DEVELOPMENTAL BIOLOGY OF TWO SPECIES OF LEAFROLLER EGG PARASITIDS

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ABSTRACT

Leafrollers (Lepidoptera: Tortricidae) are important pests of many horticultural crops. Leafroller eggs in New Zealand are attacked by the trichogrammatid parasitoids *Trichogrammatoidea bactrae* and *Trichogrammanza funiculatum* (Hymenoptera: Trichogrammatidae). Conventionally, trichogrammatids are used for pest control through augmentation of numbers by making mass releases. Laboratory tests have been carried out to ascertain the potential of the two egg-parasitoid species to act as biological control agents for the key leafroller pests in New Zealand. *T. funiculatum* had a slightly slower developmental rate than *T. bactrae*. Temperature did not significantly affect the number of eggs parasitised by the adult parasitoids over their lifetime, but temperature did affect the percentage of adult parasitoids emerging from parasitised eggs. *T. bactrae* had higher net reproductive rates and intrinsic rates of increase than *T. funiculatum*, and at this stage appears to be the most suitable candidate for an augmentative biological control programme.

Keywords: Trichogramma, leafrollers, biological control.

INTRODUCTION

There is an increasing move in New Zealand for horticultural crops to be managed using Integrated Pest Management (IPM) or Integrated Fruit Production (IFP) systems (e.g. KiwiGreen and IFP-pipfruit). As a first step towards IFP, insecticides are only applied when pest populations can justify intervention, and where possible, selective insecticides are used. Under IFP, biological control is set to play an increasingly important role in reducing pest populations. While there has been a history in New Zealand of 'classical' biological control, where natural enemies of important pests are introduced from overseas, there has been less emphasis on enhancing the activity of natural enemies already present. There are several ways of manipulating and enhancing natural enemy populations, including the provision of flowering plants as a nectar source for adult parasitoids or by augmenting populations through mass-rearing and release programmes.

Several species of leafroller (Lepidoptera: Tortricidae) are important horticultural pests in New Zealand, including *Epiphyas postvittana* (Walker), *Ctenopseustis obliquana* (Walker), "*Cnephasia*" *jactatana* (Walker) and *Planotortrix octo* Dugdale (Wearing *et al.* 1991). Leafrollers in New Zealand are attacked by several species of egg parasitoids (Hymenoptera: Trichogrammatidae) (Thomas 1989; Valentine and Walker 1991). Parasitism levels are generally very low, and do not provide the level of leafroller control required in commercial horticultural plantings (P. Stevens, unpubl. data). However, in many other countries, control of lepidopterous pests by mass rearing and release of *Trichogramma* spp. has occurred for many decades (Elzen and King 1999). Effective biological control through augmentation of natural enemies requires a substantial knowledge of the parasitoid biology and host associations. As a first step in evaluating the potential of using egg parasitoids currently present in New Zealand for augmentative biological control of leafrollers, colonies of two parasitoid

species (*Trichogrammanza funiculatum* Carver and *Trichogrammatoidea bactrae* Nagaraja) have been established. Both species are solitary endoparasitoids of leafroller eggs. This paper describes the results of laboratory tests to determine biological parameters (temperature/development rates, net reproductive rate and intrinsic rate of increase) of the two species.

METHODS

Parasitoid colonies

Insects used to establish the laboratory colonies were obtained from parasitised leafroller eggs batches found on avocados in Auckland (*T. bactrae*) and kiwifruit leaves in the Bay of Plenty (*T. funiculatum*). Samples of adults were provided to Dr. J. Berry (Landcare Research) for identification. The colonies were reared on *C. obliquana* eggs that were obtained from the insect rearing unit at HortResearch, Mt Albert. Colonies were maintained at 18°C and a 16:8 h light:dark regime.

Experimental design to obtain developmental parameters

A caged cohort of newly emerged (<24 h after emergence) parasitoids was established by enclosing a single male and female adult parasitoid pair within a plastic tube (75 mm long and 10 mm diameter) containing a single *C. obliquana* egg batch (<24 h after oviposition). A smear of parasitoid food (Froud 1997) was placed on the inside of each tube and the tube sealed with cotton wool. A total of 20 pairs of each parasitoid species were set up and held in one of four constant temperature conditions (15, 18, 20 or 25°C in 16:8 h light:dark).

The adult parasitoids were checked daily for survival. To determine the daily rate of parasitism, the host egg batch in each tube was replaced daily for the lifetime of the female parasitoid. All host egg batches that had been exposed to parasitoids were kept at the constant rearing temperature and checked daily for emergence of parasitoid progeny. The total numbers of parasitised eggs (as indicated by black colouration), and the numbers and sex of emerged parasitoids were recorded.

Calculation of developmental parameters

To estimate the lower developmental thresholds for the parasitoids, the developmental rate (1/number of days in each life stage) was regressed against temperature. The linear regression lines were extrapolated to zero to provide estimates of the temperatures at which development would cease (the developmental threshold (a)). The number of degree-days above the developmental zero needed to complete development (the thermal constant (k)) was calculated as 1/slope of the regression line.

The net reproductive rate, R_0 (the number of times a population would multiply each generation), for the two species of parasitoids was calculated using the methods described in Southwood (1978). A life and fertility schedule was constructed with the following columns: x (age of adult parasitoid in days), l_x (proportion of cohort surviving each day) and m_x (number of daughters produced per female each day). Columns l_x and m_x were multiplied to give the total number of female offspring produced each day. The net reproductive rate is defined as the summation of the total number of female offspring produced each day ($R_0 = \sum l_x m_x$).

The intrinsic rate of increase (r_c) was calculated according to the formula described in Krebs (1978) as $r_c = \log_e(R_0)/T$, where T is the mean period between the birth of the parent and the birth of offspring (in this case the emergence of adult parasitoid is used as the birth of offspring).

Statistical analysis

The effects of temperature on parasitism, longevity and percentage adult emergence were analysed using ANOVA. All percentages were angular transformed prior to analysis but untransformed percentages are presented in tables. Differences between treatments were tested for significance using Fishers Least Significant Difference (LSD). All analysis was carried out using the statistics software SAS (SAS Institute 1985).

RESULTS

The number of days between parasitism and adult emergence ranged from 10 to 35, depending on temperature and species (Table 1). There were slight differences between the two species with *T. funiculatum* having a slower development rate than *T. bactrae*, and this is reflected in the higher value of the thermal constant for *T. funiculatum*. There were significant linear regressions between temperature and development rate and the R^2 values indicate that the temperature effect directly accounted for approximately 88% of the variation in the observed data.

TABLE 1: Effect of temperature on development rate of *T. bactrae* and *T. funiculatum*.

Temperature (°C)	Number of days from parasitism to adult emergence	
	<i>T. bactrae</i>	<i>T. funiculatum</i>
15	32.9 ± 0.5	35.0 ± 0.3
18	19.1 ± 0.4	22.7 ± 0.3
20	15.4 ± 0.1	17.5 ± 0.2
25	9.6 ± 0.1	12.1 ± 0.3
Regression ¹	Y = -0.080 + 0.007x	Y = -0.058 + 0.006x
P value	0.001	0.001
R ²	0.8847	0.8757
Developmental zero (°C)	10.8	10.1
Thermal constant (K)	134.8	175.2

¹Linear regression of developmental rate against temperature.

Adult parasitoids survived for 8 to 37 days depending on sex and temperature (Table 2). Both male and female *T. bactrae* survived for significantly longer at 15°C compared to all other temperatures. However temperature did not significantly affect longevity of male or female *T. funiculatum*.

TABLE 2: Effect of temperature on longevity of male and female *T. bactrae* and *T. funiculatum*.

Temperature (°C)	Mean (± SE) longevity of adults (days)			
	<i>T. bactrae</i>		<i>T. funiculatum</i>	
	Male	Female	Male	Female
15	18.0 ± 2.6 a ¹	37.1 ± 3.8 a	5.8 ± 0.9 a	8.8 ± 1.7 a
18	9.7 ± 1.7 b	22.8 ± 2.2 b	5.6 ± 0.9 a	10.9 ± 1.9 a
20	8.9 ± 1.9 b	18.5 ± 2.9 bc	7.7 ± 1.9 a	12.1 ± 2.4 a
25	10.0 ± 1.3 b	12.3 ± 1.2 c	3.9 ± 1.1 a	8.1 ± 1.2 a
P value	P<0.05	P<0.05	P>0.05	P>0.05

¹Values within a column followed by the same letter are not significantly different (P>0.05).

Temperature did not significantly affect the total number of leafroller eggs parasitised by *T. bactrae* or *T. funiculatum* females over their life (Table 3). No more than 60% of the eggs parasitised, as indicated by black colouration, resulted in the successful emergence of adult parasitoids. There was a significant reduction in percentage emergence of *T. bactrae* adults at 20°C and *T. funiculatum* adults at 25°C compared to other rearing temperatures.

Calculation of net reproductive rates and intrinsic rates of increase showed that *T. bactrae* has a much higher potential to increase population size compared to *T. funiculatum* (Table 4).

TABLE 3: Effect of temperature on mean number of *C. obliquana* eggs parasitised (as indicated by black colouration) by *T. bactrae* and *T. funiculatum* over lifetime and percentage of adult parasitoids emerging from parasitised eggs.

Temperature (°C)	Mean number of parasitised leafroller eggs per female <i>T. bactrae</i>	<i>T. funiculatum</i>
15	54.5 ± 8.9 a ¹	21.5 ± 4.7 a
18	35.8 ± 6.2 a	40.1 ± 7.3 a
20	70.5 ± 16.4 a	47.1 ± 8.5 a
25	66.2 ± 8.9 a	50.3 ± 10.8 a
P-value	P>0.05	P>0.05
% emergence of parasitoids		
15	60.8 ± 3.9 a	42.2 ± 4.0 a
18	51.9 ± 5.1 a	52.6 ± 5.2 a
20	35.4 ± 6.7 b	48.5 ± 4.5 a
25	53.3 ± 4.8 a	25.3 ± 3.4 b
P-value	P<0.05	P<0.05

¹Values within a cell followed by the same letter are not significantly different (P>0.05).

TABLE 4: The net reproductive rates and intrinsic rates of increase of *T. bactrae* and *T. funiculatum* at four constant temperatures.

Temperature (°C)	Net reproductive rate (R ₀)	
	<i>T. bactrae</i>	<i>T. funiculatum</i>
15	27.5	5.4
18	12.6	5.3
20	26.1	7.9
25	25.2	8.3
Intrinsic rate of increase (r _c)		
15	0.0836	0.0442
18	0.0991	0.0537
20	0.1288	0.0805
25	0.1947	0.1113

DISCUSSION

Biological parameters obtained in laboratory studies can be used as part of a selection process to identify the best biological control agents for augmentation programmes (Bellows and van Driesche 1999). The establishment of biological parameters is also important when initiating mass rearing, as part of developing quality control procedures (Smith and Hubbes 1986). In any augmentation programme it is important to ensure that the quality of parasitoids released into the field does not decline over time. The intrinsic rate of increase is a useful parameter as it expresses the combined effects of fecundity, longevity and development on population growth.

These results indicate that both species of leafroller egg parasitoids have very similar temperature/development parameters so would be likely to survive in the same climatic zones. However *T. bactrae* has better potential to control leafroller populations through a greater overall reproductive rate compared to *T. funiculatum*. The values of r_c found can be compared with values for other species of Trichogrammatidae. Pak and Oatman (1982) reported values for *Trichogramma brevicapillum* and *T. pretiosum* ranging between 0.04 and 0.34. Smith and Hubbes (1986) reported values of r_c between 0.06 and 0.35 for *Trichogramma minutum*. They also found that the host species may be a more important factor affecting the value of r_c and metabolic processes than temperature. All the experiments in the current research were carried

out using the host species *C. obliquana*, but comparisons of results obtained with other leafroller host species is warranted in the future.

Another important factor to consider when selecting species for augmentation is the host species preference. Although Trichogrammatidae are sometimes considered as extreme generalists, attacking a wide range of hosts (Clausen 1940), more recent research has concluded that Trichogrammatidae can be host-specific. Even within species, different strains have been found to exhibit different host preferences (Glas *et al.* 1981; Pak 1986). Previous evaluations of the host preferences of *T. bactrae* in New Zealand found that *E. postvittana* was the preferentially attacked host species, but preference was influenced by the species in which the adult parasitoid had developed (Stevens 1995). Further laboratory studies to determine the host species preferences of *T. bactrae* and *T. funiculatum* need to be carried out prior to the establishment of any augmentative field trials. However, at this stage, *T. bactrae* would appear to be the better candidate for augmentation.

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