PHENOLOGY OF APPLE LEAFCURLING MIDGE (*DASINEURA MALI*) IN RELATION TO PARASITISM BY *PLATYGASTER DEMADES*

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ABSTRACT

The phenology of apple leafcurling midge (ALCM, *Dasineura mali*) and that of its parasitoid, *Platygaster demades*, was monitored in orchards over several years in the Nelson district. There were 4–5 generations of ALCM, the first two being distinct while the following generations tended to overlap. Host and parasitoid populations were generally synchronized except for the second generation when parasitoid numbers were low and parasitism levels dropped. Midge populations increased rapidly at this time and remained high in subsequent generations despite moderate levels of parasitism. Laboratory studies on the effect of temperature on host and parasitoid pupal development rates combined with weather station data and actual soil temperatures were used to develop a model to predict generation timing. *Platygaster demades* adults had a longer development period and emerged later than ALCM adults. The influence of host and parasitoid phenology on parasitism levels and biological control of ALCM is discussed.

Keywords: Apple leafcurling midge, *Platygaster demades*, phenology, biological control.

INTRODUCTION

Apple leafcurling midge (ALCM, *Dasineura mali* Kieffer) (Diptera: Cecidomyiidae) was first recorded in New Zealand in 1950 (Todd 1956) and is now widespread throughout the country (Penman 1984). Adult female ALCM oviposit between the folds of immature leaves on developing shoots and heavily infested shoot tips can become severely damaged and stunted as a result of larval feeding. There may be up to five generations per year. The first two generations are clearly defined while the remainder overlap during summer (Todd 1959). The number and timing of generations can vary between seasons and each is influenced by temperature, rainfall and latitude. In wet, warm seasons, when there is abundant shoot growth for oviposition, midge populations may increase to damaging levels. This is particularly likely on young apple trees and grafts producing numerous growing shoots.

Midge populations increase rapidly during early summer and most of the damage to trees occurs during the second generation, which coincides with the period of maximum shoot growth (Todd 1959). After January, midge infestations usually decline as the number of growing shoots decreases thereby limiting the number of sites available for oviposition.

The small black parasitoid wasp, *Platygaster demades* (Walker), which was introduced to New Zealand in 1925 to control pear leafcurling midge (*Dasineura pyri*), also attacks ALCM. In Europe, *P. demades* has been reported to play a significant role in reducing ALCM populations (Carl 1980; Trapman 1988), and so it is also considered to be the most important natural enemy of ALCM in New Zealand. Females oviposit in ALCM

eggs and the wasp larva lives inside the host egg and larva throughout its development, eventually emerging from the midge pre-pupa in its cocoon. The majority of both ALCM and *P. demades* pupate in the soil, although some ALCM form cocoons in the trees or around the calyx or stem on apple fruits. Past observations in New Zealand showed some variation in the levels of parasitism between and within seasons (Todd 1956, 1959). The variation was partially linked to seasonal variation in the multi-voltine midge populations, but despite high levels of parasitism by *P. demades*, ALCM populations can still reach damaging proportions (Todd 1959). This study investigated the relationship between host and parasitoid generations and the impact this has on seasonal parasitism levels and biological control of ALCM.

METHODS

ALCM and *P. demades* monitoring

Data on seasonal activity of ALCM and *P. demades* were gathered from a variable number of orchard sites and seasons over a ten-year period between 1995 and 2005. At least two flat plastic yellow sticky traps (190 x 180 mm) per site with a single trapping surface were hung on apple trees to monitor *P. demades*. Traps were collected and changed at weekly intervals and parasitoid counts were recorded with the aid of a binocular microscope. Up to thirty actively growing shoots (if available) were examined once or twice per week from September to April at monitoring sites and the percentage infested with ALCM eggs was recorded. Egg-laying peaks provided an indication of successive ALCM generations.

Numbers of *P. demades* were not monitored in 1996-97, but were estimated by averaging trap catch data from three sites over three seasons (2001 to 2004) and offsetting this against ALCM phenology in 1996-97 so that the first generation *P. demades* peak matched that of its host, as is observed in the field (Todd 1959; Tomkins et al. 2000) (Fig. 1).

Parasitism of ALCM

Parasitism data were collected from the same three sites where *P. demades* was monitored over three seasons (2001 to 2004). For each ALCM generation, a sample of infested shoots was collected from each monitoring site when mature ALCM larvae were observed. The shoots were sprayed with water to extract the mature larvae, 100 of which were dissected and examined with a microscope to record percent parasitism.

Emergence model

During the 2004-05 season, the effect of temperature on second and third generation ALCM and *P. demades* adult emergence was assessed in laboratory trials at 11, 15, 19, 23 and 27°C using mature (pre-pupal) fully-fed ALCM larvae collected in Nelson from the first two generations. For each temperature, at least 400 first generation and 1800 second generation larvae were transferred to potting mix and kept in containers (300 x 210 x 100 mm) covered with nylon gauze inside temperature-controlled chambers until adult emergence. The containers were checked daily and numbers of emerged adult ALCM and *P. demades* recorded. For each temperature, cumulative emergence of ALCM and *P. demades* adults were plotted against time. A simple model was computed to predict time to 50% emergence at each temperature for each generation.

Temperature loggers (iButton®) were used to record mean hourly soil temperatures at 10-20 mm (the approximate depth at which ALCM pupate) at one orchard site from 30 June 2004–14 December 2004 (8 loggers) and 7 February 2005–6 April 2005 (2 loggers). This dataset was used in conjunction with hourly weather station data (air temperature and 100 mm and 200 mm soil temperatures) to develop a multiple linear regression model predicting the soil temperatures at 10-20 mm from weather station data. Thus the historical weather station data, which were available from 1996, were used to predict the soil temperature at 10-20mm which was then used to predict time to 50% emergence of ALCM or *P. demades* adults in the field.

RESULTS

Although a large quantity of data on ALCM and *P. demades* activity was gathered over ten seasons, the number of seasons for which ALCM oviposition timing, trap catch of *P. demades* and temperature data were all available was limited. Therefore a monitoring site from 1996-97, for which a complete weather station dataset was available, was chosen as representative of ALCM phenology (Fig. 1). Most of the nine datasets containing the proportion of ALCM egg-infested shoots indicated at least four generations, with seasonal peaks occurring during October, November-December, January and February-March. The interval between the first and second generation egg peaks was approximately 55 days with the third generation egg peak occurring approximately 39 days later.

FIGURE 1: The incidence of shoots infested with ALCM eggs (%) during 1996-97 (solid line) and estimated trap catches of *Platygaster demades* (dashed line). Horizontal bars show the predicted emergence of second generation ALCM (black) and *P. demades* (grey) allowing for larval and pupal development time (dashed bars). Figures are mean percentage ALCM parasitism for each generation.

A good estimate of the average soil temperature at 10–20 mm was obtained from a combination of air temperature and soil temperatures at 100 mm and 200 mm ($R^2 = 97.5\%$) (data not shown).

For typical soil temperatures at 10–20 mm in November (14–15.5°C), the laboratory rearing data were used to predict that 50% adult emergence of ALCM in the field would occur between 41–35 days after pupation for the second generation and between 38–33 days for the third at typical soil temperatures between 16.5–18.5°C (Fig. 2). The laboratory data also demonstrated that *P. demades* took approximately 25 days longer than ALCM to reach 50% emergence (Fig. 2), which would explain why the numbers of *P. demades* caught in traps remained low during the second generation of ALCM in November (Fig. 1). Mean percentage parasitism of ALCM for each generation is shown in Figure 1.

FIGURE 2: The number of days to 50% emergence of second and third generation ALCM and *P. demades* adults at different soil temperatures. Data were collected from mature larvae placed in a covered container filled with potting mix and kept inside temperature-controlled chambers at 11, 15, 19, 23 and 27°C until adult emergence. For each temperature, at least 400 first generation and 1800 second generation larvae were used. Figures inside the cross-hatching highlight the difference in modelled emergence time between ALCM and *P. demades* at typical soil temperatures for each generation as estimated from weather station data.

DISCUSSION

Monitoring of ALCM egg-infested shoots showed four generations with seasonal peaks occurring during October, November-December and January and some overlap of generations during February-March (Fig. 1). The observed interval between first and second generation egg peaks of around 55 days (Fig. 1) can be estimated by assuming 2 days for egg-hatch from when eggs were first recorded (given that observed eggs were of unknown age and may have been close to hatching), approximately 15 days for larval development and another 40 days to 50% adult emergence.

Phenology of ALCM both within a region and between regions may be influenced by temperature, which affects development time, and rainfall, which can determine when mature larvae leave the leaf-rolls. These factors also affect the period of active shoot growth, which is important since ALCM require growing shoot tips on which to lay their eggs.

Peak *P. demades* trap-catches coincided with ALCM egg laying peaks in generations 1, 3 and 4. However, during the second generation parasitoid numbers were very low (Fig. 1). Close synchrony of first generation midge and parasitoid adults, both emerging from over-wintering populations, has been reported by Tomkins et al. (2000). The mechanism that leads to the synchrony of emergence of the first generations is unknown. Tompkins et al. (2000) suggested there may be a requirement for a period of winter chilling to end diapause of over-wintering ALCM and parasitoid pre-pupae. As the parasitoid takes longer to develop, the induction of pupation for the parasitoid probably occurs earlier than for ALCM at this time.

Seasonal mean percentage parasitism of ALCM was related to the timing of host and parasitoid peak populations. The highest levels of parasitism were recorded for the well-synchronised first generation (83%) and was 50–60% for the third and fourth generation where there was some overlap in ALCM and *P. demades* populations. Parasitism by *P. demades* was low (3%) during the second ALCM generation in November–December when parasitoid numbers were low and host and parasitoid populations were not well synchronized (Fig. 1). High levels of parasitism (80%) have been recorded in a fifth generation of ALCM in April (P.W. Shaw, unpubl. data). These parasitism figures are supported by previous research (Todd 1959).

The asynchrony of the second generation and low level of parasitism is explained by the laboratory trials that demonstrated for typical soil temperatures in November, ALCM adults take between 41–35 days from pupation to reach 50% emergence and *P. demades* take approximately 25 days longer (Fig. 2). Therefore most of the second generation *P. demades* adults will emerge some time after the peak egg-laying activity of the second generation ALCM, resulting in a low level of parasitism. These results indicate that despite considerable levels of parasitism, ALCM populations can remain high and biocontrol by *P. demades* is compromised by the asynchrony of host and parasitoid populations during the second generation. However biological control of ALCM by other natural enemies, particularly predatory bugs and mites as well as spiders can, in the absence of disruptive insecticides, contribute significantly to reduce populations of ALCM over time (Shaw et al. 2003).

This emergence-timing model provided a good prediction for second generation ALCM and *P. demades* emergence, allowing for larval and pupal development time after the first generation ALCM egg peak. Further testing of the model both in Nelson and other apple growing regions would be worthwhile to establish correct spray timing and optimise insecticide applications during ALCM egg-laying peaks, in order to reduce damage on grafted and young establishing trees.

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REFERENCES

- Carl KP 1980. Observations on the apple leaf-curling midge (*Dasineura mali* Kieffer) and a new species from apple galls, (*Macrolabis* sp.) (Dipt.: Cecidomyiidae). Anzeiger für Schadlingskunde Pflanzenschutz Umweltschutz 53: 99–102.
- Penman DR 1984. Deciduous tree fruit pests. In: Scott RR ed. New Zealand pest and beneficial insects. Lincoln University College of Agriculture, Canterbury, New Zealand. Pp. 33–50.
- Shaw PW, Wallis DR, Rogers DJ 2003. The impact of early season insecticides on biological control of apple leafcurling midge (*Dasyneura mali*). New Zealand Plant Protection 56: 164–167.
- Todd DH 1956. A preliminary account of (*Dasyneura mali* Kieffer) (Cecidomyiidae: Diptera), and an associated hymenopterous parasite in New Zealand. New Zealand Journal of Science and Technology A37: 462–464.
- Todd DH 1959. The apple leaf-curling midge, (*Dasyneura mali* Kieffer), seasonal history, varietal susceptibility and parasitism 1955–58. New Zealand Journal of Agricultural Research 2: 859–869.
- Tomkins AR, Wilson DJ, Thomson C, Bradley S, Cole L, Shaw P, Gibb A, Suckling DM, Marshall R, Wearing CH 2000. Emergence of apple leafcurling midge (*Dasineura mali*) and its parasitoid (*Platygaster demades*). New Zealand Plant Protection 53: 179–184.
- Trapman M 1988. Apple leaf gall midge population build-up and natural regulation. Fruittelt 78: 34–35.