Does Diet of Prey Affect Life Table Parameters of the Predator Podisus nigrispinus (Hemiptera: Pentatomidae)?

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Does diet of prey affect life table parameters of the predator *Podisus nigrispinus* (Hemiptera: Pentatomidae)?

Robson José Esteves Peluzio¹, Bárbara Monteiro de Castro e Castro¹,* 1, Bruno Pandelo Brügger², Angelica Plata-Rueda³, Flávio Lemes Fernandes³, Ricardo Henrique Silva Santos⁴, Carlos Frederico Wilcken⁴, José Cola Zanuncio²

**Abstract**

*Podisus nigrispinus* Dallas (Hemiptera: Pentatomidae) is reared in the laboratory and released for biological control programs. The objective of this study was to evaluate, using life tables, *P. nigrispinus* development when fed on *Anticarsia gemmatalis* Hübner (Lepidoptera: Erebidae) reared on different diets, or with the alternative prey *Tenebrio molitor* L. (Coleoptera: Tenebrionidae). *Podisus nigrispinus* was reared with soybean plants supplemented with *A. gemmatalis* caterpillars fed an artificial diet (T1), with soybean plants supplemented with caterpillars fed soybean leaves (T2), with soybean plants supplemented with *T. molitor* pupae (T3), or with soybean plants supplemented with *A. gemmatalis* pupae from caterpillars fed soybean leaves (T4). The duration of instar V and of the total nymph period of this predator were longer when preying caterpillars fed soybean plants (T2). The survival of the nymph stage was greater when fed on soybean plants with *T. molitor* pupae (T3), with *A. gemmatalis* caterpillars fed on soybean plants (T2), and with *A. gemmatalis* caterpillars fed an artificial diet (T1), relative to *A. gemmatalis* pupae from caterpillars fed soybean leaves (T4). The weights of instar V nymphs and of adult male and female *P. nigrispinus* were greater when fed with *T. molitor* pupae (T3). Life table parameters showed population growth for this predator in all treatments except when fed with *A. gemmatalis* pupae (T4). The net reproductive rate (Ro), the duration of a generation (DG), and time to double the population (TD) of *P. nigrispinus* displayed higher values when fed with caterpillars cultured on soybean (T2) and with *T. molitor* pupae (T3). The rates of increase (λ and rm) value were positive in all treatments. *Anticarsia gemmatalis* pupae from caterpillars fed soybean leaves (T4) are inadequate prey for *P. nigrispinus*. *Anticarsia gemmatalis* caterpillars fed soybean leaves (T2) or *T. molitor* pupae (T3) are a more suitable food for rearing this predator than *A. gemmatalis* caterpillars fed an artificial diet (T1).

**Key Words**: Asopinae; biological control; *Glycine max*; Heteroptera

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1Universidade Federal de Viçosa, Departamento de Fitotecnia, Viçosa, 36571-900, Brazil, E-mail: robson.peluzio@gmail.com (R. J. E. P.);
barbaramcastro@hotmail.com (B. M. C. C.), rsantos@ufv.br (R. H. S. S.)

2Universidade Federal de Viçosa, Departamento de Entomologia/BIOAGRO, Viçosa, 36570-900, Brazil, E-mail: brunopb2002@yahoo.com.br (B. P. B),
zanuncio@ufv.br (J. C. Z.)

3Universidade Federal de Viçosa, Campus de Rio Paraíba, Rio Paraíba, 38810-000, Brazil, E-mail: angelicaplata@yahoo.com.mx (A. P. R.);
flaviofernandes@ufv.br (F. L. F.)

4Universidade Estadual Paulista (UNESP), Departamento de Proteção Vegetal, Faculdade de Ciências Agronômicas, Botucatu, São Paulo, 18610-307, Brazil, E-mail: cwilcken@fca.unesp.br (C. F. W.)

*Corresponding author; E-mail: barbaramcastro@hotmail.com
Podisus nigrispinus Dallas (Hemiptera: Pentatomidae), a generalist predator, has potential for use in integrated pest management programs (IPM) (Zanuncio et al. 2008) due to its high searching ability (Malaquias et al. 2010), feeding rates (Vacari et al. 2013), and low production costs (De Bortoli et al. 2011). This predator is reared in the laboratory and released for biological control programs (Zanuncio et al. 2014) so it is important to optimize its mass rearing techniques (Zanuncio et al. 2001). Podisus nigrispinus can survive periods of prey scarcity by feeding on alternative prey (Malaquias et al. 2010). Under laboratory conditions they accept Tenebrio molitor L. (Coleoptera: Tenebrionidae) pupae, Musca domestica L. (Diptera: Muscidae), and Bombyx mori L. (Lepidoptera: Bombycidae) larvae (Neves et al. 2010), and in the field they take natural prey such Anticarsia gemmatalis Hübner (Lepidoptera: Erebidae) caterpillars (Ferreira et al. 2008). Predatory pentatomids are considered to be obligate zoophytophagous because they have better development when fed both insect prey and plants (Azevedo et al. 2007). Zoophytophagous behavior enables predatory bugs to obtain moisture and possibly nutrients (Torres et al. 2010).

The functional response of predators is affected by many factors, such as their development stage (Hassanpour et al. 2011), prey type (Farhadi et al. 2010), plant species, and plant physiology (De Clercq et al. 2000), food availability (Molina-Rugama et al. 1997), and food quality (Lemos et al. 2003). Commercialization and use of biological control agents for integrated management programs depends on producing these insects at a low cost. Life tables permit the analysis and understanding of the effect of external factors, including host plants, on the growth, survival, reproduction, and intrinsic rates of population growth (Chi & Su 2006).

The objective of this study was to evaluate, using life tables, the development of P. nigrispinus fed A. gemmatalis caterpillars reared on different diets.

Materials and Methods

PLANT AND INSECT CULTURE

The experiment was conducted in a greenhouse of the Plant Science Department at the Universidade Federal de Viçosa (UFV) in Viçosa, Minas Gerais, Brazil. Soybean seeds (cultivar UFV16) were planted in 3 L plastic pots every 15 d, from Jul 2006 to May 2007, irrigated, and thinned to 3 per pot. Fertilization was carried out according to recommendations (CFSEMG 1999). Chemical pest control products were not applied.

Anticarsia gemmatalis caterpillars were reared in the Insect Biological Control Laboratory (IBCL/BIOAGRO/UFV) on an artificial diet (Greene et al. 1976) or soybean leaves. Tenebrio molitor pupae were obtained with a precision balance (Shimadzu model AY220, produced in The Philippines; resolution = 0.1 mg). P. nigrispinus pupae were obtained using the Kaplan-Meier model (SAS Institute 1991). The weights of instar V nymphs and of newly emerged males and females P. nigrispinus were obtained with a precision balance (Shimadzu model TY124S, produced in The Philippines; resolution = 0.1 mg).

Population growth parameters and reproduction of P. nigrispinus were obtained using life table analysis. The net reproductive rate (Ro) (number of females added per female during her lifetime): Ro = Σnxmx; duration of a generation (DG) (time between the parent and offspring birth): DG = Σx. Ix. Mx/Ro; intrinsic rate of population increase (Rm) (population growth rate per unit time): Rm = ln (Ro)/DG; finite rate of population increase (λ) (number of females added to the population per female per unit time): λ = antilog (rm 0.4343); and time required for the predator to double its population in number of individuals (TD): TD = ln (2)/Rm; were calculated (Maia et al. 2000) and analyzed using the SAS statistical software (SAS Institute 1991).

Results

The duration of instar I was similar among treatments. Instars II and III P. nigrispinus were longer when fed A. gemmatalis pupae (T4), and nymphs of this predator did not complete their life cycle, with 100% mortality during instar IV when fed this host. The duration of instar V and of the total nymph period of P. nigrispinus were longer when provided with caterpillars fed with soybean plants (T2) (Table 1).

The survival of the nymph stage of P. nigrispinus was higher when fed on soybean plants reared with T. molitor pupae (T3) (97.9%), with A. gemmatalis caterpillars reared with soybean leaves (T2) (93.8%), and with A. gemmatalis caterpillars fed an artificial diet (T1) (79.2%), relative to A. gemmatalis pupae from caterpillars fed soybean leaves (T4) (Fig. 1).

Instar V, and both male and female adults of P. nigrispinus, were heavier when fed T. molitor (T3) (Table 2).

Life table parameters for P. nigrispinus varied with the prey supplied. The net reproductive rate (Ro), duration of a generation (DG), and time to double the population (TD) of this predator had higher values when allowed to feed on A. gemmatalis caterpillars reared on soybean leaves (T2) and on T. molitor pupae (T3), indicating increased offspring production per generation (Table 3). The finite (λ) and intrinsic (rm) rates of population growth of P. nigrispinus were similar among treatments.

Discussion

The quality and quantity of food affect parameters such as survival, weight gain, stage duration, egg numbers, and predator viability and longevity (Zanuncio et al. 2002). The equivalent duration of first instar P. nigrispinus is due to the pentatomid predators having no predatory
habits at this age (Torres et al. 2006; Malaquias et al. 2010). *Podisus nigrispinus* predatory behavior begins as it attains the second instar (Torres et al. 2006) and the life cycle of this predator depends on food quality and quantity (Lemos et al. 2006). The duration of the *P. nigrispinus* nymph stage was shorter when their supplemental diet included *A. gemmatalis* caterpillars reared on an artificial diet (T1) or *T. molitor* larvae (T3) than when allowed to feed on *A. gemmatalis* caterpillars reared on soybean leaves (T2). In a similar study, Medeiros et al. (2000) reported that nymph development of this predator was shorter when allowed to feed on *A. gemmatalis* caterpillars reared on an artificial diet (T1) or caterpillars fed soybean plants (T2) or *T. molitor* larvae from caterpillars fed soybean leaves (T4).

Insect population growth may be evaluated with Ro values, which uses specific female fertility at different ages (Southwood 1978). The lower net reproductive rate (Ro) for *P. nigrispinus* females when their supplemental diet included *A. gemmatalis* caterpillars reared on an artificial diet (T1), as obtained in our study, indicates that this diet is less suitable for mass production of this predator resulting in production of fewer offspring during their lifetime (De Bortoli et al. 2011). Life tables show the reproductive potential of females at different times (Medeiros et al. 2000), but dietary quality during immature stages affects insect reproduction (Mayntz et al. 2003). For example, the net reproductive rate (Ro) for *P. nigrispinus* was higher when fed *Plutella xylostella* L. (Lepidoptera: Plutellidae) pupae (267.2) than when fed larva of this species (216.1) (Vacari et al. 2013).

*Anticarsia gemmatalis* reared on an artificial diet (T1) induced lower generational duration (DG), and the period for *P. nigrispinus* to double its population size (TD). Low values of these parameters (DG and TD) are desirable in biological control programs because the possibility of obtaining more annual generations is greater, which provides financial advantages (Menezes et al. 2014). The positive rate of increase (λ and rm) value in all treatments indicates higher birth than mortality rates (Santos et al. 2014). Higher values for the Ro parameter indicates greater numbers of offspring, with this parameter being more relevant than generational duration for population increase (Menezes et al. 2014).

**Table 1.** Duration (mean days ± standard error) for instars I–V, and of the total nymph stage, of *Podisus nigrispinus* (Hemiptera: Pentatomidae) reared with soybean plants supplemented with *Anticarsia gemmatalis* (Lepidoptera: Erebidae) caterpillars fed an artificial diet (T1), on soybean plants with caterpillars fed soybean leaves (T2), on soybean plants with *Tenebrio molitor* (Coleoptera: Tenebrionidae) pupae (T3), or on soybean plants with *A. gemmatalis* pupae from caterpillars fed soybean leaves (T4).

<table>
<thead>
<tr>
<th>Instars</th>
<th>Treatments</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>T1</td>
</tr>
<tr>
<td>I</td>
<td>3.00 ± 0.00</td>
</tr>
<tr>
<td>II</td>
<td>3.96 ± 0.09 B</td>
</tr>
<tr>
<td>III</td>
<td>3.49 ± 0.16 BC</td>
</tr>
<tr>
<td>IV</td>
<td>4.21 ± 0.09 AB</td>
</tr>
<tr>
<td>V</td>
<td>5.63 ± 0.10 B</td>
</tr>
<tr>
<td>Total</td>
<td>25.20 ± 0.21 B</td>
</tr>
</tbody>
</table>

**Table 2.** Weight (mean mg ± standard error) of instar V nymphs and of newly emerged *Podisus nigrispinus* (Hemiptera: Pentatomidae) adults reared with soybean plants supplemented with *Anticarsia gemmatalis* (Lepidoptera: Erebidae) caterpillars fed an artificial diet (T1), on soybean plants with caterpillars fed soybean leaves (T2), or on soybean plants with *Tenebrio molitor* (Coleoptera: Tenebrionidae) pupae (T3).

<table>
<thead>
<tr>
<th>Stages</th>
<th>Treatments</th>
</tr>
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<tbody>
<tr>
<td>V</td>
<td>T1</td>
</tr>
<tr>
<td>Female</td>
<td>25.38 ± 1.00 B</td>
</tr>
<tr>
<td>Male</td>
<td>42.20 ± 1.08 B</td>
</tr>
<tr>
<td>Female</td>
<td>60.34 ± 2.03 B</td>
</tr>
</tbody>
</table>

**Fig. 1.** Nymph absolute survival (according to Kaplan-Meier estimator) of *Podisus nigrispinus* (Hemiptera: Pentatomidae) reared with soybean plants supplemented with *Anticarsia gemmatalis* (Lepidoptera: Erebidae) caterpillars fed an artificial diet (T1); on soybean plants with caterpillars fed soybean leaves (T2); on soybean plants with *Tenebrio molitor* (Coleoptera: Tenebrionidae) pupae (T3); or on soybean plants with *A. gemmatalis* pupae from caterpillars fed soybean leaves (T4).

with reports of adult weights from 45 to 140 mg for females and 35 to 100 mg for males (Torres et al. 2006), and independent of diet (Lemos et al. 2001, 2003). Better nutritional prey quality affects predator weight gain (Oliveira et al. 2004). Moreover, feeding on different prey throughout the life cycle, such as *T. molitor* and *M. domestica* on alternated days, supplements the predator nutritional requirements and increases production of heavier females (Zanuncio et al. 2001)

Non-significant. Means per row followed by the same letter do not differ by Tukey’s test (P = 0.05).

**Fig. 1.** Nymph absolute survival (according to Kaplan-Meier estimator) of *Podisus nigrispinus* (Hemiptera: Pentatomidae) reared with soybean plants supplemented with *Anticarsia gemmatalis* (Lepidoptera: Erebidae) caterpillars fed an artificial diet (T1); on soybean plants with caterpillars fed soybean leaves (T2); on soybean plants with *Tenebrio molitor* (Coleoptera: Tenebrionidae) pupae (T3); or on soybean plants with *A. gemmatalis* pupae from caterpillars fed soybean leaves (T4).
Thus, *A. gemmatalis* pupae fed on soybean leaves (T4) are inadequate prey for *P. nigrispinus*. *Anticarsia gemmatalis* caterpillars fed an artificial diet (T1) are less suitable prey for rearing this predator than *A. gemmatalis* caterpillars fed soybean leaves (T2) or *T. molitor* pupae (T3).

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