SUITABILITY OF VALUED EUCALYPT SPECIES FOR THE LARVAL DEVELOPMENT OF THE GUM LEAF SKELETONISER, *URABA LUGENS*

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ABSTRACT

Gum leaf skeletoniser, *Uraba lugens*, is native to Australia and is a common defoliator of *Eucalyptus*. *Uraba lugens* was first recorded in New Zealand in 1992 and is now well established in the Auckland region. As *U. lugens* has the potential to damage *Eucalyptus* in New Zealand, no-choice larval development trials were used to assess the ability of *U. lugens* larvae to develop on 18 *Eucalyptus* species that are highly valued in New Zealand. *Eucalyptus nitens* and *E. nicholii* were the most suitable larval hosts as larval mortality was low and development time was brief. Larvae reared on *E. fastigata* had a rapid development time and high growth rates resulting in heavy female pupae, although larval mortality was in the intermediate range. Species that were least suitable for *U. lugens* development included *Corymbia maculata*, *E. microcorys*, the juvenile foliage of *E. globulus globulus* and *E. globulus maidenii*.

Keywords: *Eucalyptus*, larvae, development, *Uraba lugens*, gum leaf skeletoniser.

INTRODUCTION

The gum leaf skeletoniser, *Uraba lugens* Walker (Lepidoptera: Nolidae), is native to all states of Australia except the Northern Territory (Phillips 1992). It has between 11 and 13 larval instars that defoliate plants from the genus *Eucalyptus* and other closely related genera including *Angophora* and *Tristania* (Brimblecombe 1962; Campbell 1962; Morgan & Cobbinah 1977; Cobbinah 1983; Strelein 1988). *Uraba lugens* was first recorded in New Zealand in 1992 and it is now well established in the Auckland region of the North Island. Field surveys in 2003 found that *U. lugens* had spread across 20,000 ha of the greater Auckland region (Kriticos et al. 2004) and had been collected from 39 different *Eucalyptus* spp. (Forest Health database 2005).

The genus *Eucalyptus* (Family Myrtaceae: Subfamily Leptospermoideae) contains well over 700 species (Brooker & Kleinig 1994), virtually all of which are endemic to Australia. In New Zealand, herbarium records indicate that 239 *Eucalyptus* spp. have been collected locally (C. Ecroyd, unpubl. data), and it is estimated that approximately 40,000 ha of eucalypts have been planted (Nicholas 2002). Eucalypts are planted as amenity and shelter-belt trees, for firewood, soil erosion control and more recently as a plantation species for durable timber or hardwood chips (Miller et al. 1992; Barr 1996).

The selection of a suitable plant host for larval development is primarily the role of adult female *U. lugens*. Studies by Morgan & Cobbinah (1977) have focussed on *U. lugens* oviposition-host selection and larval establishment and survival to 4th instar on a range of *Eucalyptus* spp. They concluded that the selection of oviposition-hosts by *U. lugens* included plants that ranged from highly suitable to highly unsuitable for larval establishment and development. In comparison, studies by Cobbinah (1983, 1985) explored the suitability of a selection of *Eucalyptus* spp. for *U. lugens* development from egg to adult emergence. The present paper reports on laboratory based no-choice larval

development trials that were used to assess the ability of *U. lugens* larvae to develop from neonate to adult on 18 *Eucalyptus* spp. that are considered to be either economically or aesthetically valued species in New Zealand.

MATERIALS AND METHODS

The ability of *U. lugens* to develop on *Eucalyptus* spp. and *Corymbia* spp. was determined under laboratory conditions at HortResearch, Auckland, New Zealand. Plant species were selected to represent significant New Zealand plantation timber, shelter-belt and ornamental species. The 18 species tested included seven members of the subgenus *Monocalyptus* (*E. regnans*, *E. obliqua*, *E. fastigata*, *E. globoidea*, *E. laevopinea*, *E. muelleriana* and *E. pilularis*), ten members of the subgenus *Symphyomyrtus* (*E. botryoides*, *E. cinerea*, *E. cordata*, *E. globulus globulus*, *E. globulus maidenii*, *E. microcorys*, *E. nicholii*, *E. nitens*, *E. saligna* and *E. viminalis*) and one member of the subgenus *Corymbia* (*Corymbia maculata*). Fully expanded adult-phase foliage of all species was tested as well as the juvenile foliage of *E. nitens* and *E. globulus globulus*. In the text, all references to foliage refer to adult foliage unless indicated to be juvenile by "(J)" following the species name.

No-choice larval survival and development trials were performed under controlled conditions set to simulate Auckland summer weather conditions ($22 \pm 1.5^\circ\text{C}$, 16:8 h light:dark, 75% RH). Sprigs of foliage of each plant species were placed into a two-pottle test arena (535 ml), where the stem of the foliage was held in water and separated from the upper test chamber (395 ml) by a dense paper towelling bung. Each test arena contained foliage from only one plant species and 10 replicates of each plant species were prepared. Larvae (1st-3rd instar) for use in the trial were field collected from south Auckland in January 2004. Approximately 10 individuals were transferred to foliage in each arena by "herding" larvae into a corner of a leaf and removing that corner from the rest of the leaf with a scalpel. The leaf fragment bearing the larvae was then glued onto the test foliage using Selley's KwikGripTM. The instar of larvae transferred to each arena was noted. Arenas and foliage were replaced at least weekly to minimise potential disease contaminants.

Larval mortality was recorded weekly until all larvae had either died or pupated. Once larvae had spun a cocoon, they were placed into individual 30 ml plastic cups. Approximately three days later, pupae were removed from their cocoons, weighed and sexed before being returned to the 30 ml plastic cups and checked daily for adult emergence. Pupal weight was used as an indication of potential fecundity of the adult female (Cobbinah 1983, 1985). A sub-sample of 97 adults (48 males and 49 females) was weighed to determine the relationship between adult weight and pupal weight. Knowledge of this relationship was considered important if the removal of pupae from their pupal case for weighing was found to increase pupal mortality.

All statistical analyses were performed using SAS (Version 8). Logistic regression (with the instar used to inoculate each replicate treated as a covariate) was used to test for differences in larval mortality between plant species. Mortality at 16 weeks was analysed, and larvae that had died from fungal infection were excluded from the analysis. Mortality was significantly lower ($P=0.0028$) and days to pupation significantly less ($P<0.0001$) when assays were initiated with older instar larvae. Therefore, an analysis of covariance (with the instar used to inoculate each replicate treated as a covariate) was used to test for differences between plant species in days to pupation. Data were log-transformed and pair-wise comparisons of species were made using the least significant difference (LSD) multiple comparison procedure. Growth rate was calculated using the formula: $\text{growth rate} = \text{pupal weight (mg)} / \text{development time (number days from egg hatch to pupation)}$. Pupation was used rather than adult emergence due to the high levels of mortality presumably caused by the removal of pupae from their cocoons for weighing and sexing. ANOVA was used to test for differences between species for pupal weight and growth rate. Pair-wise comparisons of species were made using the LSD multiple comparison procedure. Linear regression was used to examine the relationship between adult weight and pupal weight for both males and females.

RESULTS

Uraba lugens larval mortality 16 weeks after the start of the experiment varied significantly between plant species ($P < 0.0001$), with more than 85% mortality occurring on *E. globulus maidenii*, *E. botryoides*, *E. globulus globulus* (J), *E. laevopinea* and *C. maculata* foliage (Table 1). In contrast, low mortality (ranging between 28-35%) was recorded on *E. obliqua*, *E. nicholii* and *E. nitens* foliage. Mortality of *U. lugens* larvae feeding on the remaining 12 species was intermediate, varying between 40-80% (Table 1). Variation in percentage mortality between replicates on the same plant species was high (Table 1), with *U. lugens* failing to establish on at least one *E. globulus maidenii*, *E. cinerea*, *C. maculata*, *E. obliqua*, *E. globoidea* and *E. botryoides* replicate. However, on all plant species tested a proportion of individuals reached pupation.

The growth rate of both males and females varied significantly between different plant species ($P < 0.0001$). Females reared on *E. nitens* and *E. fastigata* had the fastest growth rate while those reared on *E. microcorys*, *C. maculata* and *E. globulus globulus* (J) had the slowest growth rate (Table 1). Males reared on *E. fastigata*, *E. nicholii*, *E. cinerea*, *E. cordata*, *E. obliqua* and *E. nitens* had the fastest growth rate while those fed on *E. microcorys*, *C. maculata* and *E. globulus maidenii* and *E. globulus globulus* (J) had the slowest growth rate (Table 1). Growth rate of female larvae on *E. globulus maidenii* and *E. pilularis* were not calculated as no females pupated on these species.

There were significant differences in development time of *U. lugens* larvae on different plant species ($P < 0.0001$). On average, larvae developing on *E. nitens*, *E. cordata*, *E. nicholii*, *E. fastigata* and *E. saligna* reached pupation within 44 days while the mean development time of larvae on all other species was greater than 47 days (Table 1). The mean development time of larvae on *E. globulus maidenii* was the longest (71 days) (Table 1).

There were significant differences in pupal weight of both males and females on different plant species ($P < 0.0001$). The heaviest female pupae were produced on *E. fastigata*, *E. regnans*, *E. botryoides* and *E. laevopinea* and the lightest were produced on *E. microcorys* and *C. maculata* (Table 1). The heaviest male pupae were produced on *E. regnans*, *E. obliqua* and *E. botryoides*, while the lightest were produced on *E. microcorys*, *C. maculata* and *E. globulus maidenii*. The pupal weight of females on *E. globulus maidenii* and *E. pilularis* were not calculated as no females pupated on these species. A significant positive correlation was found between adult weight and pupal weight of both male and female *U. lugens* (males: $y = 0.0132x - 0.3469$, $r^2 = 0.38$, $P < 0.05$; females: $y = 0.1983x - 1.1013$, $r^2 = 0.46$, $P < 0.05$).

DISCUSSION

Uraba lugens is a eucalypt specialist since the majority of feeding records in both Australia and New Zealand have been on *Eucalyptus* spp. (Brimblecombe 1962; Campbell 1962, 1966; Morgan & Cobbinah 1977; Cobbinah 1983; Strelein 1988). Of particular note is the observation that *U. lugens* may oviposit on many species of *Eucalyptus* that are unsuitable for larval development, suggesting that the criteria used to select oviposition hosts are different from those that govern the suitability of trees as a larval food source (Morgan & Cobbinah 1977).

The differences in mortality, development time and pupal weight observed in this trial can be considered to indicate differences in the suitability of different plant species for larval survival. However, a proportion of *U. lugens* individuals survived to pupation on all the species tested. Of the plant species tested, *E. nitens* and *E. nicholii* were considered the most suitable larval food plants as larval mortality was low and development time was short. Farr (2002) also lists *E. nicholii* as a "good food plant" defined by percentage larval survival past the fourth instar being 50% or greater along with a relatively rapid development time. Larvae reared on *E. fastigata* also had a rapid development time, high growth rates and heavy female pupae although larval mortality was in the intermediate range. Without field data, it is difficult to interpret the impact of intermediate mortality of *U. lugens* populations on *E. fastigata* in the field.

TABLE 1: Comparison of larval mortality and growth rate, development time, total number of pupae successfully developed and pupal weight between *Uraba lugens* reared on a variety of *Eucalyptus* spp. Values followed by the same letter in the same column do not differ significantly (P=0.05).

Genus and species	Eucalypt usage class ¹	Reps ²	Mortality week 16 (%)	Mortality range (%)	Growth rate (mg/day) ³		Development time (days)	No. female pupae (total)	Pupal weight (mg) ³	
					Female	Male			Female	Male
<i>E. globulus maidenii</i>	P	9	97.8 ^a	80-100	n.a.	0.45	71.3 ^a	0 (4)	n.a.	33.9
<i>E. botryoides</i>	S	10	90.4 ^{ab}	60-100	1.64	0.99	47.5 ^{cde} gh	1 (4)	96.5	53.2
<i>E. globulus globulus</i> (J) ⁴	P	10	88.0 ^{abc}	64-100	0.76	0.54	65.6 ^{ab}	7 (12)	58.2	37.5
<i>E. laevopinea</i>	P	10	87.8 ^{abc}	50-100	1.41	0.81	53.0 ^{cde}	5 (9)	92.3	46.7
<i>Corymbia maculata</i>	P	9	85.0 ^{abc}	70-100	0.89	0.60	53.9 ^{cde}	2 (6)	53.1	36.8
<i>E. muelleriana</i>	P	10	79.6 ^{abcd}	60-100	1.17	0.78	59.0 ^{bc}	4 (12)	80.6	42.9
<i>E. microcorys</i>	P	10	70.4 ^{bcde}	10-100	0.84 ^d	0.52 ^e	64.3 ^{ab}	10 (22)	58.0 ^f	35.6 ^f
<i>E. saligna</i>	S	10	66.6 ^{cdef}	40-100	1.46 ^b	0.99 ^{ab}	41.9 ^h	10 (22)	76.1 ^e	46.5 ^{de}
<i>E. globoides</i>	P	10	60.6 ^{defg}	10-100	1.51 ^b	0.97 ^b	47.6 ^{efg}	13 (30)	85.1 ^{abcde}	51.2 ^{abc}
<i>E. fastigata</i>	P	10	55.6 ^{defg}	0-90	1.75 ^a	1.02 ^{ab}	42.2 ^h	11 (31)	92.5 ^a	47.6 ^{cde}
<i>E. pilularis</i>	P	10	54.1 ^{efg}	0-90	n.a.	0.83 ^d	49.1 ^{def}	0 (20)	n.a.	45.7 ^e
<i>E. viminalis</i>	S	10	53.0 ^{efgh}	0-100	1.51 ^b	0.95 ^{bc}	48.7 ^{ef}	15 (38)	87.0 ^{abcd}	51.3 ^{abc}
<i>E. globulus globulus</i>	P	10	51.3 ^{efgh}	8-90	1.19 ^c	0.77 ^d	58.4 ^{bc}	15 (35)	77.8 ^{de}	46.3 ^{de}
<i>E. cordata</i>	O	10	50.6 ^{efgh}	23-100	1.50 ^b	1.02 ^{ab}	43.8 ^{fgh}	19 (40)	80.3 ^{cde}	50.4 ^{abcd}
<i>E. regnans</i>	P	10	42.9 ^{fgh}	8-70	1.44 ^b	0.86 ^{cd}	54.0 ^{cd}	24 (50)	90.8 ^a	52.1 ^{ab}
<i>E. cinerea</i>	O	10	40.6 ^{fgh}	0-100	1.60 ^{ab}	1.00 ^{ab}	47.0 ^{efgh}	24 (45)	85.9 ^{abcd}	49.6 ^{abcde}
<i>E. nitens</i> (J) ⁴	P	5	39.8 ^{efgh}	0-100	1.46 ^b	0.95 ^{bc}	47.1 ^{efgh}	11 (24)	78.3 ^{de}	48.5 ^{bcde}
<i>E. obliqua</i>	P	10	34.2 ^{gh}	10-100	1.58 ^{ab}	1.00 ^{ab}	47.6 ^{efg}	32 (64)	89.5 ^{abc}	53.4 ^a
<i>E. nicholii</i>	O	9	33.2 ^{gh}	10-100	1.54 ^b	1.00 ^{ab}	43.5 ^{gh}	18 (43)	81.1 ^{bcde}	48.7 ^{bcde}
<i>E. nitens</i>	P	10	28.0 ^h	10-66	1.73 ^a	1.08 ^a	44.0 ^{gh}	27 (53)	89.6 ^{ab}	51.2 ^{abc}

¹P=plantation timber, S=shelter-belt and O=ornamental species.

²Excludes replicates that were entirely destroyed by fungal infection (*Beauveria*).

³Species with fewer than 10 individuals of the same sex were excluded from the analysis. However the mean is presented in this table.

⁴Juvenile foliage.

Eucalypt species that were the least suitable food plants included *C. maculata*, *E. microcorys*, *E. globulus globulus* (J) and *E. globulus maidenii*. Larval feeding on these species led to high mortality, long development times and low pupal weight, all of which are generally attributed to the presence of antifeedants and/or nutritional deficiencies (Cobbinah 1985). Farrow (1996) described *E. globulus* to be a poor host for *U. lugens* in Australia and Cobbinah (1985) reported similar results with *E. globulus* when *U. lugens* mortality, development time, growth rate and pupal weight were compared between six *Eucalyptus* spp.

Cobbinah (1985) also reported that on one of the species regularly selected for oviposition in the field (*E. gardneri*), *U. lugens* larval mortality was high. Of the surviving larvae on this plant species, larval development was slow, but their pupal weights were higher than those reared on the other food plants. The high pupal weights, according to Cobbinah (1983, 1985), indicate the high potential fecundity of surviving females. Similar results were observed using *E. botryoides* and *E. laevopinea* foliage in this trial. Cobbinah (1985) suggested that this response might be due to the presence of antifeedants and/or toxins in these plant species that act like an insecticide, selectively killing the most susceptible larvae while the superior individuals survive. In order for this to occur, Cobbinah (1985) proposed that survivors would have to possess a mechanism or the ability to develop a mechanism to overcome the toxic components of the diet. Selection of poor larval food plants for oviposition by females therefore may provide an avenue for the development of resistant strains or biotypes of *U. lugens*. However, for this to occur there would need to be a genetic basis for survival on the poor food plants and mating would have to occur between individuals that complete their development on the poor food plant (Cobbinah 1985).

Eucalyptus nitens and *E. fastigata* are important commercial plantation and farm forestry species in New Zealand (Nicholas 2002). The planting of *E. nitens* (ash) in New Zealand was particularly popular during the 1990s, but by 2002 preference had shifted to include *E. fastigata* (ash) and stringybark species, such as *E. laevopinea*, *E. globoidea* and *E. muelleriana* (Nicholas 2002; Nicholas & Hay 2003). If *U. lugens* larval survival and female fecundity (expressed as pupal weight) occurred in the field at a similar level to that recorded in this trial, this insect could become a serious pest for the New Zealand forestry industry. However, the survival of *U. lugens* larvae alone is not necessarily a good indicator of their impact on the growth of trees. The impact of *U. lugens* on tree growth also depends on factors such as the growth rate of the tree, the timing of insect damage and the insect population present. Studies are currently being completed to understand these additional factors and to predict the impact of *U. lugens* damage on the growth of trees in different regions of New Zealand (D. Kriticos, unpubl. data).

In the early 1900s, varieties of *E. globulus* were the most commonly planted commercial eucalypt in the country (Nicholas 2002). However, the arrival of Australian Eucalyptus tortoise beetle, *Paropsis charybdis* Stål (Coleoptera: Chrysomelidae) and the subsequent leaf damage suffered by these plantations, removed the *E. globulus* species complex from favour (Nicholas 2002). The results of this trial indicate that both *E. globulus globulus* (J) and *E. globulus maidenii* are relatively poor larval food plants for *U. lugens*, although it is likely that the combined impact of *U. lugens* and *P. charybdis* would be damaging for these eucalypts.

The stringybarks, *Corymbia maculata* and *E. microcorys*, are not widely planted for commercial forestry in New Zealand at present, although there has been a resurgence of interest in these species since the release of results of experimental plantings by the New Zealand Forest Service and farm foresters in 2003 (Nicholas & Hay 2003). Both of these species have been recorded as suitable oviposition hosts for *U. lugens* (Morgan & Cobbinah 1977). However, results from the present trial indicate larval survival may be poor, and hence damage could be minimal.

While most of the focus of research on the impact of *U. lugens* on *Eucalyptus* in New Zealand is targeting the potential for this insect to impact on the forestry industry, there are other concerns regarding the impact of the insect on the aesthetic value of trees in

urban areas and on human health. As the larvae of *U. lugens* are covered in stinging hairs, the development of large populations of *U. lugens* on trees in urban streets, school grounds and parks has become a public concern. For example, *Eucalyptus nicholii* is one species that is commonly planted in urban areas, and from the results of this trial, is a very suitable larval food plant for *U. lugens*.

In conclusion, while field and laboratory trials have now been performed to examine the oviposition preferences (Morgan & Cobbinah 1977) and the suitability of various eucalypts for the development of *U. lugens* larvae (Cobbinah 1983, 1985; this paper), further information on the population dynamics, potential distribution and impact of this pest on tree growth is required before the impact of *U. lugens* on eucalypts in New Zealand can be adequately predicted.

ACKNOWLEDGEMENTS

The authors would like to thank Toni Withers, Darren Kriticos and Sarah Mansfield for developing the experiment concept and applying for funding to support this research. Financial support was provided by the Ministry of Agriculture and Forestry. Thanks go to Denis Hocking for co-ordinating the delivery of foliage to HortResearch for use in this experiment, to all the foliage suppliers and to Mike Wilcox for confirming plant species identifications. The assistance of Vigil staff in the collection of *U. lugens* larvae is gratefully acknowledged, as is laboratory assistance from Natalie Page and Asha Chhagan and statistical advice from Patrick Connolly and Mark Kimberley. The authors would also like to thank John Charles for his guidance on experimental techniques and data presentation and Toni Withers, Darren Kriticos, Phillippa Stephens and Shaun Forgie for their invaluable comments on earlier versions of this manuscript.

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