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Food and nymph stage duration influence life table parameters of the predator *Brontocoris tabidus* (Heteroptera: Pentatomidae)

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ABSTRACT

Food type is important for mass rearing of *Brontocoris tabidus* (Signoret) (Heteroptera: Pentatomidae), which preys on Lepidoptera defoliators in eucalyptus plantations. The objective of this study was to evaluate the duration of nymph instars, reproduction and the life expectancy table of the predator *B. tabidus* fed with or without *Eucalyptus cloeziana* plants and *Tenebrio molitor* Linnaeus (Coleoptera: Tenebrionidae) in the field. *Brontocoris tabidus* females were separated into those with short (a) or long (b) instar durations. Life expectancy (ex) of *B. tabidus* females from nymphs with short stage duration, reared on *E. cloeziana* with prey was higher than those from long nymph stage with or without plant material. Feeding on plant material and/or prey changes life table parameters for the predator *B. tabidus*. Therefore, *B. tabidus* should be reared with prey and *E. cloeziana* to improve the mass production of this predator for biological control of defoliating caterpillars in eucalypt plantations.

1. Introduction

Generalist predators colonize different agro-ecosystems, even during periods of low prey availability (Ferreira et al., 2008; Lemos et al., 2011; Pires et al., 2011). *Brontocoris tabidus*, one of the most common predators of eucalyptus defoliating caterpillars, is reared and released for biological control in agricultural and forestry systems (Zanuncio et al., 1996, 2014).

Predators (Molina-Rugama et al., 1998) and parasitoids (Zanuncio et al., 2008) should be studied for release and to increase efficiency in biological control programs. Mass rearing of predatory insects is evaluated using reproductive parameters such as the number of eggs/female, eggs/female/day, eggs/egg mass, egg viability, oviposition, post-oviposition and pre-oviposition periods and intervals between egg laying clutches (Sá et al., 2013; Vakhide and Safavi, 2014).

Temperature affects the development, duration of the nymph instars, population dynamics and reproduction of predatory Pentatomidae (Torres et al., 1998; Medeiros et al., 2000). Rearing these insects on host plants reduces their nymph stage duration and improves their reproduction (Oliveira et al., 2002). However, these parameters should be evaluated in the field, because biotic and abiotic factors impact natural enemies and their effectiveness in biological control (Torres and Zanuncio, 2001).

The objective of this study was to evaluate the reproduction and life expectancy of *B. tabidus* originated from individuals with short and long nymph stage fed on *T. molitor* pupae with or without *Eucalyptus cloeziana* plants in the field.

2. Material and methods

The experiment was conducted in the field at the Universidade Federal de Viçosa (UFV) in Viçosa, Minas Gerais State, Brazil with a temperature of 21.16 ± 1.52 °C, relative humidity of 77.88% ± 0.98% and a photoperiod of 12:12 (L:D). *Brontocoris tabidus*

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Table 1
Parameters (mean ± standard error) of *Brontocoris tabidus* (Heteroptera: Pentatomidae) from short or long nymph stage and fed on *Tenebrio molitor* (Coleoptera: Tenebrionidae) with or without *Eucalyptus cloeziana* plants in the field.

Parameter	*Eucalyptus cloeziana*		Without plant	
	Nymph stage			
	Short	Long	Short	Long
Eggs/fem	430.10 ± 72.42 aA	191.50 ± 45.92 bA	81.00 ± 12.61 aB	95.75 ± 19.36 aA
Egg/fem/day	5.77 ± 0.54 aA	3.70 ± 0.52 aA	2.46 ± 0.48 aB	3.49 ± 0.60 aA
Viab (%)	78.38 ± 3.92 aA	78.99 ± 4.83 aA	80.09 ± 4.94 aA	69.36 ± 10.87 aA
Pre-ov (day)	13.50 ± 0.31 aA	13.90 ± 0.86 aA	13.25 ± 0.49 aA	10.13 ± 1.06 aB
Ovip (day)	48.70 ± 6.76 aA	25.70 ± 5.55 bA	11.75 ± 2.02 aB	9.13 ± 2.46 aB
Pos-ov (day)	7.40 ± 1.54 aA	6.70 ± 1.62 aA	9.00 ± 1.45 aA	8.62 ± 1.25 aA
Long (day)	69.60 ± 7.60 aA	46.30 ± 5.61 bA	33.88 ± 1.81 aB	27.75 ± 2.83 aB

Number of eggs/female (eggs/fem), eggs/female/day (egg/fem/day), egg viability (Viab), pre-oviposition (Pre-ov), oviposition (ovip), post-oviposition (pos-ovip), longevity (Long). Means followed by the same small letter per treatment, or capital letter between treatments, did not differ by Student-Newman-Keuls test (P = .05).

specimens were obtained from the rearing facility at the Biological Control of Insects Laboratory of the UFV where this predator is reared in cages with *T. molitor* pupae and *Eucalyptus* spp. branches at 25 ± 2 °C, 65 ± 10% relative humidity and a12-hour photoperiod. *Brontocoris tabidus* does not feed during the first instar when it receives only water. From the second to the fifth instar, nymphs of this predator were fed *T. molitor* pupae *ad libitum*.

The experimental design was completely randomized with two treatments and 10 replications, with 20 *B. tabidus* nymphs each. *Brontocoris tabidus* nymphs fed on *T. molitor* pupae and *E. cloeziana* plants (T1) or only on pupae, that is, without *E. cloeziana* plant material (T2). In T1, the nymphs were kept on eucalypts branches wrapped with white organza fabric bags (20 × 30 cm) and in T2 the bags were fixed on eucalypts branches without access to the plant. The *B. tabidus* nymphs received *T. molitor* pupae and water daily in 2.5 mL cylindrical tubes fixed to the plant branches (T1) with adhesive tape or at the bottom of bags (T2). At the beginning of the second instar, *Brontocoris tabidus* nymphs were transferred to the organza bags, when they began predation.

The females obtained from *B. tabidus* nymphs were separated and mated three days after emergence Zanuncio et al. (1992). Pairs (T1 = 20 pairs; T2 = 16 pairs) of *B. tabidus* were individually placed per organza bag (1 pair/bag) and fed as with their nymphs. Mortality and egg numbers per female were monitored daily and the egg masses transferred to Petri dishes (9.0 cm diameter) with a moistened cotton ball and kept in the laboratory at 25 °C, 65% relative humidity and a photoperiod of 12:12 (L:D) to verify egg viability. The duration of the nymph stage, numbers of eggs/female/day, eggs/female, egg viability, pre-oviposition, oviposition and post-oviposition periods and longevity were evaluated on a daily basis.

Brontocoris tabidus females were separated according to the nymph stage with a short (29–30 days) or long (34–38 days) duration and fed *T. molitor* pupae on *E. cloeziana* plants or, only on the prey.

Data without normal distribution and homogeneity of variance was fit as log*x*, and submitted to the Student-Newman-Keuls test at 5% significance.

Fertility life tables (Southwood, 1978) were calculated for *B. tabidus*, estimating the following parameters:- net reproductive rate (Ro) (number of females produced per female) $R_o = \Sigma l_x m_x$, where: lx = survival rate from age zero to the beginning of the age x; mx = females produced per female of age x; -generation time (T) (period between the birth of parents to their nymphs), $DG = \Sigma_x l_x m_x / R_o$, where: x = age class (x = seven days); lx = survival from age zero to the beginning of age x; mx = females produced per female of age x; -intrinsic rate of population increase (rm) (population growth rate per time unit). $r_m = \ln(R_o)/T$, where; ln = natural log; Ro = net reproductive rate; DG = generation time (days); -time required for *B. tabidus* to double its population (TD). $TD = \ln(2)/r_m$, where: ln = natural log; rm = intrinsic rate of population increase; -life expectancy (ex) was estimated with the formula: $e_x = t_x/L_x$, where: tx = total number of insects at age x, x beyond age; Lx = number of survivors at the beginning of age x.

The fertility life table parameters were estimated using the tool LIFETABLE SAS (1997).

3. Results

The nymph stage duration, number of eggs/female, eggs/female/day and the *B. tabidus* pre-oviposition period differed between treatments.

The egg viability, oviposition, post-oviposition and longevity periods were longer for *B. tabidus* originated from nymphs with short nymph duration with or without plants.

The total number of eggs per *B. tabidus* female from nymphs with a short instar duration was 81.00 without plants and 430.10 with *E. cloeziana*. Daily egg numbers for these females was 2.46 and 5.77 with and without plants, respectively (Table 1).

The oviposition period of *B. tabidus* was 9.13 days for females with long nymph instar durations fed only on prey without plant material, and 48.70 days for those from short nymph stage nymphs fed on prey and *E. cloeziana*. The longevity of this predator was 27.75 (without plant, long nymph duration) and 69.60 days (with *E. cloeziana*, short nymph duration) (Table 1).

Brontocoris tabidus had a higher net reproductive rate (Ro) (P = .03) and longer generation period (T) (P = .01) for individuals with short nymph stage. On the other hand, the nymph stage did not lead this predator to double its population (DT) (P = .4) nor its intrinsic increase rate (rm) (P = .6). The Ro (P < .01) of *B. tabidus* varied from 9.70 females/female (without plant and short nymph stage) to 70.35 females/female (*E. cloeziana* and short nymph stage) (Table 2).

The T of *B. tabidus* was from 41.44 days (without plant, long nymph stage) to 62.06 days (with *E. cloeziana*, shortnymph stage), indicating that this predator may have 8.8 and 5.9 generations per year, respectively (Table 2). The TD of *B. tabidus* ranged from 10.07 days (*E. cloeziana*, short nymph stage) to 13.33 days (without plant, short nymph stage) (Table 2).

The *B. tabidus* rm was higher (P < .01) for individuals arisen from a short nymph stage and with plant material (0.069) than those without plant material (0.0052) (Table 2).

The life expectancy (ex) of *B. tabidus* decreased until the most recent observations. Females derived from a long nymph stage fed on prey with or without plant material had ex = 4.2 days (females 91 days old) and 4.3 days (females 119 days old). Females from short nymph stage had ex = 4.6 days without plant material (77 days old) and 8.9 days with *E. cloeziana* (119 days old) with 100% probability of death during this period (Fig. 1).

Table 2
Jackknife estimation of the *Brontocoris tabidus* (Heteroptera: Pentatomidae) life table parameters from short or long nymph stage fed on *Tenebrio molitor* (Coleoptera: Tenebrionidae) with or without *Eucalyptus cloeziana* plants and pupae in field.

Parameter	*Eucalyptus cloeziana*		Without plant	
	Nymph stage			
	Short	Long	Short	Long
R_o	70.35 ± 11.84 aA	31.32 ± 7.51 bA	9.70 ± 1.51 aB	11.46 ± 2.32 aB
DG	62.06 ± 1.52 aA	53.53 ± 3.31 bA	44.13 ± 0.58 aB	41.44 ± 1.15 bB
TD	10.07 ± 0.21 aA	10.66 ± 0.48 aA	13.33 ± 0.92 aB	11.60 ± 0.91 aA
r_m	0.069 ± 0.001 aA	0.065 ± 0.003 aA	0.052 ± 0.004 aB	0.059 ± 0.005 aA

Means followed by the same small letter per treatment or capital between treatments did not differ by Student-Newman- Keuls test (P = .05).

4. Discussion

The duration of the nymph stage affects the reproduction and life expectancy of *B. tabidus* and can be used to select predators with better reproductive fitness and survival as reported for *Podisus maculiventris* (Heteroptera: Pentatomidae) (De Clercq and Degheele, 1993). However, environmental conditions such as temperature, food and the interaction of these factors may reduce or increase the developmental period (Lemos et al., 2005, 2006; Lopatina et al., 2014) and decrease reproduction growth of these predators (Zanuncio et al., 2002).

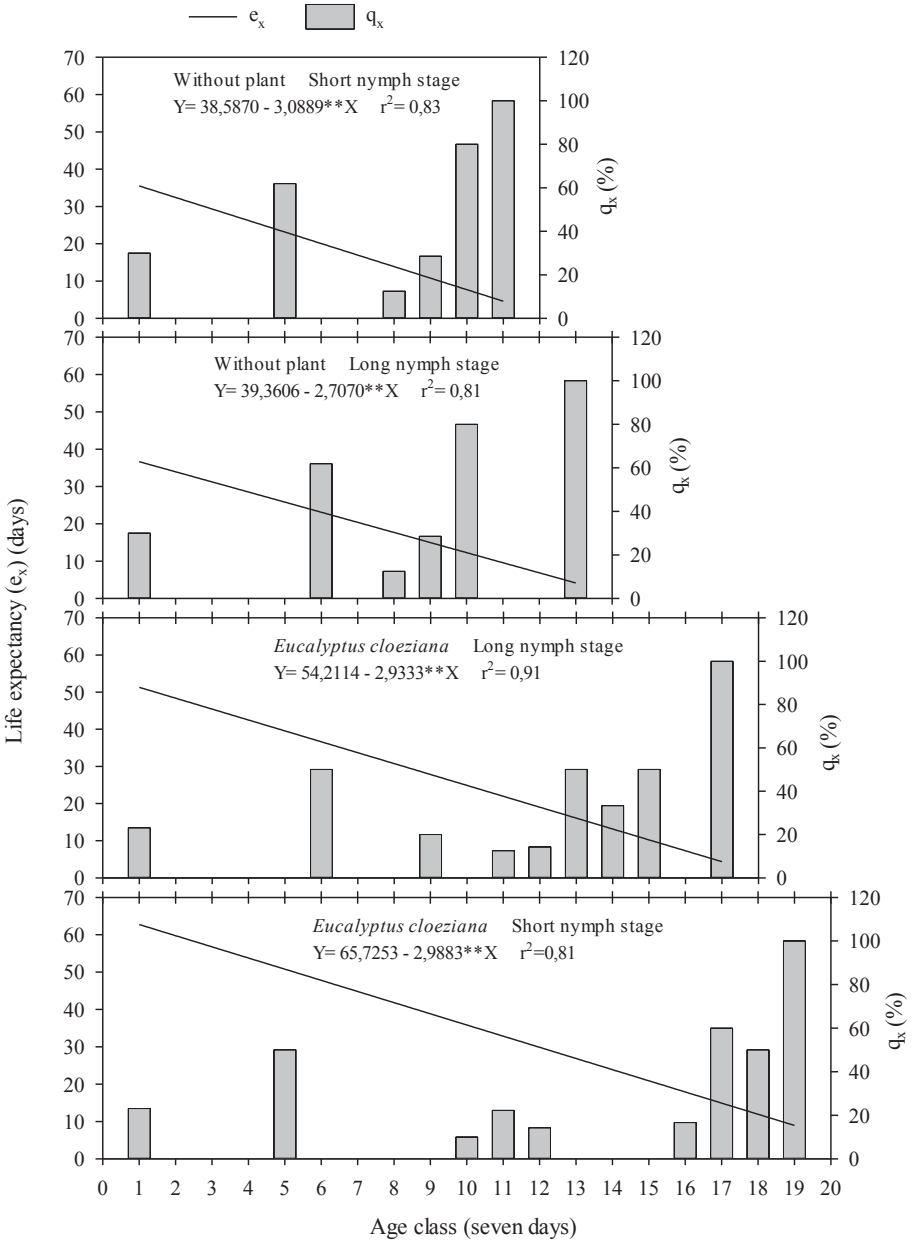

Fig. 1. Life expectancy of *Brontocoris tabidus* (Heteroptera: Pentatomidae) fed on *Tenebrio molitor* (Coleoptera: Tenebrionidae) pupae with or without *Eucalyptus cloeziana* plant, in the field. x = life expectancy of individuals with age x. qx = mortality risk.

The higher number of eggs/female of *B. tabidus* with short nymph stage may be related to their body mass, agreeing with reports for *Podisus rostralis* (Heteroptera: Pentatomidae) (Zanuncio et al., 2002) and *P. maculiventris* (Legaspi and Legaspi, 2005). Indirectly, the allocation of energy between survival and reproduction allows light females to reduce their oviposition to maintain longevity (Zanuncio et al., 2002).

Differences in egg viability produced by females according to the duration of the nymph stage of *B. tabidus* and food type agree with decreasing values of this parameter for *P. nigrispinus* with long nymph stage fed on *Anticarsia gemmatalis* Hübner (Lepidoptera: Noctuidae), *Spodoptera frugiperda* Smith (Lepidoptera: Noctuidae), *Diatraea saccharalis* (Lepidoptera: Crambidae) and *T. molitor* (Coleoptera: Tenebrionidae) (Bortoli et al., 2011). This may be explained by food quality affecting ovary development and the number of oocytes (Lemos et al., 2005).

The higher fecundity and longevity of *B. tabidus* females with short nymph stage fed on prey and *E. cloeziana* plant material agrees with that reported for other predators such as *Dicyphus hesperus* Knight (Heteroptera: Miridae) (Gillespie and McGregor, 2000) and *Supputius cincticeps* (Heteroptera: Pentatomidae) (Mourão et al., 2003), directly or indirectly affected by the food quantity and quality (Oveja et al., 2016; Müller and Müller, 2016). Inadequate conditions such as food shortages result in predators using other energy sources such as lipids for reproduction and development and in a reduction in egg numbers per female per day (Legaspi and O'Neil, 1994).

The number of eggs per *B. tabidus* female with short nymph stage fed on *T. molitor* pupae with *E. cloeziana* was 4-times higher than that of this predator with *T. molitor* pupae only (Jusselino-Filho et al., 2001) and 8.5-times higher than those fed *M. domestica* larvae (Jusselino-Filho et al., 2003). This suggests a higher nutrient assimilation by adults emerged earlier as found for *Lymantria dispar* (Lepidoptera: Erebidae) (Barbehenn et al., 2015) and better use of plant and prey nutrients (Lacerdaet al., 2004; Zerbino et al., 2015) or lower energy consumption (Arrese and Soulages, 2010).

The higher net reproductive rate of *B. tabidus* females with short nymph stage fed on *T. molitor* pupae and *E. cloeziana* once again shows the importance of plants for predators as found for *S. cincticeps* with Ro 3.4-times higher when fed on prey and plant material than on only prey (Assis Júnior et al., 1998). This shows that plant nutrients increase reproductive parameters and population growth of zoophytophagous natural enemies (Coelho et al., 2009, Mariottini et al., 2010).

The longer generation time (T) of *B. tabidus* with short nymph stage with or without plants agrees with that reported for *S. cincticeps* fed on prey with *E. urophylla* leaves (Assis Júnior et al., 1998) and *P. nigrispinus* with T ranging from 33.3 to 85.5 days (Medeiros et al., 2003). Hemiptera predators can obtain nutrients from plant material, which improves their survival (Valicente and O'Neil, 1993).

The higher intrinsic increase rate of *B. tabidus* with short nymph stage fed on prey and *E. cloeziana* is similar to that reported for predators fed on prey and plants such as *P. nigrispinus* (Oliveira et al., 2002) and *S. cincticeps* (Zanuncio et al. 2004) and also the positive effect on the intrinsic rate for leaf beetle populations (Rios et al., 2013).

The longer life expectancy of *B. tabidus* females with short nymph stage fed on prey and *E. cloeziana* plant material confirms the need of zoophytophagous predators to obtain nutrients from plants and prey (Coelho et al., 2009). This may reduce food shortage impacts, but with low reproductive capacity and survival without prey (De Clercq and Degheele, 1992). Insects feeding on diets or host plants with high nitrogen content generally have better growth rates and conversion efficiency with shorter developmental periods (Chen et al., 2004, 2008). This may be due to the role of nitrogen in metabolic processes as well as in cell and gene structure coding, a critical element for growth (Mattson, 1980).

Brontocoris tabidus with short nymph stage fed on *T. molitor* pupae and *E. cloeziana* plant material have better reproductive variables and life table parameters and should be mass-produced under these conditions for biological control programs.

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