Effect of body weight on reproductive performance of *Micromus tasmaniae* (Walker) (Neuroptera: Hemerobiidae)

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Abstract *Micromus tasmaniae* Walker is an important predator of a number of economically important pests such as aphids. The 'larger-the-better' theory predicts that reproductive fitness is positively linearly associated with body size or weight. To test whether larger insects perform better reproductively, the insect population was divided into three weight groups: light, average and heavy, and the reproductive performance of nine breeding treatments (three male weights $\times$ three female weights) was assessed. The body weight of female *M. tasmaniae* had no significant effect on reproductive fitness in terms of fecundity, fertility, fertility rate, oviposition period and longevity, suggesting that female size variation is of secondary importance in determining reproductive fitness in this species. Male size had significant positive effect on female fecundity, fertility and fertility rate and reproductive period. This suggests that heavy males may transfer larger ejaculates that provide more sperm and male-derived nutrients to females than light males.

Keywords *Micromus tasmaniae*, body weight, fecundity, fertility, reproduction.

INTRODUCTION

Body size or weight has traditionally been considered a key determinant of an organism's ecological and physiological properties (Thornhill & Alcock 1983; Honěk 1993). Fitness is generally believed to be related to body size in animals (Clutton-Brock 1988; Reiss 1989), particularly in insects (Thornhill & Alcock 1983; Honěk 1993). Large size or body mass has been used as an indication of 'good quality' because heavy females often produce more and larger eggs than light females (Cloutier

et al. 2000; García-Barros 2000). Heavy males usually have a greater sperm supply than light males (Phelan & Barker 1986; Bissoondath & Wiklund 1996).

The fitness consequences of size or weight and its correlates, especially the supply of sperm or eggs and adult longevity, are important in population dynamics and essential for understanding and modelling life history evolution and behavioural decisions (Cloutier et al. 2000; Jiménez-Pérez & Wang 2004). It is considered axiomatic for

most arthropods that the increased weight and/or size results in increased fecundity (Gilbert 1984). However, body size may not always have a positive effect on reproductive success (Wall & Begon 1987; Ohgushi 1996).

Micromus tasmaniae Walker (Neuroptera: Hemerobiidae) is an important aphidophage widely distributed in Australia and New Zealand (Wise 1963). Hemerobiids are the most important Neuroptera next to Chrysopidae in controlling soft-bodied agricultural pests (Balduf 1974). In New Zealand, its biology and ecology have been studied in the field (Hilson 1964; Leathwick 1989) and laboratory (Islam & Chapman 2001; Yadav et al. 2008). Its ability to control *Acyrtosiphon kondoi* Shinji and *A. pisum* (Harris) on lucerne (Cameron et al. 1983; Leathwick 1989) has also been evaluated. It has been reported that *M. tasmaniae* has effectively controlled lettuce aphid *Nasonovia ribisigri* Mosley in spring crops in Pukekohe, New Zealand (Workman et al. 2004). It has been suggested that *M. tasmaniae* could be an important component of integrated pest management (Rumpf et al. 1997).

The aim of the present investigation was to determine whether and how body weight of both sexes affected reproductive performance in *M. tasmaniae*.

MATERIALS AND METHODS

Breeding colony and experimental conditions

A breeding colony of *M. tasmaniae* was obtained from a commercial insectary (Zonda Resources Ltd, Pukekohe, New Zealand) and maintained in the Entomology and IPM Laboratory of Massey University, Palmerston North. The adults were housed in oviposition containers (17 cm diameter $\times$ 24 cm height) with four fine nylon mesh windows (6 cm diameter). They were fed with first to third instar pea aphids reared on potted broad bean plants. A black cotton sheet (12 cm $\times$ 12 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 plastic boxes (17 cm length $\times$ 12 cm width $\times$ 7 cm height) for hatching. The newly hatched larvae

were further reared on pea aphids in groups of 40-50 larvae, in the plastic boxes mentioned above, and emerged adults were used for further rearing. The colonies were maintained and the experiment was carried out in controlled environment rooms at $21 \pm 1^\circ\text{C}$ and 60-70% RH with a photoperiod of 16:8 h (light:dark, lights on at 0800 and off at 2400). Lighting was provided by high frequency broad-spectrum biolux tubes (Osram, Germany). Newly hatched larvae obtained from the breeding colony were transferred individually to clean glass vials (2.5 cm diameter $\times$ 8.0 cm height) with a fine nylon mesh circular window (1.2 cm diameter) on the lid. Pupae thus obtained were weighed individually using an electronic balance (Mettler Toledo, AG135, Switzerland) with a readability of 0.01 mg and newly-emerged adults were separated by sex just after emergence.

Experiment

The effect of pupal weight on reproductive output was studied by confining 126 breeding pairs until adults died in transparent plastic containers (6.5 cm diameter $\times$ 8.3 cm height) having a lid with a double layered fine nylon mesh circular window (3 cm diameter). Insects were 2 days old when used for this experiment. Twenty 1st to 3rd instar pea aphids were provided for each couple daily as food. A black cotton sheet (3 cm $\times$ 3 cm) was placed at the bottom of the plastic cylinder, for oviposition. A complete factorial block design was used for this experiment, where each sex (factor) had three different pupal weights: light, average and heavy. A light or heavy pupa was defined as one whose weight went below or above the standard deviation of the population (weights <2.10, 2.10~3.24 and >3.24 mg were categorised as light, average and heavy for males, respectively, and those of <2.67, 2.67~3.95 and >3.95 mg as light, average and heavy for females, respectively). The experimental design produced nine treatments (3 female weights $\times$ 3 male weights) of breeding pairs (Table 1).

To determine whether pupal weight had any effect on female reproductive potential, the fecundity (total number of eggs laid), fertility (total

Table 1 Number of *M. tasmaniae* breeding pairs in different body weight combinations (n = 126 pairs).

Female class	Male class	n
Light	Light	10
Light	Average	10
Light	Heavy	10
Average	Light	14
Average	Average	26
Average	Heavy	16
Heavy	Light	12
Heavy	Average	16
Heavy	Heavy	12

number of eggs hatched), fertility rate (ratio of fertility versus fecundity) and reproductive period (period during which the female laid eggs) for each female were recorded daily. Longevity (survival period of adults) of both sexes was also recorded.

Statistical analysis

A t-test was used to compare the body weight between sexes. Two-factor analysis of variance (ANOVA) followed by a least significant difference

test (LSD) was used to analyse the influence of the pupal weight on female fecundity, fertility, fertility rate and reproductive period, and male and female longevity (SAS Institute). Fertility rate was arcsine transformed to achieve a normal distribution of data residues prior to analysis (Steel et al. 1997).

RESULTS

Mean female pupal weight (mean $\pm$ SE, 3.31 $\pm$ 0.05 mg) was significantly greater than male pupal weight (2.67 $\pm$ 0.05 mg) ($P<0.0001$). For all weight categories, the mean life time fecundity (number of eggs laid), fertility (number of fertile eggs laid), fertility rate (%), reproductive period (days) and female longevity (days) were 422.62 $\pm$ 166.81, 275.18 $\pm$ 128.43, 62.76 $\pm$ 1.24, 41.67 $\pm$ 1.25 and 47.90 $\pm$ 1.24, respectively.

Average weight females mated to average or heavy weight males had significantly higher fecundity, fertility, fertility rate and reproductive period ($P<0.05$) (Table 2). However, body weight had no significant ($P>0.05$) effect on the longevity of males (from 57.08 $\pm$ 6.61 to 78.60 $\pm$ 5.06 days) and females (from 38.33 $\pm$ 2.92 to 52.75 $\pm$ 3.53 days).

Table 2 Effect of male and female pupal weight on fecundity, fertility, fertility rate, and reproductive period.

Mating pair ¹	Fecundity (no. eggs)	Fertility (no. eggs)	Fertility rate (%)	Reproductive period (days)
LF $\times$ LM	278.5 b ²	186.2 b	60.5 ab	40.1 bc
LF $\times$ AM	368.8 ab	249.0 ab	67.1 a	35.4 bc
LF $\times$ HM	319.0 ab	201.3 b	62.7 ab	35.3 bc
AF $\times$ LM	438.0 ab	295.0 ab	64.4 ab	43.6 ab
AF $\times$ AM	500.0 a	332.0 a	65.6 a	47.0 a
AF $\times$ HM	486.7 a	331.9 a	67.5 a	43.0 ab
HF $\times$ LM	368.8 ab	221.3 ab	60.4 ab	32.9 c
HF $\times$ AM	475.3 ab	291.1 ab	55.6 b	47.8 a
HF $\times$ HM	384.0 ab	243.6 ab	58.7 ab	38.5 bc
LSD	3.01	2.52	0.85	2.25

¹LF-light female, AF-average female, HF-heavy female, LM-light male, AM-average male and HM-heavy male.

²Means followed by the same letters in each column are not significantly different ($P>0.05$).

DISCUSSION

Studies of reproductive performance in female insects have often focused on direct measures of gamete production, such as egg size, egg number and ovary volume (Montague et al. 1981; Wickman & Karlsson 1989; Berrigan 1991). Fecundity in most insects varies with body size of the female (Reiss 1989). Female size is usually a good predictor of potential fecundity and species with no positive relationship between female size and fecundity are scarce (Slansky 1980; Boggs 1986; Johnson 1990). For example, in the lepidopteran leaf roller, *Cnephasia jactatana* Walker, heavy females laid larger (Marshall 1990; Iyengar & Eisner 2002) and more eggs (Cloutier et al. 2000; García-Barros 2000) than light females. If fecundity is constrained only by the size of the female, a linear fecundity-weight relationship should be expected. In the present study, however, the body weight of female *M. tasmaniae* did not affect fecundity, fertility, fertility rate, oviposition period and female longevity. This implies that female size variation is of secondary importance in determining important fitness components of the reproductive process in the *M. tasmaniae* females (Ohgushi 1996). The mechanism by which the reproductive fitness of females is not affected by their body weight remains unclear. Similar cases have been reported in the Mormon fritillary butterfly, *Speyeria mormonia* Edwards (Boggs 1986), and the small carpenter bee, *Ceratina calcarata* Robertson (Johnson 1990). Therefore, the extent to which female body weight affects reproductive fitness may vary from species to species.

Males of many animal taxa allocate most resources to mate acquisition and defence, and contributing little more than gametes to embryo production (Fox et al. 1995). In many insects, males transfer large spermatophores or ejaculates to females during mating, and extragametic substance derived from these packages are used by the recipient female (Fox et al. 1995). Wedell (1996) showed that females of comma butterfly, *Polygonia c-album* L., may use male donations for egg production and females receiving larger donations live significantly longer than those receiving smaller donations, suggesting that

females can also use males' nutrients for somatic maintenance. On the other hand, as found in an arctiid moth *Utetheisa ornatrix* L., the larger spermatophores may consist of more sperm for fertilization and nutrition for reproduction and thus stimulate females to lay more eggs, fertilize more eggs and prolong their life (Iyengar & Eisner 2002). In lacewing, males have been found to transfer spermatophores to their mates during copulation (Henry 1984; Principi 1986). In the present study, average females mated to average or heavy males had significantly higher fecundity, fertility and fertility rate and longer reproductive period. These results suggest that average and heavy males transferred larger spermatophores to females than light males.

In conclusion, female body weight of *M. tasmaniae* itself did not significantly affect reproductive fitness, but average females mated to average or heavy males had significantly higher reproductive fitness in terms of fecundity, fertility, fertility rate and reproductive period. It is thus suggested that heavy males may transfer more sperm and male-derived nutrients to females than light males. Emphasis on production of average and heavy males in the laboratory would significantly benefit mass-rearing and inundative release of this species for biological control.

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