Effect of food supply on reproductive potential of *Eretmocerus warrae* (Hymenoptera: Aphelinidae)

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Abstract *Eretmocerus warrae* (Naumann & Schmit) is a thelytokous parasitoid of greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood). It was first detected in New Zealand in 1997 during a survey of greenhouses in Auckland. Under $22\pm 1^{\circ}\text{C}$, $60\pm 5\%$ RH and 16:8 h light:dark, the effect of food supply on longevity, host feeding, fecundity and parasitism in *E. warrae* was investigated with four treatments: (1) no food and no host, (2) 10% honey solution and no host, (3) 40 2nd instar nymphs per day and no honey, and (4) 40 2nd instar nymphs per day and 10% honey solution. Results showed that parasitoids lived significantly longer when given honey but no host (8.8 days) than parasitoids given the other treatments (2.5–5.5 days) ($P<0.0001$). Honey supply significantly reduced host feeding ($P<0.05$). There was no significant difference ($P>0.05$) in lifetime fecundity (32.4–34.7 eggs), parasitism rate (14.7–16.0%) and superparasitism rate (10.3–11.4%) between parasitoids given hosts with or without access to honey.

Keywords *Eretmocerus warrae*, *Trialeurodes vaporariorum*, host feeding, fecundity, longevity.

INTRODUCTION

The greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood), is one of the most important whitefly species, causing serious economic damage to crops throughout tropical and subtropical regions and in glasshouses in temperate regions of the world (Byrne et al. 1990). It was first found in greenhouses in UK in 1856 (Van Lenteren et al. 1996). The sessile nymphs of *T. vaporariorum* have been successfully managed in glasshouse systems with parasitoids (Vet et al. 1980; Gerling 1990). Among the six *Eretmocerus* species that have been reared from *T. vaporariorum* (Zolnerowich & Rose 2008), *E. warrae* (Nauman & Schmidt) is a newly described thelytokous (no males) species (de Barro et al. 2000). It was first found in greenhouses

in Auckland, New Zealand, in 1997 (Workman et al. 2008). During the present study, adult wasps were sent to the Natural History Museum, London, for identification, and were confirmed as *E. warrae* (A. Polaszek, pers. comm.).

Adult females of many insects depend on carbohydrate-rich food as their main source of energy for longevity, fecundity and mobility (Jervis & Kidd 1986). In hymenopteran parasitoids, including *Eretmocerus* spp., longevity and in some cases fecundity may be influenced by a range of factors, such as temperature (Greenberg et al. 2000), host stage (Jones & Greenberg 1998), host density (A. Hanan, unpubl. data), host plant species (Qiu et al. 2005) and presence of food (Leatemia et al. 1995; McAuslane et al.

1996; Hardin et al. 2008). Among these factors, availability of food sources appears to be the most practical and economical means of promoting longevity (McDougall & Mills 1997). Previous studies on *Eretmocerus* demonstrated that sugar sources (e.g. saccharose and honey) and host hemolymph have a significant effect on longevity of *E. debachi* (Kuwana) and *E. mundus* (Merct) (Sengonca et al. 1994; Ghahari et al. 2005). It has also been demonstrated that *E. eremicus* lives significantly longer when fed with carbohydrate diets (Hardin et al. 2008). However, whether host feeding affects longevity and reproductive output of *E. warrae* is not clear.

Based on egg maturation, parasitoids can be classified as synovigenic (females continue to mature eggs during their adult lifetime) or pro-ovigenic (females complete oogenesis prior to eclosion) (Jervis & Kidd 1986). *Eretmocerus warrae* carries some mature eggs at eclosion and continues to mature eggs during adult lifespan (A. Hanan, unpubl. data), suggesting that it is a pro-synovigenic species (Jervis & Kidd 1986). It is well known that nutrients obtained by host feeding are used to mature eggs and sugar sources are used for the maintenance of life (Heimpel & Collier 1996). Food supply may allow pro-ovigenic species to increase longevity (Thompson 1999) and synovigenic species to increase both longevity and fecundity (Heimpel & Collier 1996). Jervis & Kidd (1986) suggested that synovigenic parasitoids whose adults feed on host fluid still require sugars as their main source of energy during the adult stage. Therefore, understanding the effect of food supply for adults on parasitoid fitness is important for mass-rearing and field enhancement of parasitoids for biological control programmes.

Prior to the present study there was no published information on the effect of non-host food (honey or sugars) on longevity, fecundity and parasitism in *E. warrae*, making it difficult to develop strategies for effective mass-rearing and field manipulation of this parasitoid. Therefore, the primary aim of this study was to determine the effect of food supply on the longevity, host feeding, fecundity and parasitism of *E. warrae*.

MATERIALS AND METHODS

Breeding colony and experimental conditions

The colonies of *T. vaporariorum* and *E. warrae* were initiated with parasitised and unparasitised pupae of *T. vaporariorum* obtained from BioForce Limited, Auckland, New Zealand. 'Moneymaker' tomato plants were used for rearing the colonies. The colonies of *T. vaporariorum* and *E. warrae* were maintained and all experiments were carried out at $22 \pm 1^\circ\text{C}$ with $60 \pm 5\%$ RH and 16:8 h light:dark, in the Entomology and IPM Laboratory, Massey University, Palmerston North, New Zealand. All parasitoids used for experiments emerged from *T. vaporariorum* pupae that were parasitised as 2nd or 3rd instar nymphs, and 2nd instar nymphs were used as hosts of parasitoids in this study.

Experiments

All experiments were carried out in plastic Petri dishes (5.5 cm diameter and 1.2 cm height). To investigate whether and how food supply affected host feeding, fecundity, parasitism and longevity of *E. warrae*, four treatments were set up: (1) no food and no host, (2) 10% honey solution and no host, (3) 40 2nd instar nymphs per day and no honey, and (4) 40 2nd instar nymphs per day and 10% honey solution. In treatments (2) and (4), 10% honey was provided in a cotton wick inserted into the Petri dish through a 1 cm hole in the lid. For each treatment, one parasitoid (<12 h since eclosion) was released into a Petri dish, allowed to stay for 24 h, and then moved into another Petri dish. This process was repeated until she died. As *E. warrae* place their eggs between the venter of whitefly nymphs and leaf surface (Hanan et al. 2009), all nymphs were turned over to determine the presence or absence of eggs under the stereomicroscope (Leica MZ12, German). The oviposition and host feeding patterns were determined by counting the numbers of eggs laid and hosts fed upon by the parasitoid. Host feeding was recorded if the nymph body fluid was found to have effused as a result of penetration of the female ovipositor into the vasiform orifice of host nymphs (Vet et al. 1980; Viggiani 1984). The longevity of adult parasitoids was also recorded. There were 20 replicates (no. of parasitoids)

in treatments (1) and (2) and 10 replicates in treatments (3) and (4).

Statistical analysis

A goodness-of-fit test was used to test the distribution of data before analysis. All data were normally distributed and analysed by ANOVA. The percentage data were arcsine transformed before analysis. When significant differences in variables occurred, means were separated using a Tukey's studentised range (HSD) test. The responses of hosts fed upon and eggs laid per day to parasitoid age were analysed using linear regression, and slopes of each category (no. of hosts fed upon or no. of eggs laid) were compared using analysis of covariance (ANCOVA).

RESULTS

The parasitoids that only got access to honey lived significantly longer than those in other treatments, and those that fed on hosts only or both hosts and honey had significantly greater longevity than those without honey and hosts ($P < 0.0001$) (Figure 1). However, the longevity was similar between parasitoids provided with hosts only and those with both hosts and honey ($P > 0.05$) (Figure 1).

In the treatments 'hosts only' and 'honey + hosts', the number of hosts fed and eggs laid significantly decreased with parasitoid age ($P < 0.0001$) (Figure 2). However, the decrease in host feeding was significantly faster in the 'host only' treatment than in the 'honey + hosts' treatment ($P < 0.0001$) (Figure 2a), while the decline in the number of eggs laid with increasing parasitoid age

Figure 1 Effect of food and host supply on the longevity of *E. warrae*.

was not significantly different between these two treatments ($P > 0.05$) (Figure 2b).

When lifetime data were considered, honey supply significantly reduced the number of hosts fed upon by the parasitoids ($P < 0.05$) (Table 1). However, honey solution did not significantly increase *E. warrae* fecundity, parasitism or super-parasitism rates ($P > 0.05$) (Table 1).

DISCUSSION

Host feeding by hymenopteran parasitoids contributes to pest control (Jervis & Kidd 1986). The present study indicates that honey solution significantly prolongs the longevity of this parasitoid (Figure 1). These results are highly consistent with the results of Hardin et al. (2008) who demonstrated that *E. eremicus* lives significantly longer when fed with carbohydrate diets. In some parasitoids like *Trichogramma* spp. honey increases adult longevity 8–11 times compared to unfed or water-fed adults (McDougall & Mills 1997). However, when both hosts and honey are provided, *E. warrae* adults live significantly shorter than those provided with honey only. This phenomenon may be attributed to the costs associated with egg maturation and oviposition when hosts are present (Charnov & Stephens 1988; Mangel 1989). It is also possible that although parasitoids still feed on honey when hosts are present, they ingest less honey due to host feeding, resulting in shorter longevity.

Heimpel & Colier (1996) reported that when presented with hosts directly after feeding on water or honey, *Aphytis aonidiae* (Mercet) fed upon fewer hosts, implying that satiation from honey or water limits the host feeding rate. The present results also show that provision of honey solution significantly reduced host feeding by *E. warrae* (Table 1), suggesting that honey supply for this species can lower its biological control efficiency by host feeding. Furthermore, with the presence of hosts honey did not significantly increase *E. warrae* reproductive output (Table 1), suggesting that sugar sources may not be necessary in mass-rearing programmes of this species for biological control. However, when

Figure 2 (a) Daily number of hosts fed and (b) eggs laid by *E. warrae* when provided with hosts only and honey + hosts. All data were pooled for regression but means ($\pm$ SE) are presented.

hosts are rare or temporarily absent in a mass-rearing or biological control programme, the increase in longevity of *E. warrae* from 5 to 9 days due to provision of honey may enable the parasitoids to survive until they find hosts.

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Table 1 Effect of host and/or honey solution on lifetime host feeding and reproduction in *E. warrae*.

Treatments	No. hosts fed	No. eggs laid	Parasitism (%)	Super-parasitism (%)
Host only	12.4 $\pm$ 0.5a	32.4 $\pm$ 2.5a	14.7 $\pm$ 1.1a	11.4 $\pm$ 2.5a
10% honey + hosts	9.6 $\pm$ 1.0b	34.7 $\pm$ 2.8a	16.0 $\pm$ 1.1a	10.3 $\pm$ 1.5a

Mean ($\pm$ SE) followed by the same letters in each column are not significantly different ($P > 0.05$).

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