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Growth of young *Eucalyptus globulus* in plantations after manual defoliation simulating insect herbivory

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ABSTRACT

The impact of three levels of manual defoliation in spring, summer or autumn on growth of young plants of *Eucalyptus globulus* Labill. was studied over one year. No extraordinary mortality owing to defoliation treatments resulted. Fifty per cent defoliation in autumn significantly reduced initial height growth, unlike 50 per cent defoliation in spring or summer. One hundred per cent defoliation in any season significantly reduced height growth. Basal area growth remained significantly reduced in September 1992 after 100 per cent defoliation in the previous spring or autumn.

These findings indicate that single 50 per cent or less defoliations of *E. globulus* by insects should be tolerable in spring or summer, but not in autumn, and that 100 per cent defoliation is unacceptable at any time.

INTRODUCTION

The Western Australian Department of Conservation and Land Management (CALM) has initiated plantings of *Eucalyptus globulus* Labill. in excess of 6000 ha throughout the south-west of Western Australia (WA) (CALM 1992). Most of the planted area is on cleared farmland or water catchments, established and managed under sharecropping arrangements between the landholder and CALM.

Defoliating insects are an unpredictable risk to yields from eucalypt plantations. Since 1988, 10 species of insect have been recorded as damaging *E. globulus* plantings in WA (Abbott 1993). Knowledge of the intensity and duration of defoliation effects on tree growth is important because insects are capable of inflicting severe defoliation at any stage of canopy development, and rotation times for *E. globulus* are intended to be short (10-15 years, Shea and Bartle 1988).

A field trial was established to assess growth and recovery responses of *E. globulus* saplings to different amounts of manual defoliation applied over the course of the first year of growth. Treatments applied in this trial were intended to emulate the gross effects of defoliators such as spring beetles (Scarabaeidae), grasshoppers (*Phaulacridium vittatum, Chortoicetes terminifera*) and autumn gum moth (*Mnesampela privata*). We addressed three questions:

(1) Does defoliation affect height and diameter growth in young *E. globulus*?
(2) Does the season of defoliation affect growth responses to defoliation?
(3) Do growth responses to defoliation persist?

METHODS

Location of Sites

Three stands of *E. globulus* were chosen from July 1991 plantings in south-west WA. Site 1 is located 7 km north of Jarrahdale townsite (32° 15' S, 116° 04' E) with an average annual rainfall (AAR) of *c.* 1100 mm. Site 2 is located 33 km east-south-east of Collie townsite (33° 28' S, 116° 28' E) with an AAR of *c.* 650 mm, while site 3 is located 20 km north-north-west of Darkan townsite (33° 13' S, 116° 38' E) and has an AAR of *c.* 600 mm. Each site was ripped prior to planting and site 1 was mounded to 30 cm prior to planting.

Experimental Design

Treatments were factorial combinations of three levels of defoliation (0 per cent, 50 per cent, and 100 per cent) applied once to each plant at one of three times (September 1991, December 1991 or March 1992). Control plants were not defoliated (i.e. 0 per cent treatment) and 100 per cent defoliation was achieved by removing all the leaves from the plant crown. The September 1991 50 per cent defoliation treatment was achieved by removing half the number of leaves evenly distributed from the crown. The 50 per cent defoliations in December and March resulted from removing the estimated topmost 50 per cent of leaf biomass from the crown.

Plants at each site were allocated a treatment at the outset of the trial and all plants except those defoliated in September 1991 were monitored before the application of treatments. Each treatment combination was allocated to five plants at each site resulting in a maximum of five control plants per site. Plants that died before application of treatment were not re-allocated replacements.

Variables Measured

The stem length of each plant was measured during the second or third week of September 1991, December 1991, March 1992, May 1992 and September 1992. Diameter over bark at 30 cm stem height was recorded from March 1992 onwards. The presence of folivores and any damage to plants were also noted.

Growth rate was calculated as increase in height or basal area in a specified period.

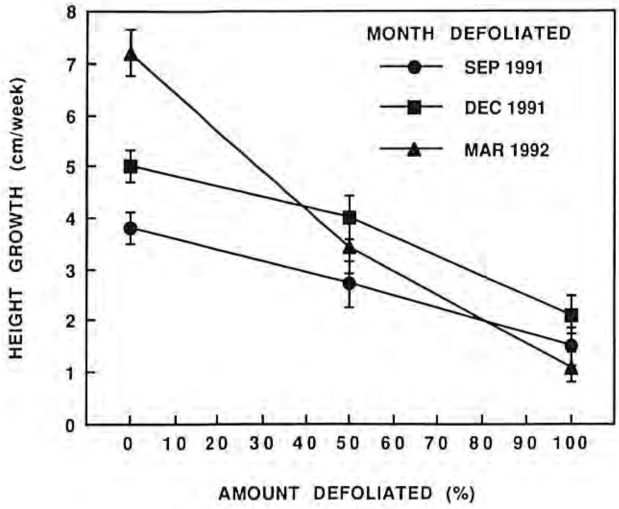

Figure 1. Effect of month and amount of defoliation on height growth rates (mean ± SE) of young Eucalyptus globulus *during the initial measurement period, approximately 3 months after defoliation.*

RESULTS

Mortality of Plants

Defoliation did not increase plant mortality (Table 1). No combination of amount and month of defoliation resulted in mortality significantly different from the control treatment (Fisher's exact tests, $\alpha = 0.05$). Only 7 of 87 defoliated plants died after defoliation. Four of 45 control plants died (Table 1).

TABLE 1

Numbers of plants dead or alive after treatment at the termination of measurements for each combination of amount of defoliation and month of defoliation.

STATUS	INTENSITY AND MONTH OF DEFOLIATION						
	50%			100%			Control
	Sept	Dec	Mar	Sept	Dec	Mar	
Dead	1	0	0	3	3	0	4
Alive	14	14	14	12	12	14	41

Timing and Amount of Defoliation

The amount and timing of defoliation and their interaction had significant initial effects on growth rates (Fig. 1). Mean height growth rates for all defoliated treatments were severely retarded compared with controls, and the amount of retardation of growth increment increased as the amount of defoliation increased (Fig. 1). Defoliation in March 1992 resulted in more severe initial retardation in height growth than defoliation in September or December because intact plants had faster growth rates in the March to May period than in the September to December and December to March periods. This probably reflected the above average rainfall at all three sites in February 1992 (Jarrahdale: 127 mm [actual] *vs* 15 mm [long term average for February]; Collie: 24 *vs* 15 mm; Darkan: 31 *vs* 15 mm).

Although the March to May measurement period, a period of rapid growth, was one month shorter than the other two initial measurement periods, this may not have contributed greatly to the much increased growth rate for controls. A longer measurement period should have reduced the measured growth rate of control plants only slightly (see Fig. 2C).

Persistence of Effects

Mean heights of completely defoliated plants remained significantly shorter than for intact plants at the termination of measurements (Fig. 2). Differences between intact and 50 per cent defoliated plants were only detected as significant for the March 1992 defoliation (Fig. 2C).

Effects on Stem Basal Area

Effects of defoliation on basal area growth were similar to the effects on height growth. Mean stem basal areas measured in September 1992 were smaller for defoliated plants than for intact plants (Fig. 3), although only September and March 100 per cent defoliated plants were significantly smaller.

Effects of Uncontrolled Background Defoliation

In September 1992 minor defoliation of a few trees by larvae of autumn gum moth (*Mnesampela privata*) was noted at site 2 and damage by parrots to stem tips was noted at site 3. Bluegum psyllids (*Ctenarytaina eucalypti*) were abundant at all three sites in September 1991 and 1992 but were unlikely to have interfered with the treatment effects.

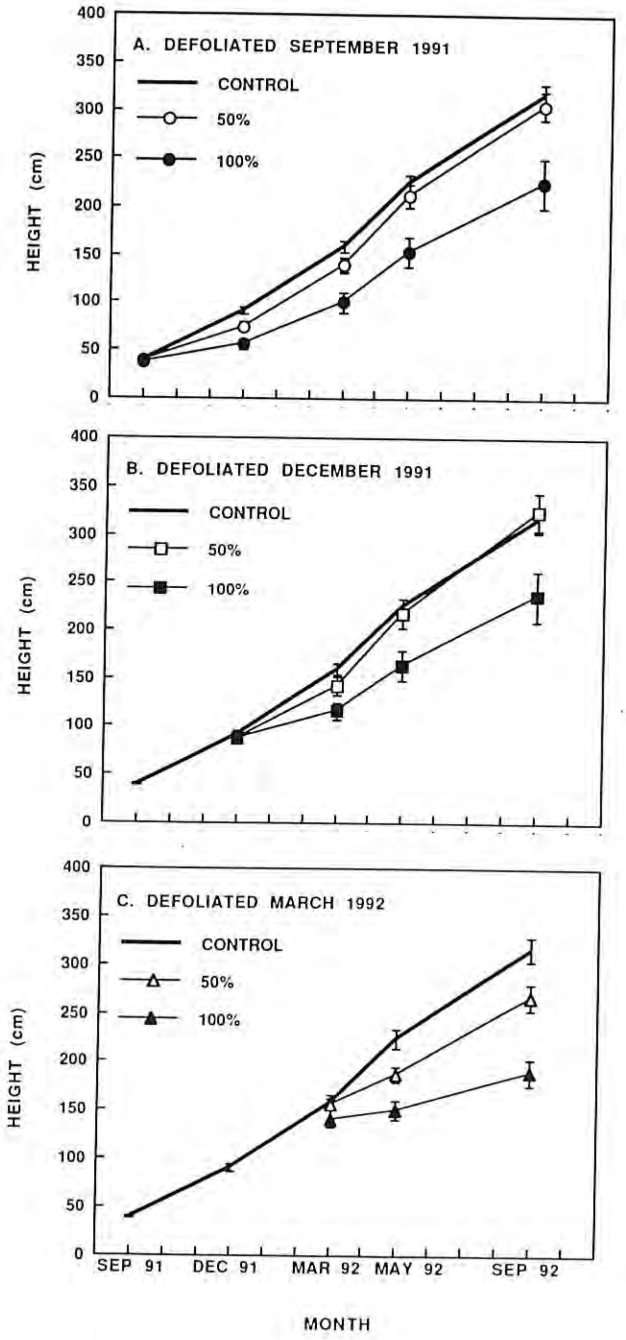

Figure 2. Height growth (mean ± SE) of Eucalyptus globulus *planted July 1991.*

DISCUSSION

It would have been preferable to investigate effects on growth of defoliation by using defoliation caused by specific insect leaf chewers compared with controls where chewers were excluded (e.g. Elliott *et al.* 1993), rather than simulated herbivory. This is because plant growth responses often indicate sensitivity to differences between simulated and actual defoliation, even when fidelity to the mechanism of natural defoliation is rigorously attempted (Baldwin 1990). Nevertheless, each of these leaf chewer groups is capable of substantial or complete defoliation of affected plants when pest populations are great.

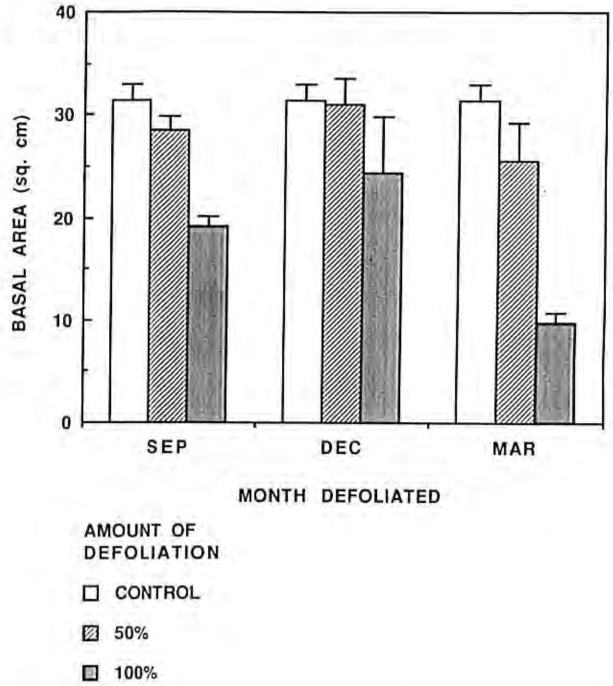

Figure 3. Basal area (mean ± SE), measured in September 1992, of Eucalyptus globulus *planted in July 1991.*

Eucalyptus globulus shows evidence of considerable ability to compensate for single defoliation intensities as large as 50 per cent. This robustness is shared with several other eucalypt species, namely *E. regnans* (Candy *et al.* 1992) and *E. grandis* (Carne *et al.* 1974) but not with *E. marginata* (Abbott *et al.* 1993) or *E. delegatensis* (Mazanec 1966). Defoliations >90 per cent by contrast always have large effects on growth (Mazanec 1967; Carne *et al.* 1974; Candy *et al.* 1992; Abbott *et al.* 1993).

The sensitivity of *E. globulus* to 50 per cent defoliation in autumn accords with observations made on two species of eucalypt in eastern Australia. Cremer (1973) observed that survival of *E. regnans* and *E. delegatensis* after total defoliation in late summer or autumn was lower than when defoliation was in spring. A late summer 'light' defoliation of *E. delegatensis* also had large impact on growth (Mazanec 1968). A single late summer defoliation of 66 per cent reduced height growth of *E. regnans* (relative to the control) compared with early summer defoliation of the same intensity, though the difference is not significant (Candy *et al.* 1992).

It appears that growth of eucalypts during spring and summer depletes starch reserves (Mazanec 1967; Cremer 1973). Defoliation in autumn prevents a tree from restoring its depleted starch to the level that would sustain refoliation (Bamber and Humphreys 1965), and this has a large impact on height and diameter growth.

Defoliation by insects is usually insidious, often involving partial consumption of leaves or particular plant tissue, unlike the instantaneous treatments of whole leaf removal applied here. For example, eggs of autumn gum moth (AGM) hatch in south-west WA soon after the first substantial autumn (April or May) rainfall and larvae commence skeletonizing juvenile foliage of affected *E. globulus*. By mid winter (July) larvae are large enough to remove laminae of leaves leaving only the mid-vein. Small trees up to 1-year-old may be completely defoliated by early spring (early September) if oviposition were dense and enough larvae survive. However, buds and the stem apex are not usually affected, resulting in a broomed appearance to severely affected trees as new leaves are produced. Progressive defoliation culminating in complete defoliation would have more severe and longer lasting effect on growth than a single complete defoliation, as indicated by Candy *et al.* (1992). Interpreting the results from the September defoliation (Fig. 2A) in the context of the time course of defoliation by AGM implies that even partial defoliation by AGM could have significant lasting effects on growth.

Removal of foliage from the upper crown did not appear to suppress growth more than diffuse removal of foliage (Fig. 1). However, disbudding with defoliation can severely suppress extension growth (Cremer 1972; Candy *et al.* 1992). Candy *et al.* (1992) found almost a year after treatment that disbudding and 50 per cent defoliation had a suppressive effect about three times that of just 50 per cent defoliation. Disbudding effects were not investigated in the current trial, although spring beetles and grasshoppers tend to be most active during spring and target expanding leaves and buds. The single 100 per cent December defoliation treatment is likely to underestimate the effects of severe disbudding and defoliation by spring beetles and grasshoppers.

Growth loss and death of trees from single large defoliations were surprisingly small. However, our experiment did not address the impact of frequency of defoliation on growth of *E. globulus*. If *E. globulus* behaves similarly to *E. marginata*, more frequent defoliations of low intensity should reduce growth more than less frequent defoliations of higher intensity (Abbott *et al.* 1993). The concern of plantation managers should therefore be directed at the more severe consequences of regular, small defoliations. This is why *E. globulus* plantations and timberbelts in WA require regular monitoring of pest insect densities. This will allow more informed usage of chemicals for protecting the wood resource from the effects of insect outbreaks and will direct the attention of managers to the vulnerability of partially defoliated trees to further damage.

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