SYNCHRONISATION OF THE PARASITOID *CENTRODORA SCOLYPOPAE* WITH ITS HOST *SCOLYPOPA AUSTRALIS*

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ABSTRACT

Eggs of the univoltine passionvine hopper *Scolypopa australis* Walker (Homoptera: Ricaniidae) are parasitised by *Centrodora scolypopae* Valentine (Hymenoptera: Aphelinidae). The life cycle of the parasitoid, and synchronisation with its host, was studied in a gully near Hamilton over four years. The parasitoid was usually univoltine, overwintering in diapause as a prepupa and pupating when host adults were present in midsummer. However, above average summer temperatures in 1981 resulted in up to 60% of the parasitoid population on a sunny slope with a NE aspect pupating before winter, demonstrating that the diapause was facultative. Photoperiod was found to be a key factor in diapause maintenance.

Keywords: *Centrodora scolypopae*, *Scolypopa australis*, egg parasitoid, synchrony, diapause.

INTRODUCTION

The only host-specific parasitoid known to attack the passionvine hopper *Scolypopa australis* Walker (Homoptera: Ricaniidae), a pest of kiwifruit in New Zealand (Tomkins et al. 2000), is the egg parasitoid *Centrodora scolypopae* Valentine (Hymenoptera: Aphelinidae) (Cumber 1966). It was first detected in the Bay of Islands, New Zealand, in 1962 (Cumber 1966), and identified as a new species (Valentine 1966). When surveyed in 1962, parasitism levels averaged 39% north of Auckland, and it was found no further south than Wanganui (Cumber 1966). A recent survey has indicated it is probably now present throughout the range of passionvine hopper (PVH) in New Zealand (Charles & Allan 2004).

Synchrony of a parasitoid with its host is critical for successful biological control (Kidd & Jervis 1996). *Centrodora scolypopae* overwinters as a prepupa and does not pupate until host adults appear in midsummer. PVH is univoltine, overwintering in the egg stage, which has a very long period of continuous development (Fletcher & Anderson 1980). This paper reports field observations and experiments on the synchrony of *C. scolypopae* with its host PVH and the effects of parasitoid diapause on synchrony.

METHODS

Parasitism of PVH by *C. scolypopae* populations was studied in a bracken and blackberry-filled gully, 1 km from Hamilton airport, from 1981-1984. On both the N.E. and S.W. sides of the gully, two 25-30 m transects, 10 m apart and parallel with the gully floor, were cut at upper and lower elevations. PVH egg populations along these transects were estimated using a modification of a height frequency vegetation sampling method (Scott 1965), whereby egg batch numbers and plant species present were recorded within 5 cm^3 volumes through successive vegetation layers one above the other, thus forming a vertical sampling column. At least 50 samples were taken per transect at each sampling date. Sampling was undertaken October-November prior to PVH nymphal emergence and May-June, once PVH oviposition had ceased. At the time of the study, *C. scolypopae* was the only parasitoid present and as an amber protuberance was left where the ovipositor was inserted into the egg, parasitism was readily discernible on examination of host eggs.

Levels of parasitism were determined and parasitoid developmental stage ascertained after clearing the host egg chorion with 70% ethanol for the egg and early instars. Although an initial trial in 1981 (P.J. Gerard, unpubl. data) showed very few adults were caught in Malaise traps, a single trap at the best location (N.E. lower transect) was maintained to monitor weekly adult activity from January-April throughout the study. Day degrees above 10°C at the site were calculated from daily maximum and minimum temperatures recorded at Hamilton airport using the model of Baskerville & Emin (1969). Numbers of *C. scolypopae* per PVH egg batch were compared for each transect for each sample period using analysis of variance, after log transformation where necessary to reduce variance heterogeneity. Tukey's least significant difference test was used to determine differences between means at P=0.05.

During 1983 and 1984, additional PVH eggs on bracken were collected from the gully at monthly intervals from February 1983 to December 1984 and were held at 25°C and 16:8 h light:dark in a moist atmosphere. Parasitised eggs were inspected at weekly intervals to identify the initiation of pupation by the presence of meconial pellets.

In October and November 1984, additional parasitised eggs were collected and divided into two groups, with one group being placed in a lightproof box alongside the second group at 25°C and 16:8 h light:dark in a moist atmosphere. Forty days after collection, 20 egg batches from each group were randomly selected. The proportion of parasitised eggs containing pupae of *C. scolypopae* in each group was assessed using Fishers Exact 2 × 2 test.

RESULTS

The usual alignment of life stages of *C. scolypopae* with those of its host at the study site is depicted in Figure 1. There was little variability in the commencement of *C. scolypopae* pupation at the site during the study period, the earliest date being 4 January 1982 and the latest between 11-18 January 1983. Adult activity was observed in malaise traps from early February till early April. Development of the eggs and larvae was usually rapid, but did vary from year to year. Many parasitoids had reached the prepupal stage in March in 1981, while in 1983 unhatched parasitoid eggs could still be found in early April. At the site, *C. scolypopae* individuals overwintered for 8-9 months as prepupae, a stage readily discernible by the appearance of a dark grey bar in the ventral layer of the PVH egg (Gerard 1989).

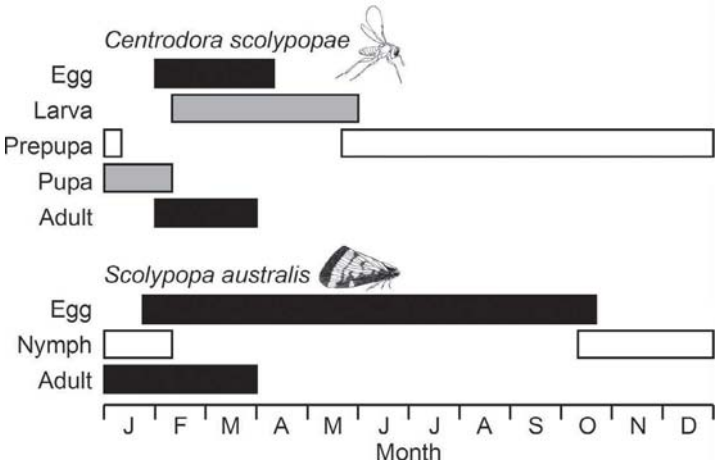

FIGURE 1: Normal life cycles of *C. scolypopae* and its host *S. australis* at a site near Hamilton airport.

In May 1981, some *C. scolypopae* prematurely pupated in the autumn and the subsequent October sampling revealed that, while some successfully emerged, most died (Table 1). While the overall level of parasitism showed a small increase from May to October (3.45 versus 3.98 parasitoids emerged per PVH egg batch), the difference was not significant (SED=0.30, LSD(P<0.05)=0.59). Premature pupation levels in subsequent years were insignificant, with a maximum of 0.1% (4/2979 parasitised PVH eggs) in 1984. The premature pupation appeared to be linked to the warm temperatures experienced early in 1981. The day degree summations for January–March were 807 in 1981, 697 in 1982, 609 in 1983 and 676 in 1984. In addition, more pupation in 1981 occurred on the sunny N.E. aspect of the gully, particularly in the upper transect, than on the more shady S.W. aspect (Table 1).

TABLE 1: Mean numbers of *C. scolypopae* found in PVH egg batches collected from bracken along four gully transects in 1981 and fate of parasitoid pupae in October.

	Mean parasitoids/egg batch in May		Mean parasitoids/egg batch in October		
Transect	Total	Pupae[1]	Total	Emerged[1]	Dead pupae[1]
N.E. upper	3.52	1.90	4.88	1.58	1.82
N.E. lower	3.67	0.87	3.42	0.43	0.75
S.W. upper	3.18	0.18	3.58	0.10	0.42
S.W lower	3.80	0.07	4.05	0.13	0.27
SED	0.60	0.17	0.59	0.15	0.21
LSD (P<0.05)	1.20	0.34	1.16	0.30	0.42
LSD (P<0.01)		0.46		0.40	0.56

[1]Means, SED and LSD back-transformed.

Once *C. scolypopae* field populations had reached the prepupal stage, the relationship between date collected from the field and days to first pupation of parasitoids collected and held at 25°C and 16:8 h light:dark was described by a quadratic equation (Fig. 2). Time from prepupa to pupation increased from a minimum in May of 10 days to a peak of over 30 days in August-September, and then declined in December to levels similar to those observed in April. When reared from eggs at a constant temperature of 25°C, the minimum time between first appearance of the prepupal and pupal stages was 11 days (P.J. Gerard, unpubl. data). Therefore, it can be deduced that the parasitoids that pupated after approximately 11–15 days (i.e. those collected in May and in December) were not in diapause, while those collected between May and December exhibited varying extents of diapause. *Centrodora scolypopae* individuals collected February and March did not enter diapause but since they were collected while still eggs and early instars, the time until pupation was correspondingly longer than those collected as prepupae.

When parasitoids collected from the field in October were held in the dark, only 7% (n=151) had pupated after 40 days, while 98% (n=136) of those held in the light had pupated (P<0.001). In contrast, no difference was found between parasitoids collected from the same location 17 days later and subjected to the same light regimes.

DISCUSSION

This study confirmed that at the study site, there was good synchrony of parasitoid and host in most years. The termination of parasitoid diapause in late October coincided with peak hatching of host eggs. Development of both species is highly dependent on temperature, and it is probable that the margin between the 14.5°C threshold for parasitoid pupation and 10°C threshold for PVH development (P.J. Gerard, unpubl. data) further facilitated synchronisation of the appearance of *C. scolypopae* adults and host eggs.

As the lower threshold for *C. scolypopae* larval development (between 10 and 12.5°C, P.J. Gerard, unpubl. data) is below that of pupae, the resulting generation of parasitoids could continue to mature in May, but pupation was inhibited with mean daily temperatures falling below 15°C. Thus the combination of cool temperatures and a photoperiod of <11 h would ensure the initiation of diapause.

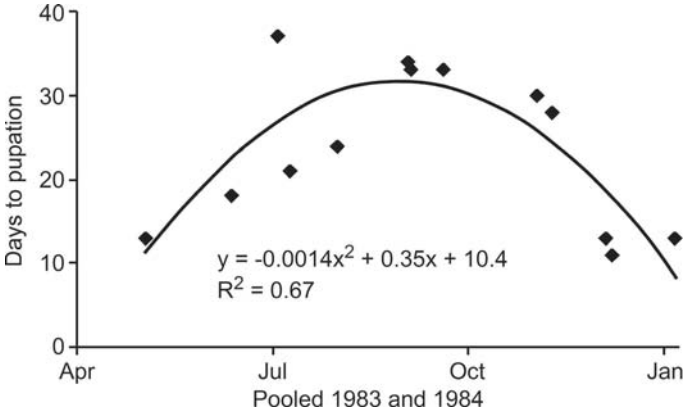

FIGURE 2: Relationship between date of collection of prepupae from the field and days to first pupation of *C. scolypopae* held at 25°C and 16:8 h light:dark (x = days since 1 May).

In 1981, many *C. scolypopae* did not enter diapause. Although laboratory tests showed that *C. scolypopae* successfully oviposit in PVH eggs of any age, and larvae can develop in mature PVH embryos, no sign of a second generation was detected in the field. Possibly, with June and July mean temperatures being below the lower threshold for egg hatch, and the likelihood of superparasitism (Gerard 1992) with the PVH egg population in bracken already ranging between 47±5% and 70±4% parasitism, very few second generation individuals would have established. At the study site, the same warm conditions that promoted premature pupation in parasitoids in 1981 also extended the duration of oviposition by the host. With low levels of parasitism in 1982, PVH populations were high the following spring (Gerard 1985).

The absence of diapause in 60% of parasitoids from the N.E. upper transect in 1981 following the warmest January-March period during the study provides strong evidence that *C. scolypopae* has a facultative diapause, and the results of the laboratory experiments indicate that diapause initiation is influenced by both temperature and light. This was confirmed by the author (P.J. Gerard, unpubl. data), who found at 15°C, all parasitoids reared from eggs entered diapause irrespective of photoperiod; those at 20°C entered diapause in the dark, but not in a long photoperiod, while those at 25°C had no diapause even without light. This interaction between temperature and light has been found in other parasitoids, including the aphelinid *Aphelinus varipes* (Foerster) (Yu 1992).

The 90% difference in pupation of parasitoid prepupae collected mid October and exposed to contrasting light regimes indicates that photoperiod is a key factor in the maintenance of diapause. As this difference disappeared when parasitoids were collected 17 days later, one may speculate that for *C. scolypopae* the critical photoperiod occurs in October, i.e. between 13 and 14 h light.

Subtropical districts in New Zealand are likely to have two complete *C. scolypopae* generations in most years. In early March 1982, the author found PVH eggs at Lake Taharoa, 35 km north of Dargaville, containing *C. scolypopae* pupae and adults about to emerge, and others at Russell containing pupae. Subsequent temperatures at these localities would have enabled a second generation to mature with ease. This second generation could improve the efficacy of *C. scolypopae* against PVH in these localities, but surveys by Cumber (1966) and Charles & Allan (2004) showed no evidence of this. Again, it is very possible many of this second generation were lost through superparasitism of previously parasitized eggs, as *C. scolypopae* marking pheromones are unlikely to be persistent for more than 10 days (Gerard 1992).

In conclusion, failure to enter diapause appears to result in parasitoid mortality and may affect abundance of the parasitoid in the next generation. This would help explain why parasitism by *C. scolypopae* is ineffective in keeping PVH infestations below damaging levels.

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