

Floral nectar versus honeydew as food for wasp parasitoids: implications for pest management in eucalypt plantations

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Summary

The longevities of two species of native wasp parasitoid (*Heteropelma scaposum* (Morley) and *Habronyx pammi* (Gauld)) given floral nectar and honeydew from scale insects are compared. These parasitoids kill autumn gum moth (*Mnesampela privata* (Guenée)) which can outbreak in eucalypt plantations and cause considerable defoliation. The longevities of male *He. scaposum* given access to flowering *Alyssum maritimum* and *Aster* 'Easter Daisy' (both exotics) were no different from those of starved wasps. Hence, inter-row sowings of these plants in plantations on ex-pasture sites are unlikely to benefit these parasitoids. Compared to starved individuals, males of both species usually lived longer when given access to *Eucalyptus globulus* subsp. *globulus* leaves. Leaves from the previous season enabled male *He. scaposum* to live longer than did current season's leaves. The inference that it was honeydew on the surfaces of *E. globulus* subsp. *globulus* leaves that increased the longevities of both species of wasp was supported when *Ha. pammi* were found to live almost three times as long as starved wasps when provided with branchlets supporting colonies of live scale insects (*Eriococcus* species). The longevities of female *Ha. pammi* as well as males of a *Pristicerus* species were also increased when they were given access to branchlets with scale insect colonies. Both *He. scaposum* and *Ha. pammi* were seen feeding on honeydew in the wild (but not on flowers). Appreciating that the presence of scale insects on some plantation trees can benefit native parasitoids is in keeping with an ecologically sustainable approach to pest management.

Keywords: forest plantations; insect pests; beneficial insects; natural enemies; parasitoids; interactions; feeding behaviour; biological control; integrated pest management; *Eucalyptus globulus*; Australia

Introduction

As Australia's reliance on native forests for woodchips is reduced, the need to produce wood and fibre from commercial plantations of *Eucalyptus* will continue to rise. Government and industry plan to establish 3 million ha of plantations (not all eucalypt) by 2020 (National Forest Inventory 2002). In the temperate regions of South Australia, Tasmania, Victoria and Western Australia, these plantations predominantly comprise two bluegum species, namely *Eucalyptus globulus* subsp. *globulus* Labill. (referred to subsequently as *E. globulus*, Tasmanian bluegum) and *E. nitens* (Dean & Maiden) Maiden (shining gum).

A wide variety of native Australian insects feed on *E. globulus* and *E. nitens* (Elliott *et al.* 1998). One of these insects, the autumn gum moth (*Mnesampela privata*), has become of particular concern because populations can outbreak and cause considerable defoliation of plantation eucalypts (Steinbauer *et al.* 2001). Usually, large populations of *M. privata* larvae are controlled with broad-spectrum insecticides, although a lepidopteran-specific insecticide has also been found to be effective (Elek *et al.* 2003). In Tasmania, the role of beneficial insects (or natural enemies) in regulating pests, specifically the leaf beetle *Chrysophtharta bimaculata* (Olivier), has long been recognised. For example, control of *C. bimaculata* by insecticide is advised only if populations of young larvae are not significantly reduced by natural mortality (Elliott *et al.* 1992). Recognition that high levels of biological control could reduce or even negate the need for insecticides has increased the focus in Australia on understanding of the identity, biology and ecology of native beneficial insects (Steinbauer and Clarke 1995; Schumacher *et al.* 2000; Naumann and Steinbauer 2001; Short *et al.* 2002).

Many beneficial insects require both hosts for reproduction and energy from food for host searching (Lewis *et al.* 1998). While native beneficial insects may not be faced with a scarcity of hosts in commercial eucalypt plantations (otherwise there would be no defoliation), we mostly do not know how these insects meet their food requirements. Without this knowledge it is not immediately apparent how plantations might be managed or manipulated in order to favour populations of certain beneficial species. Habitat manipulation for conservation biological control 'is an ecologically based approach aimed at favouring natural enemies and enhancing biological control in agricultural systems' (Landis *et al.* 2000); the potential benefits for beneficial insects of greater diversity of vegetation in eucalypt plantations was raised by Abbott (1993). Because eucalypts are native to Australia, and commercial plantations are often completely or partially integrated with native vegetation, the industry is fortunate that an ecosystem service such as pest management, which is provided by native beneficial insects, does not have to be initiated *de novo* (Strauss 2001). To date, only Mensah and Madden (1994) have investigated ways to enhance the abundance and efficacy of native beneficial insects in eucalypt plantations.

A parasitoid is an insect that requires another insect in which to reproduce, but eventually causes the death of the host (unlike a true parasite which does not kill its host). The wasps *Heteropelma*

scaposum (Morley) and *Habronyx pammi* Gauld are solitary endoparasitoids or koinobionts (family Ichneumonidae, subfamily Anomaloniinae). As adults they lay their eggs into host caterpillars and a single offspring emerges from the host pupae, usually around the time when a moth would otherwise have emerged from the pupae. *Habronyx pammi* has so far only been recorded from *M. privata* (Short 1981). In contrast, *He. scaposum* has been recorded from *M. privata* as well as lepidopteran hosts in the families Lasiocampidae and Noctuidae (Gauld 1984; Lukacs 1999; Schumacher *et al.* 2000; Short *et al.* 2002).

In these studies we investigated whether the longevity of *Ha. pammi* and *He. scaposum* increased when they were given food in the form of nectar from flowers or honeydew from scale insects. The intention was to provide the first insights into the food requirements of some Australian Ichneumonidae that can help regulate populations of *M. privata*. We wanted to consider the implications of the resource needs of these insects for pest management in eucalypt plantations.

Materials and methods

The wasps we used were collected from the wild by sweep-netting. Our field observations indicated that *He. scaposum* is most abundant early in autumn, whereas *Ha. pammi* is most abundant in late autumn and early winter. In both species, males are more abundant, more vagile, or both, than females. Therefore, our assays were conducted at times of year reflecting our ability to catch sufficient wasps, and most assays (except assay 5) used male wasps. We collected wasps from a plantation of coppiced (in December 1999) *E. globulus* at Lyneham Ridge (Australian Capital Territory, 35°14'S 149°07'E, about 620 m above sea level) that was planted in May 1994.

Assays were conducted in cages measuring 30 cm x 40 cm x 63 cm. The ceilings and three of the walls of the cages were covered in fine white mesh, and at the front was a clear Perspex hinged door. Each door had two circular holes of 10 cm diameter with white mesh sleeves to allow access to the interior when assays were in progress. Cages had no floors but sat on individual metal trays.

These trays were washed thoroughly at the end of each set of assays to remove nectar and honeydew residues that wasps in subsequent assays might feed upon. Assays were conducted in a single outdoor, roofed walk-in cage measuring 210 cm x 203 cm x 203 cm in the grounds of CSIRO Entomology at Black Mountain, Canberra. Therefore, assays were conducted at ambient temperature and relative humidity but these parameters were not measured. These parameters are likely to influence wasp longevity. Because wasps in different assays experienced different ambient temperatures and relative humidities, their longevities would have varied independently of whether they were fed or not. Therefore, the longevities of wasps from different assays could not be validly compared with one another.

Our assays (summarised in Table 1) used potted plants of two species from retail nurseries in Canberra as sources of floral nectar, namely *Alyssum maritimum* ((L.) Lam.) (synonym *Lobularia maritima* (L.) Desv., family Brassicaceae; white and pale purple flowers, from Yarralumla Nursery) and a species of *Aster* 'Easter Daisy' (family Asteraceae; pale purple flowers, from Willow Park Nursery). *Alyssum maritimum* and *Aster* 'Easter Daisy' are not native to Australia. All plants were watered on an as-needs basis and at the same time.

Branchlets of leaves of *E. globulus* were harvested from Lyneham Ridge about half an hour prior to their use in assays. They were provided with water as soon as possible after harvesting. In assays 2 to 4, we did not deliberately harvest *E. globulus* foliage on which honeydew could be seen with the naked eye. We assume that most leaves from the previous growing season (fully expanded leaves) have at least some honeydew on them; current season's leaves (especially very young leaves) are more likely to be free of honeydew or 'clean'. The scale insects responsible for the honeydew were identified as *Eriococcus confusus* Maskell and *E. coriaceus* Maskell (Gullan and Vranjic 1991). In assay 4 we compared current versus last season's leaves because we observed that last season's leaves are often covered in more sooty mould than are current season's leaves. This indicates that the surfaces of these leaves either have more honeydew than those of younger leaves or that honeydew has been on them for longer. Branchlets

Table 1. Summary of longevity assays using male wasp parasitoids

Assay	Duration (days)	Food source	No. of cages	Species of parasitoid	Wasps per cage
1	3	None (control)	4	<i>He. scaposum</i>	2, 2, 1, 1
		<i>A. maritimum</i>	4	As above	2 each
2	4	None (control)	2	<i>He. scaposum</i>	9 each
		<i>Aster</i> 'Easter Daisy'	2	As above	10, 9
		<i>E. globulus</i>	2	As above	9, 8
3A	8	None (control)	2	<i>He. scaposum</i>	6, 5
		<i>E. globulus</i>	2	As above	6 each
3B	8	None (control)	1	<i>Ha. pammi</i>	10 each
		<i>E. globulus</i>	1	As above	10 each
4	11	<i>E. globulus</i> current season	1	<i>He. scaposum</i>	6 each
		<i>E. globulus</i> last season	1	As above	5 each
5	31	None (control)	3	<i>Ha. pammi</i>	6, 6, 5
		<i>E. globulus</i> no scale, no honeydew	3	As above	6, 6, 5
		<i>E. globulus</i> with scale	3	As above	6, 6, 5

N.B. Branchlets in assays 3A and 3B comprised both current and last season's leaves.

were selectively pruned for assay 4 in order to remove leaves of unwanted ages. In order to compare the longevities of wasps when given access to honeydew, we deliberately harvested scale-infested branchlets as well as leaves that did not have honeydew on them for use in assay 5. Scale colonies usually occurred on the stems of branchlets but could occasionally also occur on the midribs of leaves if the infestation was particularly severe.

There was one food source (plant or branchlet) per cage. Wasps denied access to food (control) were kept in empty cages. Because preliminary trials had revealed that wasps would not drink from moistened cotton wicks extruding from water bottles, the mesh walls and roofs of all cages were lightly sprayed with water each time observations were made. We recorded the time (in hours) since the commencement of an assay, and the number of live wasps in each cage, three or four times per day. Wasps were recorded as dead when they would not move after gentle probing with a paintbrush. The influences of different foods on the longevities of wasps were compared using *t*-tests at the 95% confidence level (unless otherwise stated).

Results

Assay 1. We found no statistically significant difference between the longevities of male *He. scaposum* caged in either empty cages or cages where they could access nectar from *A. maritimum* (control versus *Alyssum* nectar: 2.2 ± 0.9 days versus 2.5 ± 0.4 days, respectively, $t = 0.64$ and $P = 0.53$).

Assay 2. Male *He. scaposum* lived for similar lengths of time whether they had access to the nectar of *Aster* ‘Easter Daisy’ flowers or not (control versus *Aster* nectar: 1.9 ± 0.5 days versus 1.8 ± 0.4 days, respectively, $t = 0.16$ and $P = 0.87$). In contrast, male *He. scaposum* lived longer if they had access to *E. globulus* leaves rather than being kept in empty cages (e.g. 2.6 ± 0.4 days, $t = 2.32$ and $P = 0.027$) or given access to *Aster* nectar ($t = 2.76$ and $P = 0.009$).

Assays 3A and 3B. Consistent with the results of assay 2, the longevity of male *He. scaposum* was greater when given access to *E. globulus* leaves rather than being kept in empty cages (control versus *E. globulus* leaves: 2.4 ± 0.5 days versus 3.2 ± 0.6 days, respectively, $t = 2.32$ and $P = 0.031$). In assay 3B the life span of *Ha. pammi* was significantly increased if individuals had access to *E. globulus* leaves (control versus *E. globulus* leaves: 2.6 ± 0.7 days versus 4.3 ± 1.0 days, respectively, $t = 3.05$ and $P = 0.007$).

Assay 4. The results of this assay supported field observations that leaves from last season are often covered in more honeydew

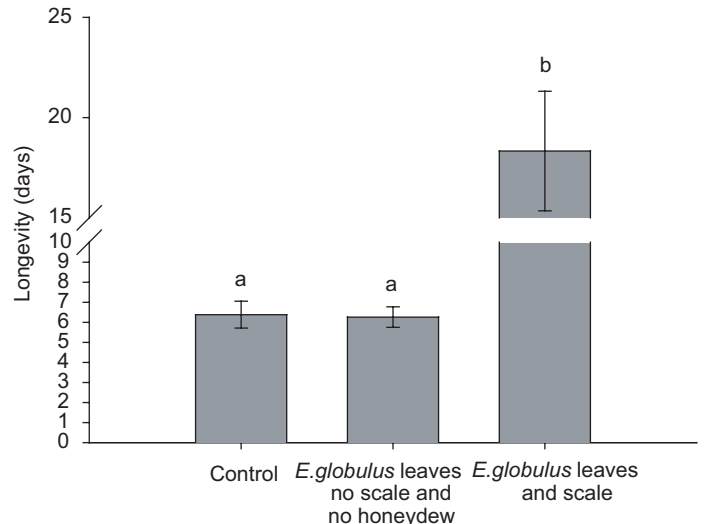


Figure 1. Longevities (means \pm 95% confidence intervals; statistical significances given in the text) of *Habronyx pammi* males denied access to food (control), with *E. globulus* leaves devoid of scale and honeydew, or with *E. globulus* leaves with scale insects

than are current season’s leaves. As a result, male *He. scaposum* that had access to last season’s leaves lived significantly longer than those that had access only to current season’s leaves (new *E. globulus* leaves versus old *E. globulus* leaves: 4.1 ± 1.0 days versus 6.6 ± 2.2 days, respectively, $t = 3.04$ and $P = 0.014$).

Assay 5. This assay confirmed that honeydew from scale insects is the food source for *He. scaposum* and *Ha. pammi* on *E. globulus* leaves and is the reason for their extended life span in assays 2 to 4. The male *Ha. pammi* given access to *E. globulus* leaves and scale-infested stems lived much longer than those denied access to food ($t = 8.29$ and $P \ll 0.001$; Fig. 1). Leaves with scale insects apparently gave the wasps access to more honeydew than clean leaves; the longevity of wasps given the former was much increased over that of those given the latter ($t = 8.46$ and $P \ll 0.001$). Indeed, the longevity of wasps given clean leaves was the same as that of those denied access to any food ($t = 0.29$ and $P = 0.77$).

During assay 5 we were also able to obtain preliminary data on the responses of *He. scaposum* females, *Ha. pammi* females and males of a species of *Pristiceros* to honeydew because our sweep-netting had been particularly fruitful (Table 2; note that all experimental conditions were the same as those for the male wasps). In the cases of the longevities of the *Ha. pammi* females

Table 2. Longevity (days) of individual wasps of other sexes and species of wasp studied during assay 5

Species and sex	Food source		
	None (control)	<i>E. globulus</i> — no scale, no honeydew	<i>E. globulus</i> with scale
<i>He. scaposum</i> females	5.6	8.1	15.6
<i>Ha. pammi</i> females	9.1, 10.1	4.6, 7.0, 7.1	14.1 19.6
<i>Pristiceros</i> sp.* males	5.0, 6.0	5.6, 6.1, 7.7	26.6, 27.7

**Pristiceros* is also a native solitary, larval-pupal endoparasitoid belonging to the subfamily Ichneumoninae; it has been recorded only from *M. privata* (Short et al. 2002)

and the *Pristiceros* sp. males, data from seven individuals is not sufficient to conduct a *t*-test. However, it is sufficient to perform the following non-parametric analysis. For both these species and sexes, the two individuals given access to leaves and scale also lived the longest. The probability that, in a group of seven wasps under supposedly identical conditions, the two given access to honeydew would die last is given by the reciprocal of '7 choose 2' ($= 7!/2! \times 5!$), or $P = 1/21 = 0.048$ (which is statistically significant at the 95% confidence level). Thus, we can have some confidence that, in the cases of both *Ha. pammi* and *Pristiceros* sp., individuals given access to honeydew will live longer than starved individuals. There is not enough data to comment upon the longevity of *He. scaposum* females given access to honeydew, although the trend was similar.

Discussion

In the field and during our assays, we observed *He. scaposum* and *Ha. pammi* eating honeydew from the surfaces of the scale insects themselves, the leaves and stems, and from the bottom of cages. In contrast, we did not see individual *He. scaposum* or *Ha. pammi* visiting wild flowers (weed or endemic species) or flowers of plants (i.e. *Alyssum* or *Aster* species) we had deliberately sown in one of our field trials. In cage assays, we did not observe any significant increase in the longevity of male *He. scaposum* given access to floral nectar from either *A. maritimum* or *Aster* 'Easter Daisy', indicating that males of this species either do not search these plants for nectar and/or cannot feed from their flowers. These observations have implications for inter-row or understorey sowings of flowering plants (i.e. habitat manipulation) in eucalypt plantations for biological control by both species of parasitoid.

Our first inference is that habitat manipulation to provide floral nectar for *He. scaposum*, as per Irvin *et al.* (2000), may not help attract and increase populations of this parasitoid. Further research is needed to investigate whether a similar claim can be made in relation to *Ha. pammi*. Moreover, additional research is needed in relation to *He. scaposum* because it is possible that this insect is not attracted to exotic plant species, or white or purple flowers or, if it is attracted to such colours, its mouthparts are unable to access nectar from flowers with structures similar to those of *Alyssum* and *Aster* (see discussions of these topics in Jervis *et al.* 1993; Idris and Grafius 1995; Baggen *et al.* 1999). Our results should not be used as reason not to investigate further the floral nectar sources that native parasitoids might feed on (for the reason outlined in the last paragraph).

Secondly, if plant species with flowers attractive to native parasitoids can be identified (preferably under field rather than laboratory conditions), it would be useful to compare their attractiveness relative to that of honeydew. Engel *et al.* (2001) reported that ants were more attracted to extrafloral nectaries than they were to colonies of honeydew-producing *Aphis fabae* Scop. because the former produced more concentrated sugars. Ants and wasp parasitoids may likewise be attracted to eucalypt-derived manna because it provides a very concentrated source of sugars (Steinbauer 1996; M.J. Steinbauer 2001–2003, *pers. obs.*). These results may indicate that ants and wasp parasitoids prefer sugars from different sources because of differences in quantity and quality. This suggests that *He. scaposum* and *Ha. pammi* may not

search for floral nectar unless it is more concentrated or offers some significant additional benefit over honeydew (or manna). We suggest that the sowing of an exotic species of plant whose flowers are found to benefit native parasitoids should only be conducted in plantations on ex-pasture sites and remote from native forests so that the plant(s) is less able to escape into sensitive natural areas and become a weed(s).

Whatever the landscape that surrounds a plantation, honeydew is not a 'selective' food source (i.e. compared to sugars contained within nectaries, *sensu* Baggen *et al.* 1999). This was one of the observations that Mensah and Madden (1994) made when they provided sugar at their feeding stations, i.e. large numbers of European wasps began arriving because they could easily access the resource provided to them. Similarly, diurnal and nocturnal insects such as flies (in suborders Brachycera (which comprises many fly parasitoids) and Nematocera), click beetles (family Elateridae), other species of wasp (family Tiphidae, subfamily Thynninae) and moths (families Noctuidae and Pyralidae) have all been seen feeding on honeydew because the food is readily available (M.J. Steinbauer 1999–2003, *pers. obs.*). More importantly, *M. privata* has also been seen feeding on honeydew at night (M.J. Steinbauer 2001, *pers. obs.*). Thus, honeydew probably benefits *He. scaposum* and *Ha. pammi* as well as *M. privata*. In the light of this observation, foresters should not try to foster larger populations of scale insects. Rather, we recommend that foresters should conserve (rather than eradicate) the few scattered scale-infested trees they are likely to locate during their routine inspections of plantations because they may be benefiting populations of native parasitoids. Only if beneficial insects are present and have sufficient energy for host searching can they mount a density-dependent response to a particular insect herbivore whose population begins to increase and cause levels of defoliation foresters are likely to consider unacceptable.

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