DEVELOPMENTAL BIOLOGY OF *METEORUS PULCHRICORNIS* PARASITISING PAINTED APPLE MOTH

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ABSTRACT

Following the discovery of painted apple moth (PAM), *Teia anartoides*, in Auckland in 1999, a long-term management programme was proposed, in case eradication failed. Research was initiated to evaluate the potential impact of natural enemies that were already present in New Zealand. Laboratory bioassays determined the developmental biology of the larval parasitoid *Meteorus pulchricornis* on PAM at five constant temperatures (13, 18, 21, 25 or 30°C). Total development time (egg to adult) ranged from 64.5 days at 13°C to 16.0 days at 25°C. *Meteorus pulchricornis* adults provided with agar-honey parasitoid diet survived an average of 6.9 days and laid an average of 21.3 eggs at 21°C. *Meteorus pulchricornis* parasitised a significantly higher number of second and third instar PAM larvae compared to other larval instars. The potential of *M. pulchricornis* as a primary regulator of PAM populations in New Zealand is discussed.

Keywords: *Meteorus pulchricornis*, painted apple moth, *Teia anartoides*.

INTRODUCTION

Painted apple moth (PAM), *Teia anartoides* Walker (Lepidoptera: Lymantriidae), was first discovered in Auckland, New Zealand in 1999. It is a polyphagous species, native to Australia and feeds primarily on Mimosaceae, (particularly *Acacia*), Fabaceae, Myrtaceae, Santalaceae and Solanaceae (Common 1990). It also feeds on a range of exotic commercial and ornamental species and is known as a minor pest in Australian forests and orchards. On arrival in New Zealand, the PAM population multiplied rapidly. It was recognised as a major threat to our native and introduced flora, which resulted in the initiation of an eradication plan. Further to this, a long-term management programme was also established to investigate other management options in case eradication failed. As part of this, research was initiated to examine the potential impact of natural enemies that were already present in New Zealand. Two parasitoid species were reared from field collected PAM samples: *Trigonospila brevifacies* Hardy (Diptera: Tachinidae) and *Meteorus pulchricornis* (Wesmael) (Hymenoptera: Braconidae). This paper reports on laboratory studies conducted to investigate the developmental biology of *M. pulchricornis* parasitising PAM and its potential as a primary regulator of PAM populations in New Zealand.

MATERIALS AND METHODS

Rearing

The *M. pulchricornis* colony was established from adults that emerged from field collected PAM larvae in 2003, and was maintained on second and third instar PAM larvae sourced from the HortResearch (Mt Albert Research Centre) PAM colony. All adults reared were female. *Meteorus pulchricornis* were reared in ventilated plastic containers (4.2 litre Klik-Clak® Store All) and maintained at 21±2°C and a 16 h photoperiod. Cubes

(2 cm³) of PAM artificial diet were also placed in each container as a food source for the PAM larvae. The artificial diet was that used for rearing gypsy moth (*Lymantria dispar*) (Odell et al. 1984), modified by the addition of ferric phosphate, and the antibiotics penicillin and streptomycin (Charles et al. 2006).

Development of *M. pulchricornis* on PAM larval instars at different temperatures

To obtain eggs of a known age, 50 third instar PAM larvae and five newly emerged (<24 h old) adult female *M. pulchricornis* were placed into a ventilated container with PAM artificial diet. After a 24 h exposure period, the PAM larvae were removed from the containers and placed individually into 30 ml plastic cups with 2 cm³ cubes of artificial diet. Ten larvae were placed into each of five different temperature regimes (13, 18, 21, 25 and 30±2°C). The larvae were observed daily, and parasitoid pupation and parasitoid emergence recorded. The size of the *M. pulchricornis* pupal cocoons was also recorded. The experiment was repeated five times.

Degree-day model development

A degree-day model for *M. pulchricornis* was developed to predict developmental rates under any fluctuating temperature regime. This required the calculation of the developmental threshold (*t*), the temperature at which an insect or developmental stage ceases to develop, and the thermal constant (*K*), the amount of heat required to complete development expressed as degree-days. The developmental threshold and the thermal constant required for each *M. pulchricornis* life stage were derived from the linear regression equation: $y = a + bx$, where *y* is the developmental rate at temperature *x*, *a* is the *y*-intercept and *b* is the slope (Sokal & Rohlf 1981). The developmental threshold and thermal constant values were calculated using the following formulae:

$$\text{Developmental threshold} \quad t = (0 - a) / b$$

$$\text{Thermal constant} \quad K = 1 / b.$$

The predicted developmental rate under any fluctuating temperature regime can be determined by summing the degree-days above *t* until the *K* value for the life stage was reached. This was achieved by accumulating the mean daily temperature minus the lower developmental threshold.

Effect of adult feeding on longevity and oviposition

Ten third instar PAM larvae and a single adult female *M. pulchricornis* were placed into a ventilated plastic container with or without a general agar-honey parasitoid diet (Sandanayaka & Ramankutty 2007). PAM artificial diet was also placed in all containers as a food source for the PAM larvae. Every 24 h, the exposed larvae were removed and replaced with fresh ones until the parasitoid died. PAM larvae that had been exposed to the parasitoids were placed into individual plastic cups as described above and observed daily for mortality, parasitoid pupation and adult parasitoid emergence. The experiment was conducted at 21±2°C and each treatment repeated 10 times.

Host stage preference

Five unparasitised PAM larvae of each instar (first, second, third and fourth) and a *M. pulchricornis* adult were placed into a ventilated plastic container with artificial diet. After 24 h, the exposed larvae were removed and placed in individual plastic cups as described above. Parasitoid pupation and adult parasitoid emergence were recorded daily. The experiment was conducted at 21±2°C and repeated 20 times.

Data analysis

Statistical analysis of the data was conducted using the computer programme Origin® 5.0 (Microcal Software Inc.). The effect of temperature on development, adult longevity and parasitism were determined by ANOVA and least significant differences (LSD) were calculated where significant differences were indicated (*P*<0.05). The relationship between temperature and developmental rate for each life stage (egg and larva, and pupa) was calculated by linear regression using Origin. Only individuals that completed development to adulthood were included in the analyses.

RESULTS

Development of *M. pulchricornis* on PAM at different temperatures

Meteorus pulchricornis developed successfully within all five temperature regimes (Table 1). Total development time (egg to adult) ranged from 64.5 days at 13°C to 16.0 days at 25°C and the developmental rate (reciprocal of development time) increased linearly with increasing temperature (13-25°C) for all life stages ($r^2 > 0.98$). The regression equations describing these relationships were $y = 0.006x - 0.053$ and $y = 0.01x - 0.096$ for egg+larval and pupal development respectively. The mean pupal lengths of *M. pulchricornis* reared at 13, 18, 21 and 25°C were significantly greater than those reared at 30°C ($P < 0.05$). *Meteorus pulchricornis* survival until adulthood ranged from 61.5% at 13°C to 95.5% at 21°C.

TABLE 1: Mean development time (days ± SEM), pupal length (mm) and survival (%) of *Meteorus pulchricornis* on PAM 3rd larval instars at different temperatures.

Temperature (°C)	Egg-Pupae	Pupae	Total (egg to adult)	Mean pupal length	Survival to adult
13	34.3 ± 0.5	30.2 ± 0.4	64.5 ± 0.8	5.8 ± 0.1	70.0
18	15.3 ± 0.1	11.3 ± 0.2	26.6 ± 0.3	5.9 ± 0.1	94.7
21	12.8 ± 0.1	8.7 ± 0.1	21.5 ± 0.1	5.9 ± 0.1	95.5
25	9.3 ± 0.1	6.7 ± 0.1	16.0 ± 0.5	5.7 ± 0.1	81.5
30	9.4 ± 0.2	7.4 ± 0.2	16.8 ± 0.1	5.4 ± 0.1	61.5

Degree-day model development

The lower developmental thresholds for *M. pulchricornis* development from egg-pupae and pupae-adult were estimated to be 8.3°C and 9.6°C, respectively. It was estimated that 255 days above a lower developmental threshold temperature of 8.8°C were required for *M. pulchricornis* to complete development from egg to adult.

Effect of adult feeding on longevity and oviposition

Meteorus pulchricornis adult longevity was significantly shorter when provided with the agar-honey parasitoid diet (6.9 days) compared to no diet (9.9 days) ($P < 0.05$). Although adults produced a lifetime mean of 21.3 offspring when provided with agar-honey diet in comparison to 16.8 offspring with no diet, this difference was not statistically significant.

Host stage preference

Meteorus pulchricornis attacked and developed on all PAM larval instars presented, but a significantly higher number of second and third instar larvae were parasitised ($P < 0.05$) (Table 2).

TABLE 2: Mean percentage of painted apple moth larvae parasitised when different instars are exposed to *M. pulchricornis*.

Larval instar	% parasitised	Total parasitoid developmental time (days) (egg to adult)	PAM larval instar from which parasitoid adults emerged
1	14	27.4 ± 0.1	3
2	41	22.4 ± 0.1	3
3	43	22.0 ± 0.1	4
4	33	22.4 ± 0.1	4

DISCUSSION

The development time of *M. pulchricornis* from egg to adult was relatively similar to those of other *Meteorus* species reported by other authors. The mean developmental time of 16.0 days at 25°C was slightly shorter than that given by Miller (1996) for *Meteorus communis* reared on *Peridroma saucia* (16.9 days at 25.5°C). Fuester et al. (1993) found that development from egg to adult of *M. pulchricornis* on gypsy moth hosts required 16–32 days at 24°C, with a mean of 20.3 days. This was slightly longer than that reported in this study, but comparable to that reported by Fusco (1981) of 20.5 days for the biparental European strain on the same hosts. These differences may be attributed to a number of variables including host, food quality, humidity and genetic variation in populations. The study also highlighted that *M. pulchricornis* favours development at temperatures between 18 and 25°C. Grant & Shepherd (1984) found similar results with *Meteorus autographa*.

Determining the developmental thresholds of both a pest and parasitoid species is important in establishing the potential impact the parasitoid will have on controlling the pest population. The estimated developmental threshold of *M. pulchricornis* (8.8°C) was slightly lower than that predicted for PAM larvae (9.6°C) (Charles et al. 2006). This indicates that when PAM numbers start to increase in the field as temperatures increase, *M. pulchricornis* adults will already be present in significant numbers. However, as the parasitoid is polyphagous, it will not specifically attack PAM larvae, instead attacking a range of Lepidopteran larvae (Berry & Walker 2004). Therefore, although it may contribute to the parasitism load of PAM throughout the year, it may not have the ability to control PAM populations on its own.

Results of this study revealed that *M. pulchricornis* adults reared from PAM were shorter-lived and less fecund than reported for those reared on other hosts. Despite using similar methodology, Fuester et al. (1993) found that the average lifespan of *M. pulchricornis* on *L. dispar* was 44 days, and that the total number of eggs per female ranged from 50 to 387, with an average of 268. This is consistent with other *Meteorus* studies (Katiyar et al. 2001; Grant & Shepherd 1984). It would appear that PAM is not an optimum host for *M. pulchricornis*, but these differences could also be attributed to other factors such as differences in rearing conditions, which were not specified by all authors.

Females of different *Meteorus* species generally attack all stages of Lepidopteran larvae but usually prefer intermediate to late instars. For example, Fuester et al. (1993) found that although first to fourth instar gypsy moth larvae were acceptable hosts for *M. pulchricornis*, significantly higher numbers of second instar larvae were parasitised. In reality, most attacks on large larvae maybe unsuccessful because of the strength of the host’s resistance (Katiyar et al. 2001), or because the long hairs on the host’s body serve as mechanical barriers to oviposition (Fuester et al. 1993).

While *M. pulchricornis* completes development on PAM, it develops only at about the same rate as its host (one generation for each generation of the host).

Also, *M. pulchricornis* is a polyphagous species, attacking many species of Lepidoptera living within the same habitat as PAM. Hence *M. pulchricornis* does not appear to have characteristics that would enable it to respond rapidly to increases in PAM populations. Therefore, while *M. pulchricornis* may provide some level of control of PAM, it would be unlikely to be a primary regulator of PAM populations in New Zealand.

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