EFFECT OF PHOTOPERIOD ON DEVELOPMENT AND REPRODUCTION IN TASMANIAN LACEWING *MICROMUS TASMANIAE* (WALKER) (NEUROPTERA: HEMEROBIIDAE)

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ABSTRACT

Tasmanian lacewing, *Micromus tasmaniae* (Walker), is an important predator of many aphid species. This study investigated the effect of four photoperiods on predation, development and oviposition of *M. tasmaniae* in the laboratory at $21 \pm 1^\circ\text{C}$ and 60% RH. Results indicated that no individuals entered diapause at either immature or adult stage. At each photoperiod, late instar larvae consumed significantly more aphids than early instar larvae ($P < 0.0001$). Developmental period of *M. tasmaniae* from egg to adult was significantly shorter at 24:0 and 16:8 h (light:dark) than at 12:12 and 0:24 h ($P < 0.0001$). Pupal mortality was significantly lower at 16:8 and 12:12 h. The reproductive period decreased significantly with increasing day length. However, fecundity and fertility were significantly higher at 16:8 and 12:12 h ($P < 0.0001$). The sex ratio was male-biased with no significant difference between photoperiods. The significance of these results in the understanding of foraging behaviour and mass rearing is discussed.

Keywords: Tasmanian lacewing, *Micromus tasmaniae*, *Acyrothosiphon pisum*, photoperiod, predation, development.

INTRODUCTION

The Tasmanian lacewing, *Micromus tasmaniae* (Walker), is an important predator of blue green lucerne aphid, *Acyrothosiphon kondoi* Shinji, and pea aphid, *A. pisum* Harris, in New Zealand (Cameron et al. 1983; Workman et al. 2004). In Australia, it preys on the eggs of *Helicoverpa armigera* Hubner (Lepidoptera: Noctuidae) (Samson & Blood 1980). Serological and laboratory feeding trials in New Zealand demonstrated the potential of *M. tasmaniae* as an effective predator of *A. kondoi* (Leathwick & Winterbourn 1984; Rohitha & Penman 1986). In the field, it has successfully controlled lettuce aphid, *Nasonovia ribisnigri* Mosley, in spring crops in Pukekohe, New Zealand, for 4 consecutive years (Cameron et al. 2007; Workman et al. 2004).

The hemerobiids are the most important Neuroptera next to the Chrysopidae in controlling soft-bodied agricultural pests (Balduf 1974). The high tolerance of *M. tasmaniae* to some pesticides led Rumpf et al. (1997) to believe that they have high potential in integrated pest management.

Photoperiod reportedly affects development and diapause of lacewings, such as *Chrysopa pallens* Rambur (Grimal & Canard 1990; Orlova 1998). However, there has been no systematic evaluation of how photoperiod influences the foraging and reproductive behaviour of *M. tasmaniae*. The objective of this study was to improve understanding of the biology of *M. tasmaniae*.

MATERIALS AND METHODS

Breeding colony

The breeding colony of *M. tasmaniae* was obtained from a commercial insectary (Zonda Resources Ltd, Pukekohe, New Zealand) during October 2007. Sixty adults were housed in a plastic container (8.5 cm diameter × 10 cm high) having a lid with a fine nylon mesh window (5 cm diameter). They were fed with 1st to 3rd instar pea aphids reared on potted broad bean plants (*Vicia faba* L.). A black cotton sheet (4 cm × 4 cm) was placed at the bottom of the plastic container for oviposition (Miller & Cave 1987). The container was examined every 24 h and eggs laid on the cotton sheet were placed in a plastic box (22 cm long × 15 cm wide × 5 cm deep) for hatching. The newly hatched larvae were further reared on pea aphids in groups of 40-50 larvae in an above-mentioned plastic box and emerged adults were used for further rearing. The breeding colonies were maintained at 21 ± 1°C and 60% RH with a photoperiod of 16:8 h (light:dark).

Development and mortality

To investigate how photoperiod affected feeding, development and reproduction, four photoperiods of 24:0, 16:8, 12:12 and 0:24 h (light:dark) were studied under the above mentioned temperature and relative humidity. Because lacewings are mainly nocturnal (Szentkiralyi 2001), the photoperiod of 0:24 h was set up to determine whether *M. tasmaniae* could be reared optimally without light in order to reduce energy costs during mass-rearing.

Eggs (< 12 h old) laid on a cotton sheet (20 ~ 50 eggs/sheet) from the breeding colony were maintained in a clean glass vial (2.5 cm diameter × 8.0 cm high) with a nylon mesh circular window (1.2 cm diameter) on the lid and transferred to the tested photoperiods. There were 10 glass vials with 200 to 500 eggs for each photoperiod. The incubating duration was recorded.

Fifty newly hatched larvae were transferred individually to above-mentioned glass vials for each photoperiod. Five, 10 and 20 pea aphids were provided twice a day to 1st, 2nd and 3rd instar larvae, respectively, until they pupated. The number of aphids consumed daily by each larval instar was recorded. Pupae were kept in the same glass vials to determine emergence under each photoperiod. The developmental duration of larvae and pupae and mortality of both larvae and pupae were recorded. The pupae and newly emerged adults were weighed individually using an electric balance (Mettler Toledo, AG135, Switzerland) with a readability of 0.01 mg to determine whether photoperiods had an effect on the growth of *M. tasmaniae*.

Reproductive potential

To determine whether photoperiod affected the reproduction of *M. tasmaniae*, one male and one female (< 12 h old) were paired in an above-mentioned plastic container with 6, 20, 19 and 17 pairs for 24:0, 16:8, 12:12 and 0:24 h, respectively. The paired adults were fed with 10 1st to 3rd instar nymphs of pea aphids twice a day until they died. The fecundity (number of eggs laid), fertility rate (proportion of eggs hatched) and reproductive period for each female were recorded daily.

Statistical analysis

A goodness-of-fit test was used to test the distribution of data before analysis. Data of *M. tasmaniae* development, female reproductive period and proportion of female progeny were not normally distributed even after transformation and thus were analysed using the non-parametric Kruskal-Wallis test (KWT) followed by Dunn's procedure for multiple comparisons. Data of body weight of pupae and adults, and female fecundity were normally distributed and analysed using ANOVA. Data on the number of aphids consumed by different instar larvae and fertility rate were subjected to square root and arcsine transformation, respectively, before ANOVA. The Marascuilo procedure of the nonparametric analysis was used to assess the mortality of larvae and pupae with a rejection level of $U_0 > \chi^2_{3,0.05} = 7.82$.

RESULTS

Development and mortality

Micromus tasmaniae completed development at all tested photoperiods. The number of aphids consumed by larvae increased significantly with their developmental stage at each photoperiod (average 8.97 ± 1.06 , 14.50 ± 1.54 and 32.76 ± 3.30 for the first, second and third instar, respectively) ($P < 0.0001$). The average number of aphids consumed by larvae ranged from 46.73 ± 1.43 to 61.63 ± 2.06 with lowest number detected at 12:12 h and highest at 0:24 h ($P < 0.05$).

At each photoperiod, the developmental period was about 5, 8 and 10 days for *M. tasmaniae* eggs, larvae and pupae, respectively. The total developmental period was significantly shorter at 24:0 and 16:8 h than at 12:12 and 0:24 h (KWT: $H=44.72$, $P < 0.0001$).

There was no significant difference in larval mortality when reared at different photoperiods ($U_0=0.80$, $P > 0.05$). However, the mortality of pupae was significantly higher at 24:0 and 0:24 h than at 16:8 and 12:12 h ($U_0=72.00$, $P > 0.0001$) (Table 1).

TABLE 1: Mortality (%) of *M. tasmaniae* larvae and pupae at four photoperiods. Values followed by the same letters in rows are not significantly different ($P > 0.05$).

Light:dark	24:0	16:8	12:12	0:24
Larva	16.00 a	18.00 a	12.00 a	0.00 a
Pupa	59.25 a	0.24 c	4.65 c	20.45 b

The body weight of cocoons was significantly higher at 24:0 h than at 0:24 h ($P < 0.05$) (Table 2). Females and males were significantly heavier at 16:8 h than at other photoperiods ($P < 0.0001$) (Table 2). Females were significantly heavier than males at 16:8 and 12:12 h ($P < 0.0001$), but not at the other two photoperiods ($P > 0.05$) (Table 2).

TABLE 2: Mean body weights (mg) of cocoons and adults of *M. tasmaniae* at four photoperiods. Means ($\pm$ SE) followed by the same letters in columns are not significantly different ($P > 0.05$).

Light:dark	Cocoon	Male	Female
24:0	3.77 ± 0.15 a	1.98 ± 0.12 b	2.20 ± 0.19 b
16:8	3.71 ± 0.15 ab	2.42 ± 0.09 a	3.51 ± 0.13 a
12:12	3.52 ± 0.14 ab	1.61 ± 0.08 b	2.25 ± 0.10 b
0:24	3.16 ± 0.11 b	1.77 ± 0.12 b	2.03 ± 0.10 b

Reproductive potential

All tested females laid fertilised eggs at the four photoperiods. The reproductive period of females significantly decreased with increasing day length (KWT: $H=26.71$, $P < 0.0001$), but the fecundity and fertility rate were significantly higher at 16:8 and 12:12 h than at 24:0 and 0:24 h ($P < 0.0001$) (Table 3). The proportion of female offspring was about 45% with no significant difference between photoperiods (KWT: $H=0.41$, $P=0.94$) (Table 3).

TABLE 3: Reproduction of *M. tasmaniae* at four photoperiods. Means ($\pm$ SE) followed by the same letters in columns are not significantly different ($P>0.05$).

Light:dark	Reproductive period (days)	Fecundity	Fertility (%)	Female offspring (%)
24:0	31.50 $\pm$ 2.13 c	153.20 $\pm$ 8.09 d	57.27 $\pm$ 4.08 c	43.10 $\pm$ 1.49 a
16:8	39.15 $\pm$ 0.36 bc	445.79 $\pm$ 9.53 a	75.75 $\pm$ 1.21 a	46.63 $\pm$ 9.76 a
12:12	40.05 $\pm$ 1.08 ab	352.11 $\pm$ 19.71 b	63.67 $\pm$ 1.08 b	46.28 $\pm$ 6.45 a
0:24	46.18 $\pm$ 1.15 a	252.69 $\pm$ 18.90 c	52.43 $\pm$ 1.36 c	46.79 $\pm$ 6.65 a

DISCUSSION

As found in green lacewing, *Chrysoperla carnea* Stephens (Balasubramani & Swamiappan 1994), *M. tasmaniae* of third instar larvae consumed the greatest portion of the total number of aphids. This may be due to their larger body size and better capacity in searching and capturing their prey.

In this study, *M. tasmaniae* developed significantly faster at long photoperiods (i.e. 24:0 and 16:8 h) than at short photoperiods (i.e. 12:12 and 0:24 h). According to Beck (1980) and Tauber et al. (1986), photoperiod may influence the development in a number of insects and growth and development are slower at short day length if insect diapause is induced by short photoperiods. However, the present results showed that *M. tasmaniae* completed its life cycle and all females oviposited fertilised eggs at all tested photoperiods, suggesting this species does not enter diapause. Canard & Volkovich (2001) also indicated that some hemerobiids have no diapause in temperate zones and life stages of cocooned pupae, reproductive adults or even eggs and active larvae can be found under short day lengths in the field, for example, in *Hemerobius neadelphus* Gurney and *H. ovalis* Carpenter (Kevan & Klimaszewski 1987). The difference in development, prey consumption, mortality and reproduction under long and short photoperiods suggests that although *M. tasmaniae* does not enter diapause, photoperiod still has a significant effect on the endogenous circadian rhythms in metabolism, respiration and hormone production, which may regulate tissue synthesis and growth of insects (Beck 1980).

Although *M. tasmaniae* can complete development and reproduce under completely dark conditions, the higher pupal mortality and lower fecundity and fertility mean such conditions cannot be recommended for mass-rearing of *M. tasmaniae* in the laboratory. *Micromus tasmaniae* reared at 16:8 h develop faster and have lower mortality, heavier adult body weight and higher reproductive output in terms of fecundity and fertility rate. Therefore mass-rearing programmes are recommended to be carried out under 16:8 h light:dark. Moreover, investigation of the environmental conditions leading to the production of female-biased progeny is warranted in further studies.

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