AESTIVATION IN APPLE LEAF-CURLING MIDGE (DIPTERA: CECIDOMYIIDAE) PARASITOID, *PLATYGASTER DEMADES* WALKER (HYMENOPTERA: PLATYGASTRIDAE)

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ABSTRACT

This study reports an investigation on the aestivation and overwintering strategies of *Platygaster demades,* an egg parasitoid of apple leaf-curling midge (ALCM), *Dasineura mali*, under natural conditions during 2005-2006. The first three generations of ALCM developed into adults during the spring-autumn of 2005/2006 and the fourth generation overwintered as larvae. All first generation *P. demades* emerged in the spring of 2005. About 64% of live individuals of *P. demades* in the second generation and 38% in the third generation entered aestivation as eggs, which hatched in mid March and early May 2006, respectively. Parasitoid eggs of the fourth generation started to hatch four weeks after the parasitised ALCM larvae entered the soil. The aestivated and fourth generation parasitoids overwintered as immature stages and started emerging in late September 2006. The emergence patterns of overwintered parasitoids and ALCM were highly synchronized in the following season.

Keywords: *Platygaster demades*, *Dasineura mali*, aestivation, overwintering, emergence.

INTRODUCTION

Apple leaf-curling midge (ALCM), *Dasineura mali* Kieffer (Diptera: Cecidomyiidae), is a serious pest in most apple growing regions of New Zealand (Tomkins et al. 1994; Smith & Chapman 1995). The high incidence of ALCM infestations in many commercial orchards has raised problems and concerns in the apple industry (Smith & Chapman 1995, 1997). *Platygaster demades* Walker (Hymenoptera: Platygastridae), an egg parasitoid of ALCM, was introduced to New Zealand in 1925 to control pear leaf-curling midge, *Dasineura pyri* (Bouché), and was first observed parasitising ALCM in 1954 (Todd 1956).

Both ALCM and *P. demades* have four life stages: egg, larva, pupa and adult. ALCM eggs are laid on upper surfaces of uncurled or partly uncurled leaves, and the eggs hatch in 3-5 days depending on temperature. Larvae grow and develop on the leaves, which makes the leaves roll up. The mature larvae then leave the plant and drop to the ground for pupation (Todd 1956). *Platygaster demades* eggs are laid into ALCM eggs and start hatching after the mature ALCM larvae leave the plant and commence spinning their cocoons. The parasitoid larvae destroy the host and complete their development in the larvae and early pupae of ALCM (Todd 1956).

Todd (1959) reported 4–5 generations a year for both ALCM and *P. demades*. Recent observations (2005-2007; X.Z. He, unpubl. data) show that these two species have four generations a year in Palmerston North, with the oviposition by adults of each generation occurring as follows: overwintered generation, late September–late October; first generation, late November–early January; second generation, mid January–early March; and third generation, early March–early April. Tomkins et al. (2000) reported the emergence of overwintered populations of ALCM and *P. demades* in spring. More recently, Sandanayaka & Charles (2006a) investigated the effect of temperature and diet on adult longevity of *P. demades.* However, information on the seasonal cycle of *P. demades* under natural conditions is still lacking, making it difficult to understand its population dynamics and co-evolution of the host-parasitoid system.

This study investigated the aestivation and overwintering of *P. demades* in the field, information that is vital to the understanding of the seasonal cycle of *P. demades*.

MATERIALS AND METHODS

Weekly monitoring of ALCM population in an organic orchard at Massey University, Palmerston North, commenced in early September 2005 when apple buds started germination. Sixty actively growing shoots were randomly selected and examined each week to estimate the oviposition period and larval development stages of each ALCM generation. To determine the emergence and development of both ALCM and *P. demades* in the field, mature ALCM larvae were collected from apple trees in the above orchard and buried in 40 metal mesh dishes (2 cm in height and 8.5 cm in diameter with aperture size < 0.5 mm) on 1 November 2005, 24 December 2005, 30 January 2006 and 8 March 2006, coinciding with the first, second, third and fourth (overwintering) ALCM generations, respectively. The dishes were filled with soil and buried (2 cm deep) horizontally under apple trees in the orchard. Of the 40 dishes buried for each generation, 20 dishes with 100 mature ALCM larvae each (emergence dishes) were used to investigate the emergence patterns of ALCM and *P. demades*, and 20 dishes with 50 mature ALCM larvae each (development dishes) were employed to monitor the development of the parasitoid. The parasitism rate of each ALCM generation was measured by dissecting 100 mature ALCM larvae on the date that the above dishes were buried for each generation.

For emergence dishes, a transparent plastic cylinder was pushed into the soil on the top of each dish and fastened by two 5 cm steel nails. The cylinders were the same diameter as the dish and 10.5 cm in height, with a metal mesh top and two holes covered with metal mesh (3 cm in diameter) on opposite walls for ventilation (aperture size of the mesh <0.5 mm). All cylinders were examined daily and emergence of both ALCM and its parasitoids recorded.

For development dishes, two dishes of each generation were brought to the laboratory weekly and the ALCM larvae and cocoons were dissected under a microscope to determine the developmental stages of *P. demades*. The exception was the fourth generation where only one dish per week was dissected. Eggs that failed to hatch when all non-aestivated individuals of the same generation had become adults were considered to have entered aestivation.

Due to the unexpectedly high proportion of parasitoids remaining at the egg stage in the second and third *P. demades* generations and as all 20 development dishes for these generations had been dissected by 10 weeks, some ALCM from the emergence dishes were used to continue the development study. ALCM cocoons (300 and 250 for the second and third generation, respectively) were extracted from the emergence dishes and reburied in fresh dishes in the field. Every week seven and five cocoons were dissected from these dishes for the second and third generations, respectively. The emergence of parasitoids from the remaining cocoons was observed daily until all emerged.

In this study, only live individuals were used for analysis.

RESULTS

The parasitism rate was 55.0, 40.9, 67.6 and 73.1% for the first, second, third and fourth (overwintering) generations of ALCM, respectively.

All *P. demades* developed and emerged in the first generation of ALCM with no individuals remaining as immature stages. In the second ALCM generation, the non-aestivated *P. demades* (36.4%) emerged until 14 February 2006. Dissections on 18 February 2006 indicated that 63.6% parasitoids still remained as eggs, which started to hatch 4 weeks later (18 March 2006) (Fig. 1). In the third ALCM generation, 62.5%

P. demades adults emerged until 14 April 2006, with 37.5% of individuals remaining as eggs at that time. These eggs started to hatch 3 weeks later (6 May 2006) (Fig. 1). In the fourth generation, no *P. demades* adults emerged in the autumn of 2006, and eggs started hatching 5 weeks (6 April 2006) after ALCM larvae entered the soil (Fig. 1). All parasitoid eggs in the second, third and fourth generations hatched by the end of May 2006 (Fig. 1).

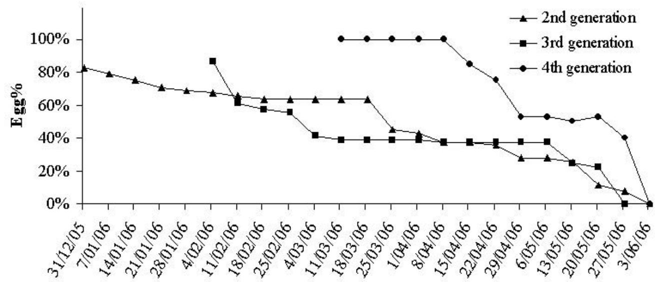

FIGURE 1: Development of *P. demades* eggs in the second, third and fourth generations in the field during 2005/2006.

Parasitoids of the second, third and fourth generations started pupation between late June and early July 2006 (10 July, 4 July and 28 June 2006, respectively). All live individuals completed pupation during late August (22 August 2006 for the third generation) and early September 2006 (7–9 September 2006 for the second and fourth generations). Therefore, the aestivated *P. demades* in the second and third generations and all *P. demades* in the fourth generation overwintered. All non-parasitised ALCM in the first three generations emerged in the spring, summer and autumn, respectively, and the fourth generation overwintered.

Figure 2 illustrates the emergence of overwintered parasitoids of different generations, indicating that the three generations of overwintered *P. demades* had the same emergence pattern in the new season. The adult emergence of overwintered *P. demades* and ALCM was highly synchronised (Fig. 2).

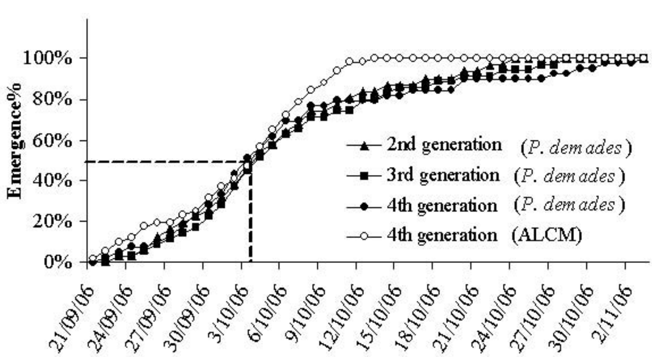

FIGURE 2: Emergence of the adult *P. demades* and ALCM from overwintering field populations during 2005/2006.

DISCUSSION

Among parasitoids, seasonal coincidence with their hosts is vital to the success of biological control programmes and diapause is one of their major adaptations to synchronise their activity with biotic resources and environmental constraints (Tauber et al. 1986). Aestivation is a kind of diapause during summer (Masaki 1980). The present study found that *P. demades* aestivated as eggs in a high proportion of the second and third generations. After hatching these *P. demades* overwinter as larvae or pupae, along with all individuals in the fourth generation. Aestivation as eggs has also been found in *P. subuliformis* (Kieffer), an egg parasitoid of brassica pod midge (*Dasineura brassicae*) (Murchie et al. 1999), and some other egg parasitoid species, such as *Anagrus takeyanus* Gordh & Dunbar (Tsukada 1999).

In the present study, the parasitism rate for the second generation was about 41%, which was much higher than the 1–2% reported in 1950s (Todd 1959). Reasons for this are not clear and warrant further investigation.

Although the aestivated eggs in the second and third generations and eggs in the fourth generation hatched in different months from autumn to winter, insects of these three generations completed pupation at the similar time. Furthermore, the emergence of *P. demades* adults from the three overwintered generations was highly synchronised with that of ALCM of the fourth (overwintered) generation in the new season (Fig. 2). The results of the present study may explain the high parasitism rate of ALCM in the first generation (Todd 1959).

Sandanayaka & Charles (2006b) suggest that ALCM may become a contaminant of export fruit if mature larvae fall into the calyx of the fruit and pupate there. All unparasitised ALCM in the first three generations emerged normally during the season. Therefore, it is thought that the main cause of fruit contamination could be ALCM parasitised by aestivated *P. demades* and fourth generation ALCM (Fig. 1) attaching to the fruits.

ACKNOWLEDGEMENTS

We thank Drs Mike Butcher, Pip Gerard and Sue Zydenbos for their constructive comments on an earlier draft and Pipfruit New Zealand Ltd for financial support.

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