**EFFECT OF PARASITISM BY *APHIDIUS EADYI*
(HYMENOPTERA: APHIDIIDAE) ON REPRODUCTION OF
PEA APHID, *ACYRTHOSIPHON PISUM* (HEMIPTERA:
APHIDIDAE)**

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ABSTRACT

The effect of parasitism by *Aphidius eadyi* Stary, González & Hall on reproduction of pea aphid, *Acyrtosiphon pisum* (Harris), was studied in the laboratory. Aphids attacked as 1st and 2nd instars became mummies in the 4th instar; parasitised 3rd instar nymphs became mummies in the adult stage without producing any progeny. Parasitised 4th instar nymphs and adults produced progeny but had a shorter reproductive period and produced fewer ($P < 0.0001$) progeny than unparasitised aphids. Parasitised 4th instar nymphs and adults had significantly lower intrinsic rates of increase (r_m), net reproductive rates (R_0), shorter generation time (T) and longer doubling time (DT) than unparasitised aphids. The potential impact of the parasitoid on host population growth is discussed.

Keywords: pea aphid, *Acyrtosiphon pisum*, *Aphidius eadyi*, reproduction, population growth.

INTRODUCTION

Parasitism by entomophagous parasitoids increases mortality and reduces growth, longevity and reproductive potential of the hosts. Many studies have reported that aphids parasitised by hymenopteran parasitoids in an early life stage die before reproducing, but those parasitised in older life stages may produce a limited number of progeny before mummification (Fox et al. 1967; Campbell & Mackauer 1975; Lui & Hughes 1984; Mackauer & Kambhampati 1984; Sequeira & Mackauer 1988).

Pea aphid, *Acyrtosiphon pisum* (Harris), is an important pest of lucerne in New Zealand. *Aphidius eadyi* Stary, González & Hall is a specific parasitoid of pea aphid, and an important agent for biological control of this pest. Both species occur throughout New Zealand (Cameron & Walker 1989). A lack of information makes it difficult to understand the effect of *A. eadyi* on pea aphid populations in the field. Here, we report the effect of parasitism by *A. eadyi* on pea aphid survival, reproduction and population growth.

MATERIALS AND METHODS

Healthy pea aphids and those parasitised by *A. eadyi* were collected from red clover, *Trifolium pratense* L., on an AgResearch farm at Aorangi near Palmerston North in early January 2002. Aphids were reared in the laboratory on potted broad beans, *Vicia faba* L. cv. Pride, in an aluminium framed cage (64 cm length $\times$ 45 cm width $\times$ 40 cm height) with fine metal mesh on the back and both sides and perspex and aluminium alloy on the top and bottom, respectively. The colony was maintained and experiments were conducted at $20 \pm 1^\circ\text{C}$ and RH 60-70% with a photoperiod of 16:8 h light:dark.

In this study, parasitised individuals ($n = 20$) of five life stages (4 nymphal instars and adults) were established. To obtain pea aphids of known life stage, adults were introduced onto a bean plant and removed after 5 h and the resulting progeny reared. To obtain

parasitised aphids, we released a mated *A. eadyi* female into an enclosed Petri dish (8.5 cm diameter × 1.3 cm height) where 20 newly moulted aphids of the same life stage were maintained. Aphids that received one ovipositioning strike from the female were removed until 20 individuals were collected. Each attacked aphid was individually introduced onto a bean plant held in a transparent plastic cylinder (8.5 cm diameter × 12 cm height, with three gauze-covered holes for ventilation) and observed once a day at 1200 h. We recorded the survival period of aphids and the period they started reproduction after being parasitised. Offspring were counted and removed. At the same time, 10 unparasitised adults reared individually in cylinders served as controls to compare progeny production and reproductive period.

The daily survival rate of each stage and fecundity were compiled into a life table according to the method of Birch (1948) and Jervis & Kidd (1996). We estimated the intrinsic rate of increase, r_m , by solving the Lotka-Euler equation ($\sum e^{-r_m x} l_x m_x = 1$), and calculated the net reproductive rate ($R_0 = \sum l_x m_x$), mean generation time (days) ($T = \log_e(R_0)/r_m$) and doubling time (days) ($DT = \log_e(2)/r_m$), where x is the pivotal age, l_x the proportion of the females surviving to age x and m_x the number of offspring produced per female at age x . A jackknife method (Caswell 1989) was used to estimate standard errors of above parameters.

Aphids that did not become mummies were considered unparasitised and were not included in statistical analysis. Data were analysed using ANOVA. When significant differences in variables occurred, means were separated using Tukey’s studentised range (HSD) test ($P=0.05$). All analyses were conducted on SAS STAT 8.1.

RESULTS

Survival

Aphids parasitised as 1st and 2nd instars became mummies in the 4th instar; all parasitised 3rd and 4th instar nymphs reached adult stage. Survival periods of parasitised aphids were similar regardless of the stage attacked ($P>0.05$) (mean ± SE: 7.40 ± 0.13 , 7.32 ± 0.11 , 7.15 ± 0.08 , 7.05 ± 0.05 and 7.05 ± 0.05 days, for parasitised 1st, 2nd, 3rd, 4th instars and adults, respectively; Tukey test, $q<3.93$). Survival of parasitised aphids was significantly shorter than that of unparasitised adults (20.8 ± 1.10 days) (Tukey test, $q>4.11$; $P<0.0001$)

Reproduction

Aphids parasitised as 4th instars and adults started reproduction about 5 and 1 days, respectively, after attack (Fig. 1). Aphids parasitised as 4th instars had a shorter reproductive period and produced fewer progeny than those parasitised as adults, and parasitised adults had a shorter reproductive period and produced fewer progeny than unparasitised adults ($P<0.0001$) (Table 1).

TABLE 1: Effect of parasitism by *Aphidius eadyi* on reproductive period and progeny production of pea aphid¹.

Aphid	Reproductive period	No. of progeny
Parasitised 4th instar	2.05 (0.12) c	9.79 (0.80) c
Parasitised adult	3.95 (0.09) b	27.80 (0.91) b
Unparasitised adult	16.00 (0.47) a	113.40 (3.57) a

¹Means (± SE) followed by the same letters in columns were not significantly different ($P>0.05$).

FIGURE 1: Influence of parasitism by *Aphidius eadyi* on fecundity (no. progeny/day) (open circles) and survival (%) (closed circles) of pea aphids, *Acyrtosiphon pisum*. (a) parasitised 4th instars, (b) parasitised adults and (c) unparasitised adults.

Life table

Parasitism by *A. eadyi* severely affected the population growth of pea aphids (Table 2). Aphids parasitised as 4th instars had a lower intrinsic rate of increase (r_m) and net reproductive rate (R_0), a shorter generation time (T), and a longer doubling time (DT) than those parasitised as adults ($P < 0.0001$). Parasitism in adults led to a lower r_m and R_0 , a shorter T and a longer DT when compared to unparasitised aphids ($P < 0.0001$) (Table 2).

TABLE 2: Effect of parasitism by *Aphidius eadyi* on life table parameters of pea aphid¹.

Aphid	r_m	R_0	T	DT
Parasitised 4th instar	0.2494 c (0.0001)	9.2000 c (0.0494)	8.8966 c (0.0217)	2.7793 a (0.0075)
Parasitised adult	0.3636 b (0.0010)	27.5000 b (0.0482)	9.1159 b (0.0212)	1.9066 b (0.0050)
Unparasitised adult	0.4005 a (0.0001)	113.4000 a (0.3969)	11.8119 a (0.0084)	1.7306 (0.0001) c

¹Means ($\pm$ SEs) followed by the same letters in columns were not significantly different ($P>0.05$).

DISCUSSION

The efficiency of parasitoids in the control of aphids depends on their ability to reduce aphids' reproductive potential by lowering the intrinsic rate of increase (r_m) or net reproductive rate (R_0), shortening the generation time (T) or extending the doubling time (DT). We found that parasitism of early instars prevented any reproduction and that parasitism of late instars and adults significantly reduced numbers of progeny compared with unparasitised aphids.

In the field, the success of *A. eadyi* in pea aphid control will be affected by the age structure of aphid populations. Sequeira & Mackauer (1988) stated that parasitoids that attack young host stages are likely to be more effective at suppressing aphid populations than those that attack the older hosts. Growing populations generally have a high proportion of individuals in young age classes (Schowalter 2000) and this occurs early in the season. In this study, pea aphids that were parasitised by *A. eadyi* in the 1st, 2nd and 3rd instars did not contribute to population growth, with r_m being zero. Thus, attack by *A. eadyi* early in the season should significantly suppress populations of pea aphid in the field, inhibiting its dispersal and population buildup later in the season.

Parasitism by *A. eadyi* shortened the aphids' reproductive period and reduced the number of progeny due to the destructive feeding by the developing parasitoid larvae. Similar results have been reported for pea aphid–*A. smithi* Sharma & Subba Rao (Campbell & Mackauer 1975) and pea aphid–*Praon pequodorum* Viereck (Sequeira & Mackauer 1988) systems. Aphids parasitised as 4th instars and adults could still produce some progeny. Our results indicated that aphids parasitised as 4th instars achieved a net reproductive rate three times lower than aphids parasitised as adults, and parasitised adults yielded four times less than unparasitised aphids. It is predicted that parasitism by *A. eadyi* would decrease the overwintering population of pea aphid late in the season.

The effect of parasitism on pea aphid population growth is reflected in changes in the intrinsic rate of natural increase (r_m) (Campbell & Mackauer 1975). When the age structure of aphid populations and parasitism distribution among aphid ages are stable in an unlimited environment, r_m can be used to predict the population growth of pea aphid (Carey 1993; Schowalter 2000). However, the effect of *A. eadyi* on biological control of the pea aphid also greatly depends on the population growth of the parasitoid itself. Variation in the stability of the parasitoid population, especially the sex ratio of parasitoids and distribution of parasitism between host ages, may mean that aphid population growth can only be predicted over a short period. Other parasitoid species such as *A. ervi* Haliday can also attack the pea aphid in New Zealand. Sequeira & Mackauer (1988) stated that the changes in reproductive pattern of pea aphid reflect a general response to parasitism rather than that induced by different parasitoid species. Therefore, if the effect of parasitism by *A. ervi* on pea aphid reproduction is similar to that by *A. eadyi*, this model could be used to predict the population growth of pea aphid regardless of the parasitoid species. Modelling parasitism adds to the understanding of the pea aphid population dynamics in the field.

ACKNOWLEDGEMENTS

The editor and Dr David Logan made constructive comments on the early manuscript, for which we are very grateful. Research reported here was partially supported by Massey University.

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