*Australian Journal of Ecology* (1987) 12, 175–181

# The impact of defoliating insects on the growth of eucalypt saplings

M. D. LOWMAN
HAROLD HEATWOLE
*Department of Zoology, University of New England, Armidale, NSW 2351, Australia*

**Abstract**

*The effect of spraying insecticide on eucalypt saplings was experimentally tested in a New England woodland. Replicate branches of five species were sprayed fortnightly with Thiodan over a period of 4 months. Their leaf damage, leaf flushes, stem growth, and bud production were compared with those of control branches. Loss of leaf area to insect grazers was extremely variable, ranging from very low levels (e.g. 1.8% for sprayed new leaves of* Angophora floribunda*) to nearly total defoliation (97.1% for unsprayed new leaves of* Eucalyptus viminalis*). The sprayed branches consistently suffered less herbivory and grew more than the controls.*

## Introduction

As part of a research project on the defoliation of eucalypts by insects, this field experiment was designed to measure the impact of insects on eucalypt saplings. The two major questions addressed were: (i) Does insecticide application alter the extent of defoliation of eucalypt saplings? and (ii) Does insect exclusion have any immediate effects on the growth of the saplings, as measured by stem elongation or number of leaves produced?

### *The study area*

Field work was conducted in the Eastwood State Forest, located 12 km east of Armidale. This site represents one of the few relatively undisturbed open woodlands in the Armidale region, subject only to cattle grazing as permitted by Forestry and occasional (albeit illegal) tree-felling. The trees are up to 20 m in height, with initial signs of dieback in their canopies (dying branches, epicormic shoots, open crowns). The dominant species are *Eucalyptus blakelyi* Maiden, *E. viminalis* Labill., *E. melliodora* A. Cunn. ex Schau., and *E. caliginosa* Blakely et McKie with lesser numbers of *Angophora floribunda* (Sm.) Sweet and *Acacia melanoxylon* R. Br. Open areas with sapling regeneration are scattered amidst the woodlands. The average annual rainfall is 792 mm (50 year mean, Anonymous 1982).

## Methods

The insect exclusion experiment took place in a cleared area (about 0.5 ha) adjacent to the woodland where many eucalypt saplings had regenerated. Saplings of the following major tree species were selected for experimentation: *E. viminalis*, *E. melliodora*, *E. blakelyi*, *E. caliginosa*, and *A. floribunda*. Nine saplings of each species were marked (except for *A. floribunda* of which only six individuals of similar size could be located). The saplings were selected for their similarity: height 1–3 m; apparently vigorous well developed canopies; location within 50 m of other individuals of the same species in full sunlight on flat terrain. On each individual, six branches at 1–2 m height above ground level were marked permanently with plastic tags and all leaves numbered sequentially from the base outwards with waterproof marking pens (Lowman 1984). New leaves were numbered as they emerged. All labelling and preliminary measurements were completed during July–September 1982 and the experiment commenced in September 1982. On each sapling, three branches were sprayed fortnightly with Thiodan (a general, non-persistent insecticide containing the active

ingredient 350 g/l Endosulfan) using a small hand sprayer which allowed careful control of the spray. The remaining three marked branches were left as controls and were not sprayed. The spraying continued over 4 months, during the major growth flush of the saplings (September–January). At the end of each month, the following information on the branches was recorded: stem elongation, number of new leaves flushed, number of leaves senesced, number of buds produced, and grazing damage to each leaf. The methods for measuring defoliation of individual leaves are described elsewhere (Lowman 1984). Wilcoxon Sums statistical tests were used to compare sprayed and control branches.

## Results

Throughout the 4 months, the sprayed branches were different from the controls in both herbivory and growth (Fig. 1). In all species, the sprayed branches produced a higher number of new leaves per branch, with the *main flush occurring in October. Consequently,* sprayed branches had greater total numbers of leaves (both new and old); there was one exception, a sapling of *E. viminalis* whose control branches retained more of their old leaves than did the sprayed branches. In some cases (e.g. *A. floribunda* and *E. melliodora*), the control branches actually showed an overall loss of leaves per branch over the experimental period, since the number of leaves flushed was less than the number that senesced. Stem growth was greater in sprayed than in unsprayed branches for all species.

Insect damage both to new leaves and to entire branches with leaves of all ages was higher in the control branches than in the sprayed ones. Herbivory of most new leaves occurred within 1–2 months after they flushed. Insects selectively grazed new foliage; new leaves suffered 1–3 times more herbivory than did entire branches. New leaves of control

→

FIG. 1. Mean growth and herbivory changes of five species of eucalypt saplings over 5 months: (o) = control branches; (e) = insecticide-sprayed branches. Each point represents the cumulative change from the commencement of the trial (± s.e.m.): (a) Total number of new leaves per branch; (b) Total number of leaves per branch; (c) Stem growth; (d) New leaf herbivory and (e) Entire branch herbivory.

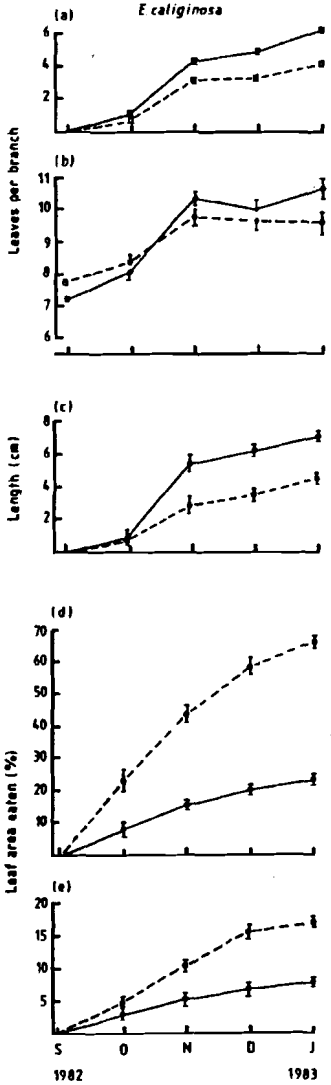





FIG. 1. continued.

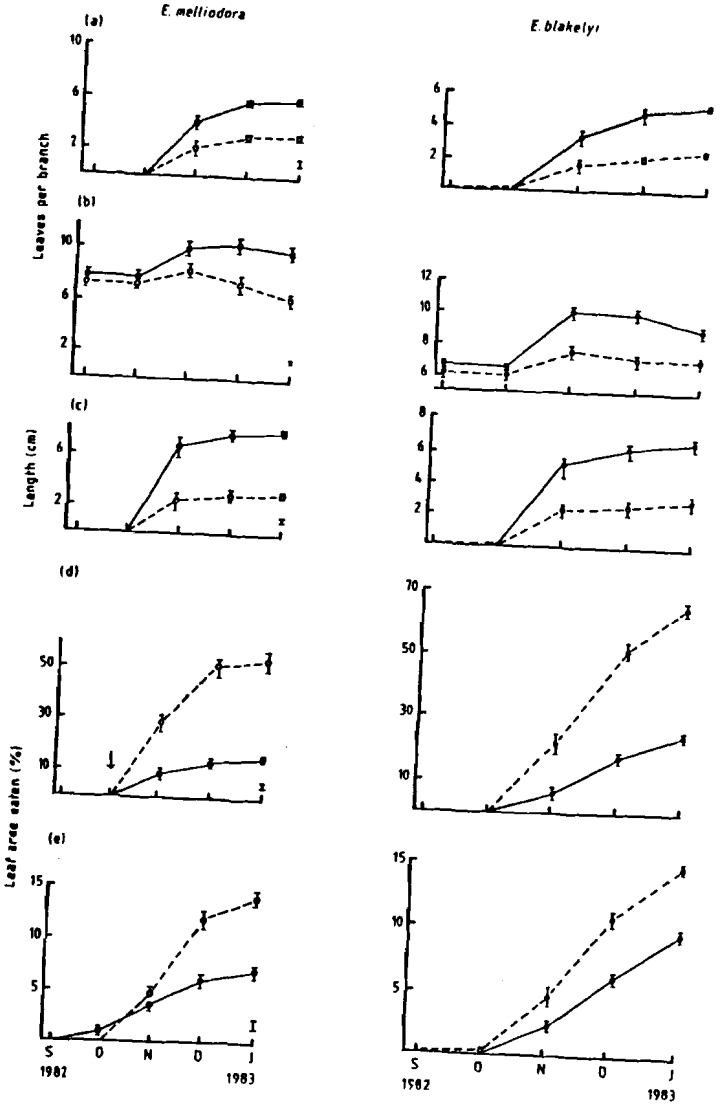
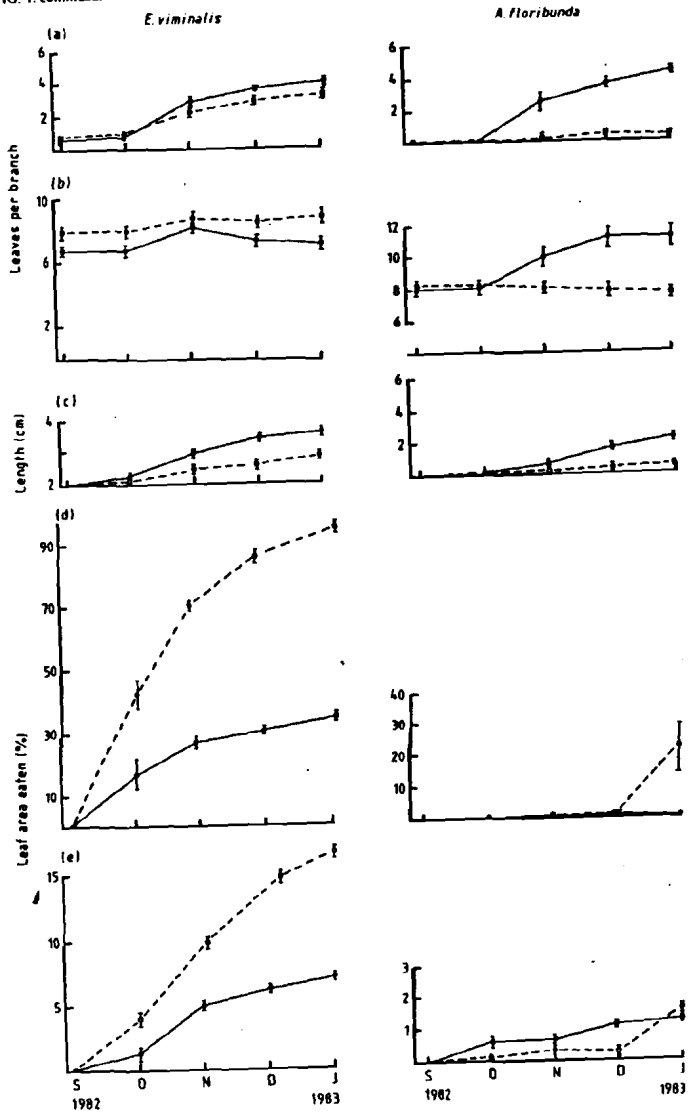


FIG. 1. continued.






branches lost up to 70% of their mean area in *E. caliginosa* and *E. blakelyi*, and 97% leaf area per new leaf in *E. viminalis* when defoliation levels were cumulated at the end of the 4 month period. In contrast, the new leaves of sprayed branches of these species suffered only one-third the loss of leaf area occurring on control branches: 20% for *E. caliginosa* and *E. blakelyi*, and 35% for *E. viminalis*. Mean area of leaf loss on entire sprayed branches (including both young and old leaves) ranged from as high as 20% for *E. caliginosa* and *E. viminalis* to less than 2% for *Angophora floribunda*.

The mean differences between sprayed and control branches for all five species are summarized in Table 1. The mean number of leaves per branch before commencement of the experiment was the same for both treatments (7.4 leaves), and the average leaf areas previously consumed by herbivores were similar (11.3% sprayed, 11.5% controls). The herbivory levels on the control branches had approximately doubled by 4 months after treatment to 20.4% mean leaf area loss per leaf. In contrast, the sprayed branches showed a decrease in herbivory to 10.3%, presumably since new leaves sustained little or no defoliation, and mature leaves showed little damage beyond that previously acquired. Sprayed branches produced an average of five leaves, whereas control branches produced only an average of 2.8 leaves. Average losses of leaf area were 61.2% and 19.4% for control and sprayed branches, respectively. Both stem growth and bud production were generally higher on the sprayed branches, although not consistently so for all species in the latter.

These observed differences between control and sprayed branches were tested for significance between treatments (Table 2). In four of the five species, there were no significant differences in 'total branch herbivory' between the sprayed and control branches before the experiment, but all showed significant differences after the experiment, with control branches having been much more heavily defoliated. One species (*A. floribunda*) exhibited the reverse trend; however, there were fewer saplings available for study of this species, and herbivory was negligible on all branches (Fig. 1). Similarly, there were too few replicates available in three species to perform statistical tests on 'new leaf herbivory'. This was because not all saplings underwent ade-

TABLE 1. Mean cumulative differences in all measured aspects of growth and insect herbivory between sprayed and unsprayed branches on saplings of five tree species*

| | With insecticide | | | | | | | Without insecticide | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant characteristic | 1 | 2 | 3 | 4 | 5 | $\bar{x}$ | (s.e.m.) | 1 | 2 | 3 | 4 | 5 | $\bar{x}$ | (s.e.m.) |
| Number of leaves before | 7.1† | 7.6 | 6.6 | 7.5 | 8.0 | 7.4 | 0.2 | 7.7 | 7.2 | 6.0 | 8.0 | 8.1 | 7.4 | 0.4 |
| Percentage herbivory before | 10.6 | 9.2 | 15.6 | 8.8 | 12.1 | 11.3 | 1.2 | 10.6 | 13.4 | 17.0 | 8.9 | 7.6 | 11.5 | 1.7 |
| Number of leaves after | 10.6 | 9.1 | 8.7 | 7.4 | 11.1 | 9.4 | 0.7 | 9.5 | 3.8 | 7.8 | 9.0 | 7.8 | 8.0 | 0.6 |
| Percentage herbivory after | 9.9 | 8.6 | 14.4 | 9.7 | 8.7 | 10.3 | 1.1 | 17.8 | 23.5 | 27.6 | 20.1 | 13.0 | 20.4 | 2.5 |
| Number of new leaves produced | 6.3 | 5.9 | 5.2 | 3.5 | 4.1 | 5.0 | 0.5 | 4.2 | 3.6 | 2.6 | 3.4 | 0.3 | 2.8 | 0.7 |
| *New leaf herbivory* (%) | 23.6 | 13.6 | 24.0 | 34.3 | 1.8 | 19.4 | 5.5 | 66.1 | 52.5 | 67.8 | 97.1 | 22.5 | 61.2 | 12.1 |
| Stem growth | 7.7 | 6.9 | 6.6 | 2.6 | 2.1 | 5.2 | 1.2 | 4.2 | 3.2 | 2.8 | 1.8 | 0.1 | 2.4 | 0.7 |
| Number of buds produced | 1.5 | 1.4 | 0.6 | 0.4 | 1.6 | 1.1 | 0.3 | 1.0 | 1.3 | 1.2 | 1.3 | 0.6 | 1.1 | 0.1 |

*Species: 1 = *E. caliginosa*, 2 = *E. melliodora*, 3 = *E. blakelyi*, 4 = *E. viminalis*, 5 = *A. floribunda*. †Each number represents the mean of three branches of five trees.

TABLE 2. Statistical differences (Wilcoxon Sums tests) between sprayed and unsprayed eucalypt branches in total branch herbivory (before and after treatment)

| Species | Total branch herbivory | | New leaf herbivory | Stem growth |
|---|---|---|---|---|
| | Before | After | After | After |
| *E. caliginosa* | NS | $P<0.05$ | $0.025>P>0.01$ | NS |
| *E. melliodora* | NS | $0.05>P>0.025$ | $P=0.01$ | $P=0.025$ |
| *E. blakelyi* | NS | $P<0.003$ | – | $0.025>P>0.01$ |
| *E. viminalis* | NS | $0.025>P>0.01$ | – | NS |
| *A. floribunda* | $P=0.05$ | NS | – | – |

quate leaf flushing during the experiment: all species showed growth (Fig. 1) in some branches, but unless leaves flushed in at least six of the nine replicate saplings, the Wilcoxon Sums test was not performed. In the two species where adequate replication occurred, sprayed branches showed significantly lower herbivory than did controls. Stem growth, however, showed significant differences in only two of the four species tested. This result implies that perhaps growth-related activities do not show a strong, immediate response to defoliation levels; rather, growth differences may be an indirect consequence of herbivory that become apparent only after a lapse of time.

## Discussion

Spraying with insecticides clearly reduces the amount of herbivory (especially on young leaves), increases stem growth and production of new leaves, but does not greatly affect bud production, at least over a short time (4 months). The likely sequence of responses is: (i) the insecticide kills insects or makes the sprayed foliage less palatable to them, thereby reducing their consumption of it and leaving a greater leaf area intact; (ii) the larger leaf area produces a greater amount of photosynthate, leading to (iii) an enhancement of growth. Like many studies (e.g. Morrow & La Marche 1978; Mackay *et al.* 1984) the present experiment can not rule out a direct stimulatory effect of the insecticide itself upon growth. However, the present authors consider this explanation less likely than the one postulated above, especially in view of the marked differences in herbivory rates between sprayed and unsprayed branches. Glasshouse experiments have shown that seedlings of one species (*E. blakelyi*) showed no growth response to insecticide application (Nadolny 1984).

This study deals only with relatively short-term effects. There may well be additional long-term ones. Morrow & La Marche (1978) noted temporal differences in the effect of spraying upon growth. Increased growth occurred during the first season on the sprayed halves of trees because translocation remained localized within the sprayed half. However, in the following year growth in diameter also improved in the control half because photosynthate was drawn down to the roots over winter and then distributed to both halves the next spring. The New England region of Australia has suffered extensively from rural dieback in recent decades and all of the species of trees in the present study have been affected (Mackay *et al.* 1984; Heatwole & Lowman 1986). Herbivorous insects, expecially christmas beetles (*Anoplognathus*) and chrysomelid beetles have been suggested as a major cause of stress causing, or at least contributing to, this malady (reviewed by Old *et al.* 1981). There are few empirical data relevant to this claim, since most studies have been visual assessments of overall crown damage (e.g. Williams & Nadolny 1981; Sinden *et al.* 1983; Mackay *et al.* 1984) but not quantified measurements of leaf area losses. This study indicates that saplings of species involved in dieback show reduced growth coincident with increased herbivory, even when in apparent health. Severe and repeated defoliation such as that observed to be associated with dieback may well contribute to a loss of vigour of trees and make them more susceptible to other stresses.

## Acknowledgments

The authors are grateful to Andrew Burgess, Chris Donovan, Wayne Higgins, David Lowman and Karen Scott for assistance in the field, and to the NSW Forestry Commission for a permit to conduct research in Eastwood State Forest. This work was funded by the Australian Research Grants Scheme. Sandra Higgins typed the manuscript.

## References

Anonymous (1982) A tabular summary of 50 years of rainfall in the Armidale region published in the 6 January 1982 issue of the *Armidale Express*.

Heatwole H. & Lowman M. (1986) *Dieback. Death of an Australian Landscape*. Reed Books, Sydney.

Lowman M. D. (1984) An assessment of techniques for measuring herbivory: is rain forest defoliation more intense than we thought? *Biotropica* 16, 264–8.

Mackay S. M., Humphreys F. R., Clark R. V., Nicholson D. W. & Lind P. R. (1984) Native tree dieback and mortality on the New England tablelands of New South Wales. Forestry Commission NSW. Research Paper.

Morrow P. A. & La Marche V. C. (1978) Tree ring evidence for chronic insect suppression of productivity in subalpine *Eucalyptus*. *Science* 201, 1244–6.



Nadolny C. (1984) Eucalypt dieback on the Northern Tablelands of NSW, MSc thesis, University of New England, Armidale.

Old K. M., Kile G. A. & Ohmart C. P. (eds) (1981) *Eucalypt Dieback in Forests and Woodlands*. CSIRO, Melbourne.

Sinden J. A., Jones A. D. & Fleming P. J. (1983) Relationships between eucalypt dieback and farm income, stocking rate and land value in southern New England, New South Wales. University of New England, Armidale.

Williams J. B. & Nadolny C. (1981) A survey of eucalypt species involved in New England dieback. In: *Eucalypt Dieback in Forests and Woodlands* (eds. K. M. Old, G. A. Kile and C. P. Ohmart) pp. 74–86. CSIRO, Australia.

(Final manuscript received June 1986)