Biology and life table of *Stethorus tridens* fed *Tetranychus bastosi* on physic nut

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Abstract

This study provides information about the life cycle of the predator *Stethorus tridens* Gordon (Coleoptera Coccinellidae), and its potential to control the pest *Tetranychus bastosi* Tuttle, Baker et Sales (Acari Tetranychidae). Life table parameters of *S. tridens* fed *T. bastosi* infesting physic nut (*Jatropha curcas*) were evaluated. The mean life cycle of *S. tridens* was 12.35 days and mean longevity was 57.1 days, with an average of 101.1/female. The life table parameters of *S. tridens* were: specific fertility came to a maximum of 2.49 eggs; survival probability: 0.92%; net reproduction rate: 53.05 individuals; average generation time: 17.09 days; intrinsic rate of growth: 0.23 females/day; finite rate of increase: 1.26 individuals/female; and population doubling time: 2.98 days. These results indicate that *S. tridens* develops successfully when fed *T. bastosi* on *J. curcas*.

Key words: biological parameters, *Jatropha curcas*, Stethorini, red spider mite, Tetranychidae.

Introduction

Coccinellids of the genus *Stethorus* Weise (Coleoptera Coccinellidae) are specialist predators of tetranychid mites (Putman, 1955), and they forage on a wide range of cultivated plants on which tetranychids are abundant (Biddinger et al., 2009). Several species have been reported to be effective biological control agents mainly due to their voracity, adult longevity and ability to migrate to agricultural crops (Chazeau, 1985; Rott and Ponsonby, 2000; Biddinger et al., 2009).

Tetranychid mites are considered the main pest mites for infest several economically important crops. Among spider mite species, *Tetranychus bastosi* Tuttle, Baker et Sales (Acari Tetranychidae) is the most important physic nut (*Jatropha curcas*) mite (Sarmento et al., 2011; Pedro-Neto et al., 2013), causing extensive damage to jatropha cultivated in several regions of Brazil (Santos et al., 2010). The control of *T. bastosi* requires the use of synthetic acaricides that are not registered for the crop (AGROFIT, 2018), and among other aspects, this approach can cause problems such as pesticide resistance in the target organisms, fruit residues and environmental pollution (Watanabe et al., 1994; Escudero and Ferragut, 2005). In this context, studies are being conducted on the natural enemies of tetranychid mites to evaluate their potential for the biological control of this pest (Oliveira et al., 2007; Marques et al., 2015).

The Stethorini comprise beetles that specialize on phytophagous mites. Among them, *Stethorus tridens* Gordon (Coleoptera Coccinellidae) is noteworthy and was recorded associated with *T. bastosi* on Solanaceae in North-East and South-East Brazil (Fiaboe et al., 2007; Britto et al., 2009; Costa et al., 2017).

Life table studies are fundamental for understanding the population dynamics of a species since they provide a comprehensive view of its survival, development and reproduction in certain environmental conditions (Coppel and Mertins, 1977). According to Bellows and Van Driesche (1999), there are several approaches to evaluate the impact of natural enemies on biological systems, and one is life table construction and analysis.

In this context, the development and fertility life table parameters of *S. tridens* fed with the pest mite *T. bastosi* on *J. curcas* were evaluated. We tried to answer to the following questions: (i) Does the predator can develop successfully feeding on *T. bastosi* on jatropha plants? (ii) Does the predator show greater population growth compared to the pest?

Materials and methods

Rearing *T. bastosi* and *S. tridens*

Populations of the predator *S. tridens* and the spider mite *T. bastosi* were obtained from experimental jatropha plantations belonging to the Active Germplasm Bank of the Lauro Bezerra Station of the Pernambuco Agronomy Institute (IPA - Serra Talhada, Pernambuco State, PE, Brazil).

A morphological study of the male genitalia of specimens was conducted to confirm the identity of *Stethorus* beetles. The males were dissected and compared to the original description of *S. tridens* (Gordon, 1982) in the Gordon and Chapin (1983) identification key. The male genitalia had a pair of lateral teeth and a triangular apex on the basal lobe, diagnostic characters of this species.

*T. bastosi* colonies were kept in the laboratory on Gerbox® plates (11.0 × 11.0 × 3.0 cm) containing foam (3.0 cm thick) that were moistened with distilled water and covered with filter paper. A jack bean leaf, *Canavalia ensiformes* (L.) DC., was placed on the paper, and its borders were surrounded by moist cotton wool to prevent the mites from escaping (Reis and Alves, 1997).

The predators were reared in plastic pots (9 cm diameter) on *T. bastosi* infested jatropha leaves. Leaf petiole were kept in small tubes of water to maintain turgidity (Costa et al., 2017); the leaves were changed every two
days to maintain satisfactory densities of *T. bastosi*. The rearing units were maintained in air-conditioned chambers (27 ± 2 °C, 70 ± 10% RH and a 12-h photophase). The jatropha plants used in the experiment were grown in 5-L pots containing soil, commercial substrate and bovine manure at a 3:1:1 ratio, irrigated every 2 days, housed in 1.5 × 1.0-m cages coated with fabric and maintained in the experimental area.

**Biology**

Thirty eggs of standardized age (up to 24 hours) were obtained from the reared *S. tridens* females; each egg was placed in an individual plastic pot (9 cm diameter) containing one *T. bastosi*-infested jatropha with the petiole in a tube containing water.

Observations were performed at 24-h intervals to determine the duration and survival of each of the developmental instars of *S. tridens*. When the insects reached adulthood, one adult male was added to each of the arenas containing females for mating, and when the male died, it was replaced by others until the female died. The eggs laid by the females were raised separately to the adult stage to determine the progeny sex-ratio.

All tests were conducted in controlled growth chambers at 27 ± 2 °C, 70 ± 10% RH and a 12-h photophase. The experiment was conducted in a completely randomized design with 30 replicates, and the data were subjected to analysis of variance using the program Sisvar version 5.6 (Ferreira, 2011).

**Fertility life table**

Life table parameters were determined from the survival and fecundity data of *S. tridens* females, and the following development and survival parameters of the juvenile and adult forms of the progeny were obtained during the biological evaluation: intrinsic population growth rate (*r*); net reproduction rate (*R*); finite rate of population increase (*λ*); average generation time (*T*); population doubling time (*T*D); specific fertility (*mx*); and survival rate (*s*). The biological parameters were calculated using the LIFETABLE.SAS tool developed by Maia et al. (2000) in the “SAS System” environment of SAS software version 8.02 (SAS, 2001).

**Results**

**Biology of *S. tridens***

Data on the development of *S. tridens* (egg, four larval instars, pupa and adult) are presented in table 1; there were no significant differences between males and females.

Newly deposited *S. tridens* eggs are bright, milky white and elongated, but the colour may gradually change to orange during the incubation period. The eggs were individually deposited on leaf ribs and adhered firmly to the leaf surface (figure 1 a-b).

The mean development time for *S. tridens* eggs was 3.5 days, corroborating the observations by Fiaboe et al. (2007) on *S. tridens* fed with *Tetranychus evansi* Baker et Pritchard (table 1). Four larval instars were observed over a total of 5.9 days (table 1), which was consistent with the observations by Hodek (1973) for most coccinellid species. The larvae show blackish coloration and numerous dark brown bristles along the dorsum, and all stages are similar. They are differentiated based on the size of the cephalic capsule and the presence of the exoskeleton (figure 1 c-d) (Khan et al., 2002).

The 1st, 2nd and 3rd larval instar periods were short, during which the larvae actively searched for food. The development time of the 4th instars was longer, and according to Hodek (1973), this allows the individuals to obtain the nutritive substances required for transformation into pupa and their later emergence as adults. As the 4th instar larvae matured, they reduced feeding activity and moved little, becoming red and fixing to the substrate of the leaf by means of a viscous fluid to pupate.

The pupal stage is one of the inactive phases in Coccinellidae. The pupa is reddish orange when newly transformed and becomes blackish, covered with numerous bristles (Chazeau, 1985). They are attached by the abdomen to the leaf surface until they emerge as adults (figure 1 e-f). In the present study, this period lasted an average of 2.95 days in both males and females (table 1).

Newly emerged adults had a reddish coloration that gradually changed to black (figure 1 g-h). The duration of development from the egg to the adult stage lasted an

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**Table 1. Duration (mean ± standard error) of the biological stages of *S. tridens* fed *T. bastosi* on *J. curcas* in the laboratory.**

<table>
<thead>
<tr>
<th>Biological phase</th>
<th>Survival (%)</th>
<th>Development time (days)²</th>
<th>Females (n = 11) b</th>
<th>Males (n = 9)</th>
<th>Mean (n = 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg</td>
<td>96</td>
<td>3.5 ± 1.0</td>
<td>3.6 ± 1.0</td>
<td>3.5 ± 1.0</td>
<td></td>
</tr>
<tr>
<td>Larval instars</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>100</td>
<td>1.3 ± 1.1</td>
<td>1.3 ± 0.5</td>
<td>1.3 ± 0.47</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>100</td>
<td>1.2 ± 0.4</td>
<td>1.4 ± 0.7</td>
<td>1.3 ± 0.57</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>100</td>
<td>1.1 ± 0.3</td>
<td>1.0 ± 0.0</td>
<td>1.05 ± 0.22</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>93</td>
<td>2.2 ± 0.4</td>
<td>2.3 ± 1.3</td>
<td>2.25 ± 0.97</td>
<td></td>
</tr>
<tr>
<td>Larval stage</td>
<td></td>
<td>5.7 ± 0.5</td>
<td>6.1 ± 0.6</td>
<td>5.9 ± 1.12</td>
<td></td>
</tr>
<tr>
<td>Pupal stage</td>
<td>89</td>
<td>3.0 ± 0.4</td>
<td>2.9 ± 0.3</td>
<td>2.95 ± 0.39</td>
<td></td>
</tr>
<tr>
<td>Egg - adult</td>
<td>93</td>
<td>12.2 ± 1.2</td>
<td>12.6 ± 1.3</td>
<td>12.35 ± 1.23</td>
<td></td>
</tr>
<tr>
<td>Longevity</td>
<td>57.9 ± 19.2</td>
<td>56.1 ± 14.4</td>
<td>57.1 ± 17.09</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

² Mean ± standard error; b number of observations.
average of 12.35 days (table 1), and these results were similar to those obtained by Roy et al. (2002) for Stethorus punctillum (Weise) reared on Tetranychus medanieli McGregor.

Of the 30 S. tridens eggs, only 20, 11 females (55%) and 9 males (45%), reached the adult stage. S. tridens adults lived 57.1 days on average, with some females living 83 days. Higher values were found by Fiaboe et al. (2007) and Perumalsamy et al. (2010), confirming observations by Hodek (1973).

The pre-oviposition, oviposition and post-oviposition periods and the number of eggs deposited by S. tridens females are reported in table 2.

The total fecundity of S. tridens females at 27 °C was lower than that of other Stethorini species at lower temperatures, including Stethorus japonicus Kamiya (501 eggs, Mori et al., 2005), Stethorus madecassus Chazeau (184 eggs, Chazeau, 1974), Stethorus picipes Casey (221 eggs, Tanigoshi and McMurtry, 1977) and S. punctillum (279 eggs, Roy et al., 2002).

The eggs were deposited individually or in bunches (4-5 eggs / spot). After the oviposition period, the female S. tridens entered a period of senescence (post oviposition) and death. These values were similar to those of other species, such as S. japonicus predating Tetranychus urticae Koch (Mori et al., 2005).

Fertility life table of S. tridens

The highest mx value was observed in the age intervals between days 14 and 17 (figure 2). Then, there was a decline in fertility until the 22nd day and a subsequent increase until the 24th day, presenting a maximum rate of 2.49 eggs per female per day followed by a gradual decrease in mx. The lx (0.92) remained constant until the 25th day, after which there was a marked decrease (lx = 0.85) (figure 2).

The pre-oviposition, oviposition and post-oviposition period and the number of eggs deposited by S. tridens females are reported in table 2.

Table 2. Duration, in days, of the pre-oviposition, oviposition and post-oviposition periods and the number of eggs deposited by S. tridens females fed T. bastosi on J. curcas leaves in the laboratory.

<table>
<thead>
<tr>
<th>Periods</th>
<th>Mean ± SE^a (n = 11)^b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-oviposition</td>
<td>7.9 ± 1.2</td>
</tr>
<tr>
<td>Oviposition</td>
<td>43.9 ± 12.7</td>
</tr>
<tr>
<td>Post oviposition</td>
<td>5.2 ± 1.3</td>
</tr>
<tr>
<td>Number of eggs / female</td>
<td>101.1 ± 33.7</td>
</tr>
</tbody>
</table>

^a Standard error; ^b number of observations.

Regarding the fertility life table parameters (table 3), the mean Ro was 53.059 females/female.

The rm value indicates the capacity of a population to increase logarithmically, and an increase of 0.232 females per female per day was observed in this study, which was higher than that reported for other species, including S. punctillum (0.100, Roy et al., 2002), S. japonicus (0.156, Mori et al., 2005) and S. tridens (0.104, Fiaboe et al., 2007). Furthermore, rm is strongly correlated with development time and oviposition rate, and as the development time of S. tridens is similar to that of the above species, the differences in rm values can be attributed to differences in oviposition rate (Mori et al., 2005).

In theory, a predator that has an rm equal to or greater than that of its prey efficiently regulates the prey population (Sabelis, 1992; Roy et al., 2003). This is an important parameter in the selection of promising biological control agents, but other parameters such as predation ability, search time, voracity and longevity may also contribute to predator-prey dynamics (Roy et al., 2003).
Figure 2. Survival probability ($l_x$) as a percentage and specific fertility ($m_x$) as the mean number of eggs/day of adult female *S. tridens* fed *T. bastosi* on *J. curcas* leaves in the laboratory.

### Table 3. Fertility life table parameters of *S. tridens* fed *T. bastosi* on *J. curcas* leaves in the laboratory.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intrinsic growth rate ($r_m$) (females/female/day)</td>
<td>0.232</td>
</tr>
<tr>
<td>Finite rate of increase ($\lambda$) (individuals/female)</td>
<td>1.261</td>
</tr>
<tr>
<td>Net reproductive rate ($R_0$) (females/female)</td>
<td>53.059</td>
</tr>
<tr>
<td>Average generation time ($T$) (days)</td>
<td>17.091</td>
</tr>
<tr>
<td>Population doubling time ($T_d$) (days)</td>
<td>2.982</td>
</tr>
<tr>
<td>Sex ratio</td>
<td>0.57</td>
</tr>
</tbody>
</table>

According to Rabinovich (1978), $\lambda$ differs from $r_m$ because it represents a finite rate of population increase and not an instantaneous rate. That is, it is the number of individuals added to the population per individual per unit of time. In this study, the value of $\lambda$ confirmed the value of $R_0$, revealing that a population increase was occurring from one generation to another. The positive growth capacity indicates that the conditions to which the insects were submitted correspond to an environment favourable to their development (Milléo et al., 2014).

The $T$ value of *S. tridens* is related to the mean time between two successive generations, and the $T_d$ was 2.98 days. The *S. tridens* sex ratio was 0.57. This agrees with results reported for *S. japonicus* and *Stethorus vagans* (Blackburn) (Mori et al., 2005).

Laboratory studies have reported similar $r_m$ values for *S. tridens* and predatory mites of the family Phytoseiidae, which are widely used to control pest mites. A value of 0.22 was found for *Euseius concordis* (Chant) predating *T. bastosi* at 25 °C (Marques et al., 2015), which reinforces the potential of *S. tridens* to control this pest mite. When compared to the reported $r_m$ values for *T. bastosi* on jatropha at 25 °C, (0.22, Pedro Neto et al., 2013), the $r_m$ of *S. tridens* (0.23) was higher than that of the pest (table 4). This indicates that *S. tridens* has a superior capacity for population growth compared to its prey, and thus it could efficiently control this mite.

Furthermore, these coccinellids are known to be voracious predators of tetranychid mites (Biddinger et al., 2009; Britto et al., 2009). One *S. tridens* individual consumes an average of 122 eggs, 147 larvae and 32 adults of *T. bastosi* per day. They also show strong aggregating responses, both numerical and functional, to prey density (Costa et al., 2017).

### Table 4. Population growth parameters of *S. tridens* and *E. concordis* compared to those of *T. bastosi* on *J. curcas*.

<table>
<thead>
<tr>
<th>Species</th>
<th>$T$ (°C)</th>
<th>$r_m$</th>
<th>$\Lambda$</th>
<th>$R_0$</th>
<th>$T$</th>
<th>$T_d$</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Stethorus tridens</em></td>
<td>27</td>
<td>0.23</td>
<td>1.26</td>
<td>53.05</td>
<td>17.09</td>
<td>2.98</td>
<td>Present work</td>
</tr>
<tr>
<td><em>Euseius concordis</em></td>
<td>25</td>
<td>0.22</td>
<td>1.24</td>
<td>54.9</td>
<td>7.77</td>
<td>3.16</td>
<td>Marques et al., 2015</td>
</tr>
<tr>
<td><em>Tetranychus bastosi</em></td>
<td>25</td>
<td>0.22</td>
<td>1.25</td>
<td>45.41</td>
<td>17.17</td>
<td>3.15</td>
<td>Pedro Neto et al., 2013</td>
</tr>
</tbody>
</table>
Conclusions

The biological results, along with the fertility life table, show that *S. tridentis* can develop and reproduce when fed with *T. bastosi* on jatropha plants. In addition, because its population growth is greater than that of its prey, *S. tridentis* is a potential biological control agent for *T. bastosi* on jatropha crops.

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