THE EFFECT OF PARASITISM BY *APHIDIUS ERVI* ON DEVELOPMENT AND REPRODUCTION OF THE PEA APHID, *ACYRTHOSIPHON PISUM*

X.Z. HE¹, Q. WANG¹ and D.A.J. TEULON²

¹*Institute of Natural Resources, Massey University, Private Bag 11222, Palmerston North, New Zealand*

²*Crop & Food Research, Private Bag 4704, Christchurch, New Zealand*

Corresponding author: q.wang@massey.ac.nz

ABSTRACT

The effect of parasitism by *Aphidius ervi* Haliday (Hymenoptera: Aphidiidae) on development, survival and reproduction of pea aphid, *Acyrtosiphon pisum* (Harris) (Hemiptera: Aphididae), of different ages was studied in the laboratory. Aphids parasitised when 1 and 2 days old (1st and 2nd instar) died at the 4th instar. However, those parasitised when 3 to 6 days old (3rd and 4th instar) could reach the adult stage following parasitism and those that were parasitised after 4 days old (late 3rd instar) were still able to produce progeny. In comparison with the unparasitised aphids, the parasitised aphids had a significantly shorter reproductive period and produced significantly fewer progeny, and thus had significantly lower intrinsic rates of increase, net reproductive rates, shorter generation time and longer doubling time. The potential impact of the parasitoid on host population growth is discussed. **Keywords:** pea aphid, *Acyrtosiphon pisum*, *Aphidius ervi*, reproduction, population growth.

INTRODUCTION

Many studies have reported that hymenopteran endoparasitoids can reduce the reproductive potential of aphids (Lui & Hughes 1984; Mackauer & Kambhampati 1984; Sequeira & Mackauer 1988; Tang & Yokomi 1996; He et al. 2003; Lin & Ives 2003). The majority of these studies indicate that aphids parasitised in their early instars die before reproduction but those parasitised at later stages of development may reach the adult stage and produce a limited number of progeny before mummification. Most aphid populations consist of multiple stages of development. Therefore, knowledge of the effect of parasitism on development, reproduction and population growth of aphids of different ages is critical to the success of biological control (Tsai & Wang 2002; Zhang & Hassan 2003).

The pea aphid (*Acyrtosiphon pisum* (Harris)) is a pest of lucerne in New Zealand (Cameron & Walker 1989), originally probably from the Palaearctic (Blackman & Eastop 2000). It was first found in Auckland in October 1976 (Archibald 1979). *Aphidius ervi* Haliday is a solitary endophagous parasitoid of several pest aphid species on economically important crops, such as legumes and cereals (Starý 1978; Powell 1982). It was imported to New Zealand from California to control the pea aphid and blue green lucerne aphid, *Acyrtosiphon kondoi* Shinji (Cameron & Walker 1989).

Several authors (Pennacchio et al. 1995; Digilio et al. 1998; Rahbé 2002) have studied biochemical changes in pea aphid caused by *A. ervi*. However, little is known about how parasitism by *A. ervi* affects the population of the pea aphid, making it difficult to evaluate the biological control efficiency of this parasitoid. This paper is the first to investigate the effect of parasitism by *A. ervi* on the development, reproduction and population growth of *A. pisum* at different stages of development.

MATERIALS AND METHODS

Breeding colony and experimental conditions

A breeding colony of *A. ervi* was established from individuals that emerged from blue-green lucerne aphids which were collected from lucerne on the AgResearch farm at Aorangi near Palmerston North in December 2002. Prior to the experiments, the colony was reared on pea aphid feeding on potted broad bean, *Vicia faba* L. cv. Pride, for five generations. The colony was maintained and all experiments were carried out at $20 \pm 1^\circ\text{C}$ and 60-70% RH with 16:8 h light: dark.

Development and reproduction

The effect of parasitism by *A. ervi* on the growth and reproduction of pea aphids at different stages of development (1–10 days old = 1st instar to adult) was investigated. To obtain parasitised aphids of the same age class, a single mated *A. ervi* female was released into a Petri dish (8.5 cm diameter $\times$ 1.3 cm height) containing 10 aphids of the same age. Aphids that received a single oviposition strike from the female parasitoid were removed and replaced with unparasitised individuals of the same age until 15 parasitised aphids were collected. Parasitised aphids were placed individually onto a bean plant, which was held in a transparent plastic cylinder (He et al. 2003). There were 10 treatments (age classes) and 15 replicates (number of parasitised aphids) for each treatment in this study. Survival, development and reproduction of parasitised aphids were monitored at 24 h intervals. Any offspring from these aphids were counted and removed. In addition, the survival and reproductive periods of aphids were also recorded. Fifteen unparasitised aphids (start at 1 day old) reared individually in cylinders served as controls and their survival and reproduction were monitored as above.

Population growth

The daily survival rate and reproduction of aphids were compiled into a life table to assess the population growth according to the method of Jervis & Kidd (1996). The intrinsic rate of increase (female/female/day; r_m) was estimated by solving the Lotka-Euler equation ($\sum e^{-r_m x} l_x m_x = 1$). Other calculations included the net reproductive rate (females/females/generation; $R_0 = \sum l_x m_x$), mean generation time (days; $T = \log_e(R_0)/r_m$) and doubling time (days; $DT = \log_e(2)/r_m$). In these calculations x is the pivotal age, l_x is the proportion of the females surviving to age x , and m_x is the number of offspring produced per female at age x . For each treatment and the control, a jackknife method (Caswell 2001) was used to estimate the means and standard errors of the above life table parameters by partitioning the 15 parasitised aphids into 5 groups of 3 individuals.

Statistical analysis

A linear regression (PROC REG) was used to identify the relationships between aphid age at the point of parasitism, reproductive period and the number of progeny produced. A logistic regression (PROC NLN) was applied to analyse the relationships between aphid age (x) at the point of parasitism and r_m (i.e. $r_m = c/(1+\exp(a+b*\ln(x)))$), where the constant c represents the maximum possible value of r_m ; and a and b are constants to fit the curve). All other data were analysed using an ANOVA (PROC GLM). When significant differences in variables occurred, means were separated using a Tukey's studentised range (HSD) test ($P>0.05$). All analyses were performed using SAS.

RESULTS

Development and survival

Aphids parasitised at 1 and 2 days old (1st and 2nd instar) became mummified in the 4th instar. However, aphids parasitised at 3 to 6 days old (3rd and 4th instar) continued development to the adult stage. For all ages, parasitised aphids died about 7 days after being parasitised and their longevity was significantly shorter than unparasitised aphids ($P<0.0001$) (Table 1).

TABLE 1: Effect of parasitism of pea aphid by *A. ervi* on survival (days), reproductive period (days) and number of progeny. Means ($\pm$ SE) followed by the same letters in columns are not significantly different ($P>0.05$).

Aphid age (days)	Survival (days)	Reproductive period (days)	No. of progeny
1 (1st instar)	8.13 $\pm$ 0.09 j	---	---
2 (2nd instar)	9.13 $\pm$ 0.09 ij	---	---
3 (3rd instar)	10.20 $\pm$ 0.11 hi	---	---
4 (3rd instar)	11.13 $\pm$ 0.09 gh	2.07 $\pm$ 0.15 g	4.93 $\pm$ 0.43 g
5 (4th instar)	12.07 $\pm$ 0.07 fg	2.33 $\pm$ 0.16 fg	10.07 $\pm$ 0.90 g
6 (4th instar)	13.13 $\pm$ 0.09 ef	3.13 $\pm$ 0.13 f	19.40 $\pm$ 1.13 f
7 (adult)	14.07 $\pm$ 0.07 de	4.20 $\pm$ 1.75 e	30.47 $\pm$ 1.48 e
8 (adult)	15.13 $\pm$ 0.09 cd	5.20 $\pm$ 0.11 d	39.07 $\pm$ 1.49 d
9 (adult)	16.20 $\pm$ 0.11 c	6.33 $\pm$ 0.19 c	52.33 $\pm$ 0.88 c
10 (adult)	17.47 $\pm$ 0.17 b	7.60 $\pm$ 0.19 b	62.60 $\pm$ 1.92 b
Control	27.87 $\pm$ 0.82 a	15.60 $\pm$ 0.38 a	111.20 $\pm$ 3.17 a

Reproduction

Only aphids parasitised when ≥ 4 days old (late 3rd instar) produced any progeny. Most of these aphids started reproduction from 8 days old. Parasitised aphids had a significantly shorter reproductive period and produced significantly fewer progeny than healthy aphids ($P<0.0001$) (Table 1). For the parasitised aphids, the reproductive period and the number of progeny produced increased significantly with the age when the aphid was parasitised ($P<0.0001$) (Figs 1 & 2, respectively).

FIGURE 1: Relationship between host age at parasitisation and reproductive period.

Population growth

Parasitism by *A. ervi* significantly affected the population growth of pea aphids ($P<0.05$), reflected in changes in the intrinsic rate of increase (r_m), net reproductive rate (R_0), generation time (T), and doubling time (DT) (Table 2). Aphids parasitised as immature stages (≤ 6 days old) had a significantly lower r_m and R_0 , shorter T , and longer DT than those parasitised as adults and healthy aphids ($P<0.0001$). The r_m increased rapidly with the increase of aphids' age when they were parasitised and reached a plateau at 9 and 10 days old ($P<0.0001$) (Fig. 3).

FIGURE 2: Relationship between host age at parasitisation and reproduction of progeny.

TABLE 2: Effect of parasitism by *A. ervi* on life table parameters of pea aphid. Means ($\pm$ SE) followed by the same letters in columns are not significantly different ($P>0.05$).

Aphid age (days)	r_m	R_0	T	DT
4 (3 rd instar)	0.1799 $\pm$ 0.0083 e	4.93 $\pm$ 0.39 g	8.71 $\pm$ 0.09 d	3.95 $\pm$ 0.21 a
5 (4 th instar)	0.2573 $\pm$ 0.0050 d	9.13 $\pm$ 1.17 g	8.86 $\pm$ 0.07 d	2.94 $\pm$ 0.35 b
6 (4 th instar)	0.3398 $\pm$ 0.0075 c	19.40 $\pm$ 1.18 f	8.69 $\pm$ 0.02 d	2.05 $\pm$ 0.05 c
7 (adult)	0.3705 $\pm$ 0.0056 b	30.47 $\pm$ 0.85 e	9.21 $\pm$ 0.07 c	1.87 $\pm$ 0.03 d
8 (adult)	0.3924 $\pm$ 0.0072 ab	39.07 $\pm$ 1.53 d	9.33 $\pm$ 0.07 c	1.77 $\pm$ 0.03 d
9 (adult)	0.3972 $\pm$ 0.0031 a	52.07 $\pm$ 0.67 c	9.95 $\pm$ 0.05 b	1.74 $\pm$ 0.01 d
10 (adult)	0.3979 $\pm$ 0.0033 a	62.60 $\pm$ 2.52 b	10.29 $\pm$ 0.06 b	1.73 $\pm$ 0.01 d
Control	0.4018 $\pm$ 0.0023 a	113.00 $\pm$ 2.51 a	11.89 $\pm$ 0.13 a	1.74 $\pm$ 0.02 d

FIGURE 3: Relationship between host age at parasitisation and r_m .

DISCUSSION

Results of this study show that, in comparison with the unparasitised pea aphid controls, parasitism by *A. ervi* significantly reduced pea aphids' survival period, reproductive potential and population growth. However, when compared to *Praon pequodorum* Viereck (Sequeira & Mackauer 1988), another parasitoid of pea aphid, *A. ervi* has greater potential to suppress aphid populations because those parasitised by *P. pequodorum* produce 20 to 30 more progeny than those parasitised by *A. ervi*. The effect of parasitism by *A. ervi* on pea aphid reproduction is similar to that by *Aphidius eadyi* Starý, González & Hall (He et al. 2003).

The efficiency of parasitoids in the control of aphids depends on their ability to suppress aphids' population growth. Aphids parasitised by *A. ervi* continued to feed and grow until they were killed by the developing parasitoid larva. Because the time from being parasitised to mummification is about 7 days for all parasitised aphids, their survival and reproduction depend on the time when they are parasitised. Aphids parasitised ≤ 3 days old died at the fourth instar or early adult stage. In contrast, those parasitised when ≥ 4 days old were able to reach the adult stage and successfully reproduce. This may be because the aphid embryos in the later instar and adult stages have developed a resistant cuticle by the time of oviposition by the parasitoid (Polaszek 1986) and have thus escaped consumption by the developing parasitoid larvae.

The present study indicates that parasitised aphids' development, survival, reproduction and population growth vary with their age at the time of parasitism. It appears that attacking young hosts will be more effective in suppressing aphid populations than attacking the adult aphids. According to Schowalter (2000), early in the season, growing populations have a high proportion of aphids in young age classes. Thus, the application of *A. ervi* early in the season could significantly suppress populations of pea aphid in the field, inhibiting its dispersal and population build-up later in the season.

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