

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* L.) 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* L.) mite (Sarmiento *et al.*, 2011; Pedro-Neto *et al.*, 2013), causing extensive damage to jatropa 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 jatropa 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 jatropa 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 jatropa 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, $70 \pm 10\%$ 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 development 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, $70 \pm 10\%$ 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_m); net reproduction rate (Ro); finite rate of population increase (λ); average generation time (T); population doubling time (Td); specific fertility (mx); and survival rate (lx). 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

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

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

^a Mean \pm standard error; ^b number of observations.



Figure 1. Stages of *S. tridens* development: (a-b) eggs; (c-d) larvae; (e-f) pupae; (g-h) adults fed *T. bastosi* on *J. curcas* leaves in the laboratory.

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 mcDanieli* 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 period 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).

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.

Periods	Mean ± SE ^a (n = 11) ^b
Pre-oviposition	7.9 ± 1.2
Oviposition	43.9 ± 12.7
Post oviposition	5.2 ± 1.3
Number of eggs / female	101.1 ± 33.7

^a Standard error; ^b number of observations.

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

The r_m 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, r_m 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 r_m values can be attributed to differences in oviposition rate (Mori *et al.*, 2005).

In theory, a predator that has an r_m 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).

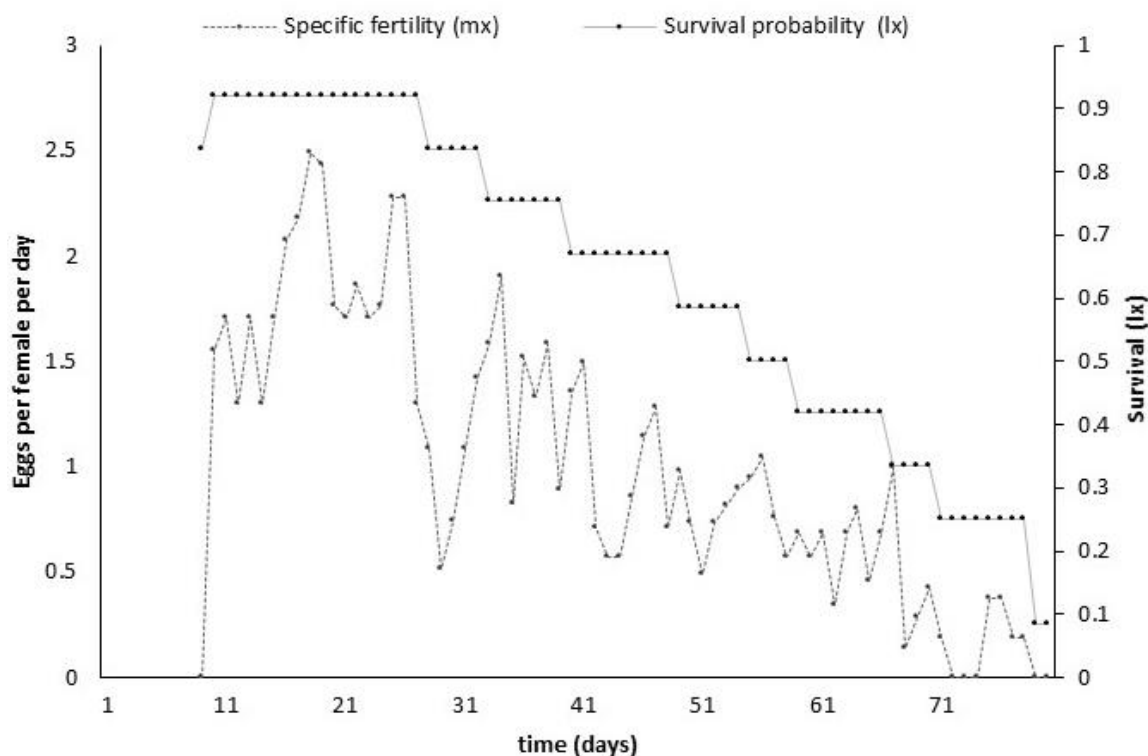


Figure 2. Survival probability (lx) as a percentage and specific fertility (mx) as the mean number of eggs/day of adult female *S. tridens* fed *T. bastosi* on *J. curcas* leaves in the laboratory.

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

Parameter	Value
Intrinsic growth rate (r_m) (females/female/day)	0.232
Finite rate of increase (λ) (individuals/female)	1.261
Net reproductive rate (R_0) (females/female)	53.059
Average generation time (T) (days)	17.091
Population doubling time (T_d) (days)	2.982
Sex ratio	0.57

According to Rabinovich (1978), λ 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 λ 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) preying *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*.

Species	T	r_m	Λ	R_0	T	T_d	Reference
<i>Stethorus tridens</i>	27 °C	0.23	1.26	53.05	17.09	2.98	Present work
<i>Euseius concordis</i>	25 °C	0.22	1.24	54.9	7.77	3.16	Marques <i>et al.</i> , 2015
<i>Tetranychus bastosi</i>	25 °C	0.22	1.25	45.41	17.17	3.15	Pedro Neto <i>et al.</i> , 2013

Conclusions

The biological results, along with the fertility life table, show that *S. tridens* 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. tridens* is a potential biological control agent for *T. bastosi* on jatropha crops.

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