core areas of all plots in August '88, March '89, August '89 and June '90, as well as immediately before and after thinning. We intend to continue monitoring growth of the coppice crop until the end of the rotation. To characterise coppice growth the following measurements were recorded:

(a) Height of the tallest stem on a stump.

(b) Diameter at Breast Height (DBH) of all stems on a stump with DBH ≥ 2.0 cm.

(c) Crown volume index (CVI), with the foliage of all stems on a stump being regarded as one crown. This was calculated as hd^2 where h is crown depth (the vertical distance between the highest and lowest green leaf) and d is crown diameter (measured horizontally along and across the rows). CVI is one indication of the evaporation potential of trees, an important variable for trees planted for salinity control as maximum water use is desired.

Rainfall on the study site was not measured directly but records from a pluviometer in the Mairdebing Experimental Catchment, 5 km to the north-west, were used to indicate monthly rainfall over the study period. Estimates of long term average monthly rainfall were obtained by first estimating average annual rainfall from isohyets (Figure 1) then dividing up that rainfall into monthly amounts based on rainfall records from isohyets (Fig. 1) and the proportion of total rainfall each month at the nearest station with long term rainfall records i.e. Darkan 28 km to the north-east, where rainfall was recorded from 1898.

RESULTS

Rainfall

Yearly rainfall was 431 mm (1987), 650 mm (1988) and 549 mm (1989) compared to the long term average of 650 mm.

Actual and average monthly rainfall data are shown in Fig. 3. Of particular interest is the rainfall in the 3-4 months following felling i.e. when stumps were producing coppice. As shown in Fig. 1, rainfall following December '87 felling was even less than the comparatively low average monthly rainfall rates for summer but rainfall in the 3-4 months after felling in March '88 and August '88 was close to average.

Effect of block, felling time and fertiliser

Coppice stems were measured at the same period of elapsed time after felling when coppice thinning was done (i.e. 21 months after felling). Therefore the effect of block, felling time and fertiliser was evaluated for that time. The only significant ($p < 0.05$) effects were due to felling time (Table 2). i.e.

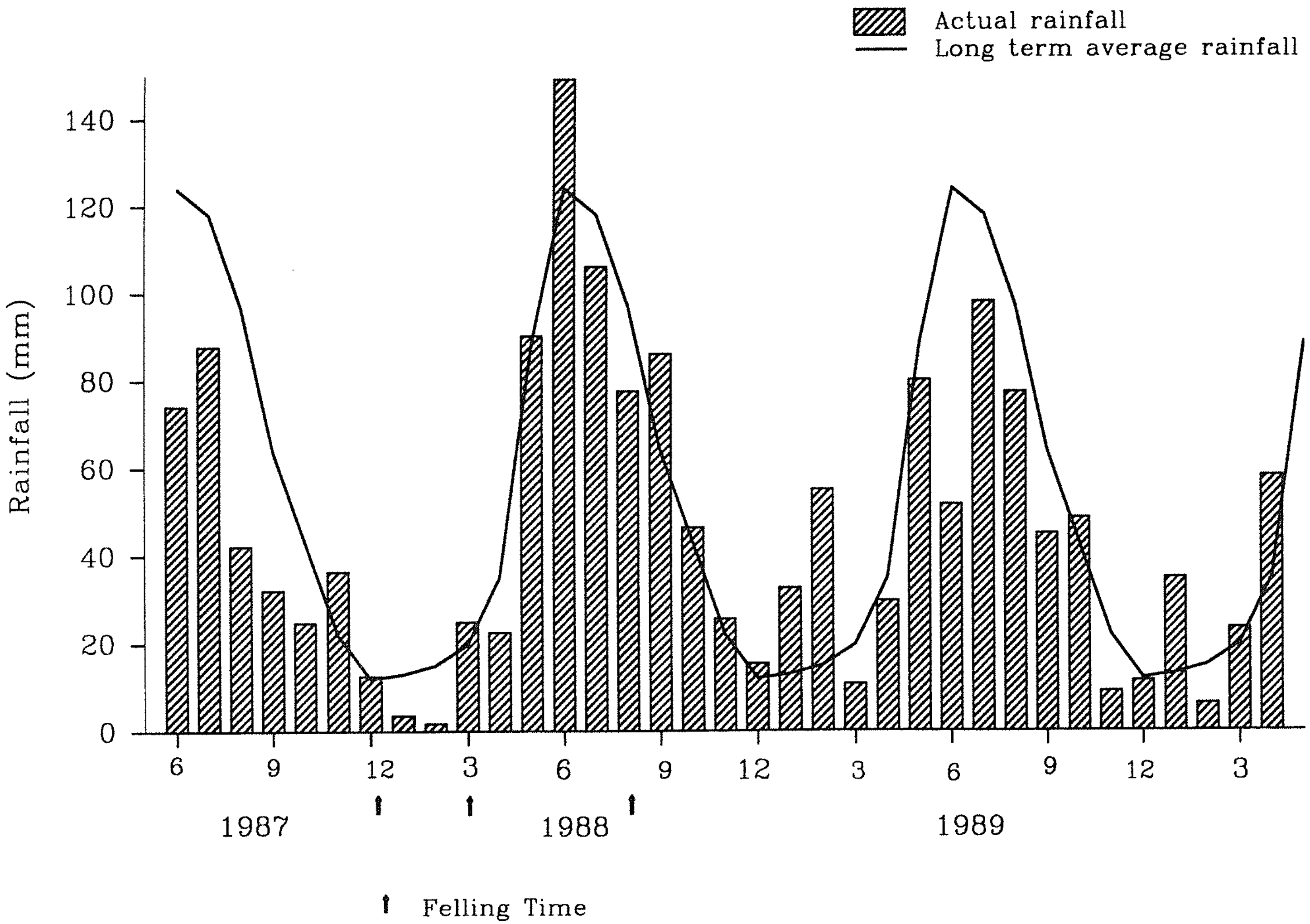

Figure 3. Actual and average monthly rainfall on the study site.

(i) March '88 felling gave considerably better survival than felling in December '87 or August '88.

(ii) March '88 and August '88 felling gave considerably better height and basal area growth in the first 21 months after felling than December '87 felling.

Table 2. Effects of (a) Block, (b) Felling time , and (c) Fertiliser on stump survival and coppice growth 21 months after felling.

(a) Block	Stump survival (%)	Mean tree height (m)	CVI (m^3/ha x 10^3)	BA (m^2/ha)
1	80	5.8	31	3.5
2	93	5.6	30	3.2
3	88	5.6	33	3.2
	p=0.10	p=0.54	p=0.77	p=0.77

(b) Felling time	Stump survival (%)	Mean tree height (m)	CVI (m^3/ha x 10^3)	BA (m^2/ha)
Dec. '87	81	4.6	26	2.5
March '88	95	6.0	33	3.8
Aug. '88	86	6.4	35	3.6
	p=0.02	p=0.0001	p=0.18	p=0.03

(c) Fertiliser (kg/ha)	Stump survival (%)	Mean tree height (m)	CVI (m^3/ha x 10^3)	BA (m^2/ha)
0	90	5.6	31	3.1
300	88	5.9	33	3.5
1000	83	5.6	30	3.2
	p=0.57	p=0.28	p=0.84	p=0.74

Notes: (i) Measurements made immediately prior to coppice thinning

(ii) p = probability that differences between above values occurred by chance alone. Calculated from ANOVA.

(iii) In each of Tables (a), (b) and (c) data are averaged for the other two variables (out of block, felling time and fertiliser level)

Effect of coppice thinning

The immediate effects of coppice thinning on mean tree height, CVI and basal area are shown in Table 3 and Fig. 4. Thinning to one or two stems per stump caused very little (≤ 2%) reduction in mean tree height. However, the reductions in CVI and basal area were substantial. Thinning to one stem per stump reduced CVI and basal area to around 25-28% of pre-thinning levels while thinning to two stems per stump reduced CVI and basal area to around 49-50% of pre-thinning levels.

Table 3 Effect of coppice thinning 21 months after felling on mean tree height, CVI and basal area.

No. stems per stump	Mean tree height (m)			CVI (m^3/ha x 1000)			Basal area (m^2/ha)		
	Before	After	Before/after	Before	After	Before/after	Before	After	Before/after
1	5.70	5.58	98%	33.4	9.2	28%	3.6	0.9	25%
2	5.64	5.57	99%	29.6	14.6	49%	3.0	1.5	50%

Note: Data are averaged for all blocks, felling times and fertiliser levels

Recovery from coppice thinning was fairly rapid. For example, interpolating (or extrapolating) from the data for December felling (Fig. 4) indicates that recovery to pre-thinning levels following thinning to one stem per stump was (or would be) around 1 month (mean tree height), 13 months (CVI) and 8 months (basal area). The equivalent recovery times from thinning to two stems per stump were 1, 11 and 5 months respectively.

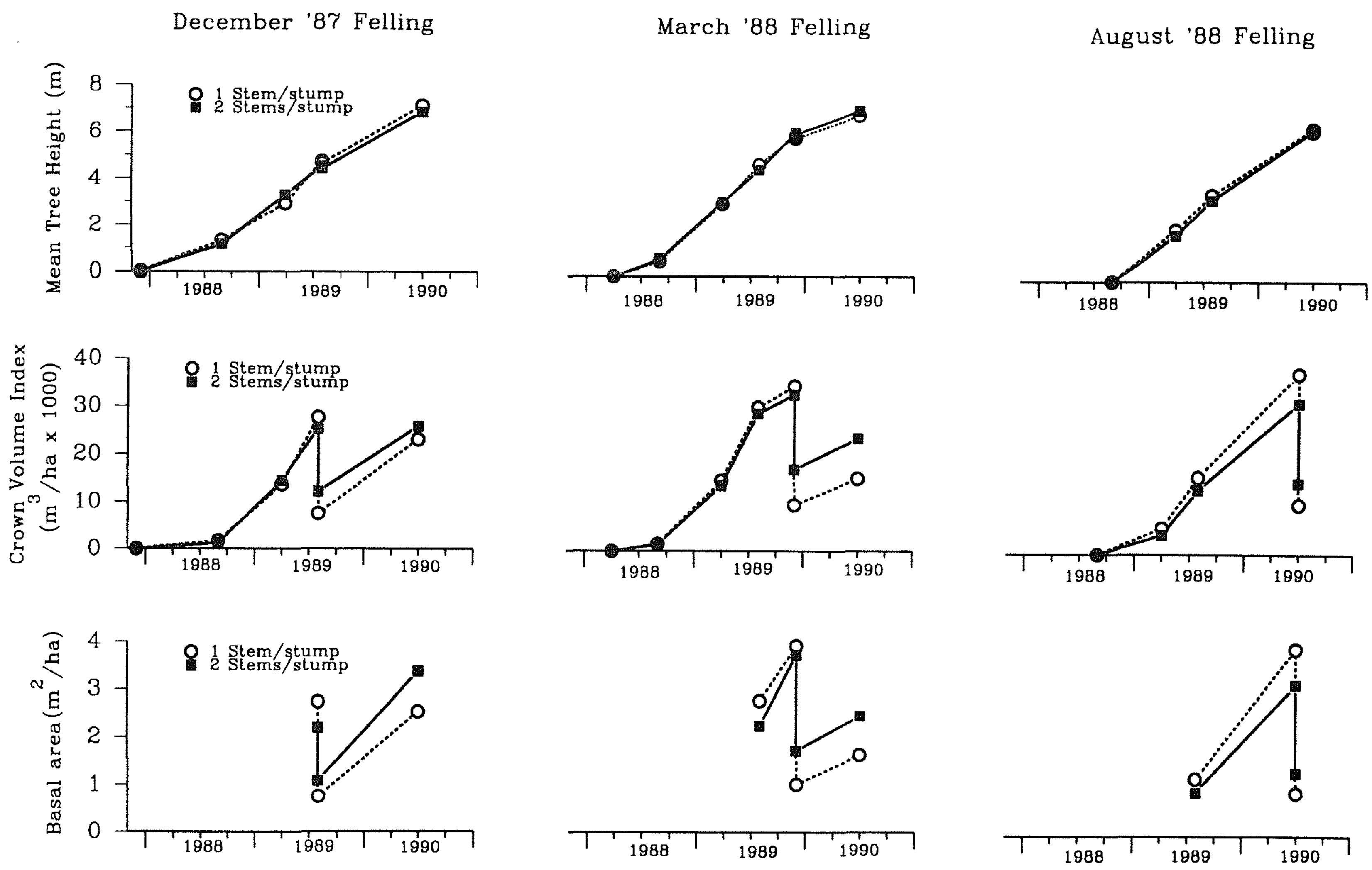

Figure 4. Variation in mean tree height, CVI and basal area up to June 1990 for each of the felling time x coppice thinning treatments. Note that coppice thinning was done 21 months after the first rotation was felled. This is indicated by the sudden decline in CVI and Basal area.

DISCUSSION

Felling time

It is likely that the strong effect of felling time on stump survival at the study site relates to moisture availability in the few months after felling when stumps were producing coppice. Thus, the order of stump survival (March felling > August felling > December felling) correlates with moisture availability (rainfall excess over evaporation) in the three months after felling. However, the Malcolm's site (average rainfall 600-650 mm/yr) is close to the lower limit of rainfall considered adequate for dense *E. globulus* plantations in the south-west of Western Australia. By contrast, areas of higher rainfall, felling time may not be so critical because of moisture availability.

March felling resulted in the least stump mortality despite the fact that fresh coppice from March felling would have been exposed to colder (mid-winter) temperatures than the new coppice from the other felling time treatments. This indicates that the coppice was not adversely affected by cold temperatures though more study is needed to confirm this. Had there been sufficient room at the study site to incorporate a fourth felling time treatment in the experiment it would have been interesting to also have felled in June. This would have exposed the stumps to the coldest temperatures immediately following felling.

While March and August felling gave better early (first 21 months) coppice growth than December felling monitoring over the full rotation is required to confirm any trends. It is likely that the early growth rates reflect the combined effects of seasonal variations in moisture availability and temperature but it is difficult to separate the two effects.

Fertiliser

The failure to detect a response by the coppice to fertiliser indicates that some factor, other than nutrients, limited the growth of the coppice. This may have been moisture.

The soil and leaf nutrient levels measured at the study site (Table 1) indicate that nutrient levels may have been high enough to prevent any response to fertiliser. However, in another experiment, under similar site conditions (including similar soil nutrient levels), we found that *E. globulus* seedlings responded to N and P fertilisation (Ritson and Pettit, unpublished results). There was a lasting (≥ 3 yrs) growth response to P, but only a short term (2 yrs) growth response to N by the seedlings. Thus our results correspond to the South African experience (WRI 1972) that fertilising eucalypt coppice is not worthwhile but fertilising seedlings may be. Presumably the difference between seedlings and coppice is that the coppice is sustained by a much more extensive root system i.e. the coppice can draw on a much larger pool of nutrients.

Another possible explanation for the failure to detect a response by the coppice to fertiliser may relate to the effect of the fertiliser in stimulating weed competition. A general observation was that fertilising stimulated weed growth dramatically, particularly wild radish (*Raphanus raphanistrum*). It is likely that the weeds competed with the coppice for moisture and, possibly, nutrients. However, if weed control is required to allow the stumps to take advantage of fertilisation, this would add greatly to the expense of the operation. Chemical weed control options would be limited due to the sensitivity of eucalypts to most herbicides. Mechanical weed control options may have problems too e.g. slashing may be only partially effective in controlling weeds due to regrowth while ploughing may damage roots existing from previous rotation(s)

Coppice thinning

Although the immediate effects of coppice thinning were substantial reductions in CVI and basal area the quick recovery rates indicate this would not cause major losses of transpiration or growth.

It is clearly too early to evaluate whether it is better to thin to one or two stems per stump. This will require monitoring over the full length of the rotation.

CONCLUSIONS

Felling of an 8 year old plantation of *E. globulus* in the 600-700 mm/yr rainfall zone of the Wellington Reservoir Catchment confirms the good coppicing ability of this species.

There was a strong effect of felling time on stump survival. The order of stump survival according to felling time was March (95%) > August (86%) > December (81%). These differences probably reflect soil moisture availability at the time of felling and in the first few (around 3) months after felling.

March and August felling gave better early (first 21 months) height and basal area growth than December felling. Monitoring over the full rotation is required to determine if these will be lasting effects.

There was no significant effect of fertilising with N, P, K and trace elements on growth rates of the coppice. This may have been because nutrients were not limiting growth or because fertilising stimulated weed competition. Any weed control necessary to take advantage of fertilisation would be difficult and expensive.

Coppice thinning caused only minimal (≤ 2%) reductions in mean tree height. In contrast, thinning to one stem per stump reduced CVI and basal area to approximately one quarter of pre-thinning levels while thinning to two stems per stump reduced CVI and basal area to approximately half of pre-thinning levels. Recovery to pre-thinning levels following either coppice thinning treatment was fairly rapid. This indicates that thinning would not seriously effect the water use capacity of trees planted for stream salinity control in water supply catchments.

It is too early in the study to evaluate whether it is better for pulpwood production to thin to one or two stems per stump.

Growth of the coppice in all treatments should be monitored over the full rotation (expected to be around 8 years for pulpwood production) to evaluate the growth rates of the coppice and to confirm initial results.

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