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BIOLOGICAL CONTROL

Tachinid Fly Parasitism and Phenology of the Neotropical Red-Shouldered Stink Bug, *Thyanta perditor* (F.) (Heteroptera: Pentatomidae), on the Wild Host Plant, *Bidens pilosa* L. (Asteraceae)

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Abstract

Field and laboratory studies were conducted with the Neotropical red-shouldered stink bug *Thyanta perditor* (F.) (Heteroptera: Pentatomidae) aiming to evaluate parasitism incidence on adults by tachinid flies (Diptera: Tachinidae), which were raised in the laboratory for identification. Egg deposition by flies on adult body surface was mapped. In addition, nymph and adult incidence on the wild host plant black jack, *Bidens pilosa* L. (Asteraceae), during the vegetative and the reproductive periods of plant development was studied. Seven species of tachinid flies were obtained: *Euthera barbiellini* Bezzi (73% of the total) and *Trichopoda* cf. *pictipennis* Bigot (16.7%) were the most abundant; the remaining five species, *Gymnoclytia* sp.; *Phasia* sp.; *Strongygaster* sp.; *Cylindromyia* cf. *dorsalis* (Wiedemann); and *Ectophasiopsis ypiranga* Dios & Nihei added 10.3% of the total. Tachinid flies parasitism on *T. perditor* adults was significantly greater on the dorsal compared to the ventral body surface. On the dorsal surface, the pronotum was significantly preferred and the wings the least preferred site. No differences were observed on the number of tachinid fly eggs deposited on wings, considering the "under" and "above" sites. Results indicated a significantly greater number of nymphs on mature compared to immature seeds. Adults significantly preferred immature compared to mature seeds; both were less abundant on leaves/stems and inflorescences.

Introduction

Recent field observations conducted in southern Brazil suggest that Tachinidae parasitism on stink bugs is intense and variable (ARP and TL, unpublished). We have observed a wide range of different Tachinidae species parasitizing the commonly called red-shouldered stink bug *Thyanta perditor* (F.). The generalized presence of whitish eggs externally to the host body could belong to species from the tribe Gymnosomatini (Phasiinae) or Eutheriini (Dexiinae). However, many phasiines have piercer structures that they use to introduce their eggs inside the host (Dupuis 1963).

There are several species of *Thyanta* distributed in the Nearctic Region, which are frequently reported colonizing crop plants, although they seldom reach pest status (e.g., Bundy & McPherson 2000, Buntin & Greene 2004, Suh *et al* 2013, Reay-Jones 2014). In a similar way, in the Neotropical Region, *Thyanta* species are also reportedly associated with crop plants, in particular the common *T. perditor* (Perez *et al* 1980, Panizzi & Herzog 1984, Ferreira & Silveira 1991).

Thyanta perditor is polyphagous and has been associated with at least 15 different plant species from eight botanical families; however, on only three species (soybean, wheat, and the weed *Bidens pilosa* L. (Asteraceae)), the bug was reported to develop and reproduce (Smaniotto & Panizzi 2015). Studies have demonstrated that *T. perditor* nymphs and adults fed with reproductive structures of winter cereals (wheat and barley) and black jack presented, in general, a high performance (Tomacheski *et al* 2019). Since the 1980s, it is known to have strong association with the fully developed plants of the weed black jack, *B. pilosa* (Panizzi & Herzog 1984). Recent studies indicated that among seedlings of non-cultivated plants, black jack, along with the wild poinsettia (also called in Brazil milkweed), *Euphorbia heterophylla* L. (Euphorbiaceae) are ranked as preferred hosts (Tomacheski and Panizzi 2018, Tomacheski *et al* 2019). However, the association of *T. perditor* nymphs and adults with its preferred wild host plant, black jack, has never been studied in detail. For example, no data are available on possible nymphal and adult preferences for particular structures of the plant, such as leaves/stems, inflorescence, and seeds (immature or mature).

Therefore, in this study, we aimed to evaluate (1) the occurrence of different species of tachinid flies parasitizing adult *T. perditor*; (2) the allocation of egg deposition of flies on the different areas of the body surface (dorsal and ventral) of adult bugs; and (3) the nymph and adult incidence of *T. perditor* on vegetative and reproductive structures of the weed plant, black jack.

Materials and Methods

Stink bug checking for tachinid flies in the laboratory

Adults of *T. perditor* were collected in the field from the weed plant black jack, *Bidens pilosa* (L.). Surveys were carried out at random and monthly during January, April, May, June, and July 2018, in rural areas of Francisco Beltrão Co. (latitude 26°04′52″S, longitude 53°03′18″W) in Paraná state, Brazil.

Stink bugs were transported to the laboratory and observed to determine if they were visually parasitized (i.e., presence of at least one whitish fly egg externally attached on the stink bug body) or not. Although some species of tachinids have mechanisms to introduce their eggs directly into hosts, herein, the parasitism rate was based exclusively on the presence or absence of eggs on the exoskeleton (including underneath the wings of the bugs).

To check for flies' emergence, bugs were placed in plastic rearing boxes (25 × 20 × 20 cm) lined with filter paper. As food source, branches of black jack plants carrying all vegetative and reproductive structures (leaf, inflorescence, immature and mature seeds) were provided, which were placed inside small glass jars (100 mL) containing water. As tachinid larvae exit from the bugs' body, they were allowed to pupate. The pupae then were individually placed in plastic Petri dishes (5-cm diameter), lined with moistened filter paper. Plastic boxes and Petri dishes were kept in a walk-in chamber at 25 ± 1°C, 65 ± 10% relative humidity, and photoperiod of 14L:10D h.

As adult flies emerged, they were killed using jars with ether as killing agent; after that, they were pinned and deposited in the EMBRAPA Trigo entomology collection for later identification. Flies were examined and identified using taxonomic keys (Bezzi 1925, Guimarães 1976, Dios & Nihei 2017), original descriptions and comparison with museum specimens, and their abundance was calculated.

Tachinid flies egg allocation on the stink bug body surface

The allocation of tachinid eggs on the body of *T. perditor* was determined. The dorsal surface was separated into different sites: head, pronotum, scutellum, and wings. The wings were considered in two ways: under (hidden) and above the wings (Fig. 1). This was done because some tachinids use to lay their eggs under the wings (e.g., Eger 1981, Aldrich *et al* 2006, Agostinetto *et al* 2018), which, sometimes, makes the parasitism to pass unnoticed.

Data on the incidence of tachinid parasites eggs on *T. perditor* were calculated to determine the percentage of parasitism for each previously mentioned site during each month and are illustrated. Mean cumulative numbers (%) for the entire sampling period (January to July 2018) were also calculated.

Stink bug field surveys and plant structures explored

Field surveys were conducted to evaluate the incidence of *T. perditor* nymphs and adults on the different vegetative and reproductive structures of the weed, black jack (*Bidens pilosa*). Black jack plants that were examined were fully developed, carrying flowers (inflorescence) and exposed seeds on different stages of maturation. They were located in between cultivated plants (soybean and maize plantations), on the edge of cultivated fields, and on nearby native vegetation.

Black jack plants were examined in order to find nymphs and adults of *T. perditor* colonizing them. As nymphs and adults were located, the following plant structures were annotated: leaf/stem (vegetative structures), inflorescence, immature seed, and mature seed (reproductive structures) (Fig 2). After the records were taken, nymphs were left undisturbed. Adults, however, were hand-collected and placed in plastic bags for later examined in the laboratory. This was done to check for the presence of whitish eggs of some tachinid flies, which deposit their eggs on the stink bug body surface; these egg observations resulted in estimation of the level of parasitism (Harris & Todd 1980, Eger 1981).

Data on the preference (%) of *T. perditor* nymphs and of adults for the different vegetative and reproductive black jack plant structures were calculated and graphically illustrated for

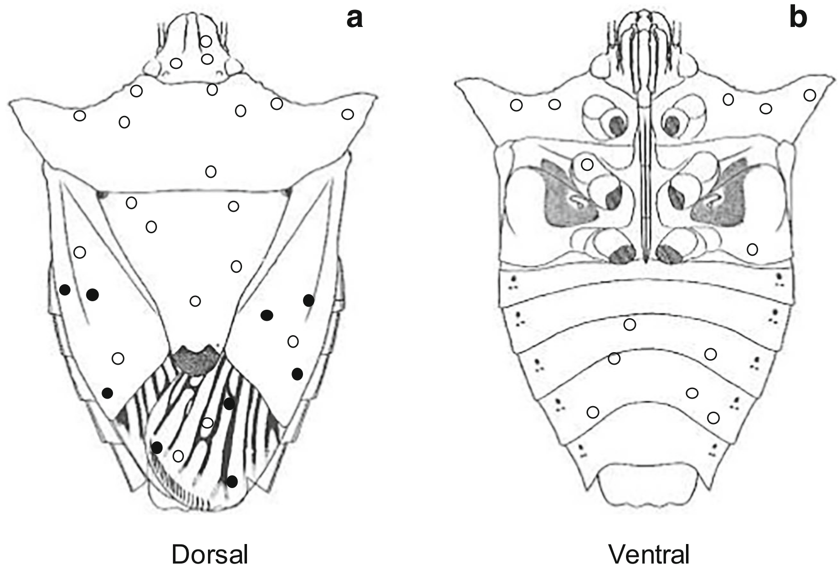

Fig 1 Schematic representation of the tachinid eggs distribution on the dorsal (A) and ventral (B) surfaces of adult *Thyanta perditor*. Full white dots (○) represent eggs laid on the exposed dorsal and ventral body sides; full black dots (●) represent eggs laid under the wings (hidden).

each month of sampling. Mean cumulative numbers (%) for the entire sampling period were also calculated.

Statistical analysis

Data on the egg allocation of tachinid flies on "dorsal vs. ventral surfaces" of the body of adult *T. perditor* in each month were compared using Pearson's chi-square test (χ^2). Means (± SE) cumulative percentages, i.e., all months pooled together, comparing "dorsal vs. ventral surfaces" and "under vs. above wings" were compared using the Student's *t* test ($P < 0.05$). The mean (± SE) cumulative percentages on dorsal surface areas (head, pronotum, scutellum, and wings) were previously submitted to the Bartlett test to check for homogeneity of variances ($P < 0.05$), and transformed into arcsine $\sqrt{(x/100)}$; then means were compared using the Tukey test ($P < 0.05$).

Data on the preference ratios (%) of *T. perditor* nymphs and adults between "vegetative vs. reproductive periods" of black jack plants in each month were compared using Pearson's chi-square test (χ^2). For reproductive structures, comparisons between "immature vs. mature seeds" (inflorescence was not considered because the number of nymphs were negligible) were performed using Pearson's chi-square test (χ^2). The means (± SE) cumulative number (%), i.e., all months pooled together, between "vegetative vs. reproductive periods" were previously submitted to the Bartlett test

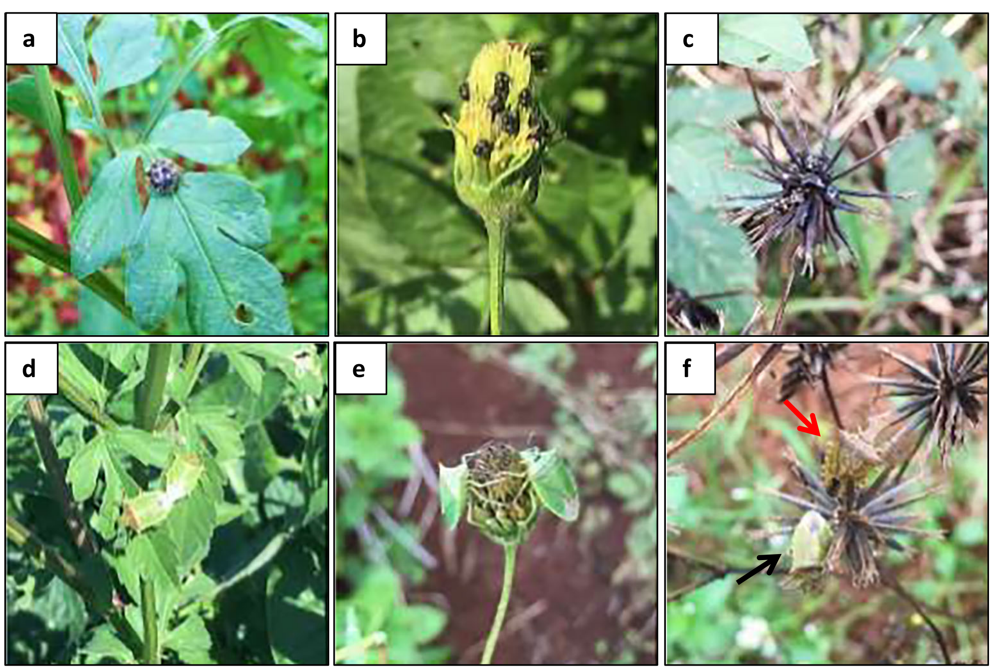

Fig 2 *Thyanta perditor* colonizing black jack plants, *Bidens Pilosa*, in the field in Francisco Beltrão Co., Paraná state, Brazil. A = nymph on leaf; B = nymphs on immature seeds; C = nymphs on mature seeds; D = adults on leaf; E = adults on immature seeds; F = adults on mature seeds (brownish morph—red arrow and greenish morph—black arrow).

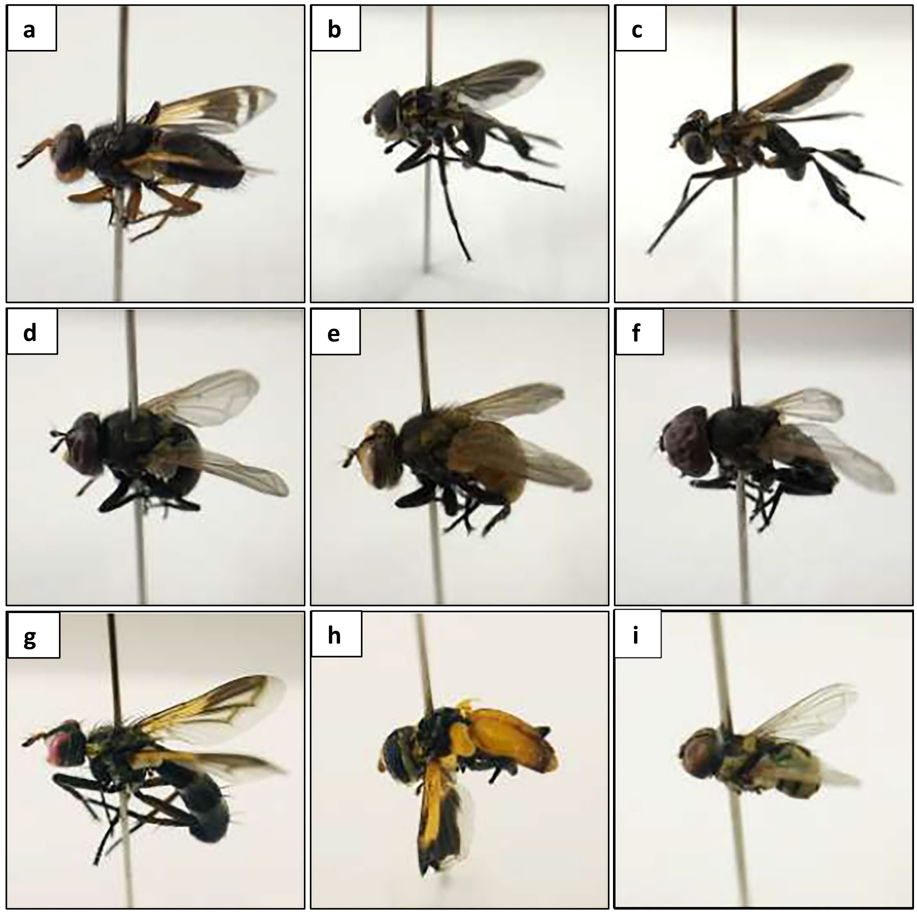

Fig 3 Species of tachinid flies parasitizing adults of *Thyanta perditor* collected on jack black plants, *Bidens pilosa*, in Francisco Beltrão Co., Paraná state, Brazil. A = *Euthera barbiellini*; B and C = *Trichopoda* cf. *pictipennis*; D = *Gymnoclytia* sp. male; E = *Gymnoclytia* sp. female; F = *Phasia* sp.; G = *Cylindromyia* cf. *dorsalis*; H = *Ectophasiopsis ypiranga*; and I = *Strongygaster* sp.

to check for homogeneity of variances ($P < 0.05$), and then transformed using the arcsine √(x/100) transformation to attend the pre-requisites of analysis of variance (ANOVA); means were separated using the Tukey test ($P < 0.05$).

Statistical analyses performed used the functions available in the R software (R Development Core Team 2016), which included "Bartlett.test" for homogeneity of variances, and "aov" for one-way analysis of variance model, in which the dependent variable was the analyzed variable and the independent variables were either the different sites of egg allocation or the plant structures. When applicable, means separations were done using "TukeyC" package (Faria *et al.* 2018) and the *t* test function in the R software. For data submitted to Pearson's chi-square test (χ^2), the "chisq.test" function in the R software was used.

Results

Tachinid flies identification in the laboratory

Of the *T. perditor* adults collected from black jack plants in the field (total of 1,533 adults), ca. 16% were parasitized (ranging from 5.5 to 28.6% during the surveys). Seven different species of tachinid flies were obtained: *Euthera barbiellini* Bezzi; *Trichopoda* cf. *pictipennis* Bigot; *Gymnoclytia* sp.; *Phasia* sp.; *Strongygaster* sp.; *Cylindromyia* cf. *dorsalis* (Wiedemann); and *Ectophasiopsis ypiranga* Dios & Nihei (Fig 3). A total of 219 pupae were obtained from the parasitized bugs reared in the laboratory, of which 126 produced adult flies. The most abundant species was *E. barbiellini* with 92 specimens (73% of the total). The second most abundant was *T.* cf. *pictipennis* with 21 specimens (16.7%). The remaining species consisted of 13 specimens (10.3% of the total).

Tachinid flies egg allocation on the stink bug body surface

A total of 329 tachinid eggs were deposited on the *T. perditor* adults collected in the field. More eggs were laid on the dorsal surface of bugs than on the ventral surface. This was consistent for all the samples taken during all months (> 79% of parasitism rate), as demonstrated by the highly significant ($P < 0.001$, df = 1) values of chi-square calculated (January $\chi^2 = 33.64$, $N = 83$; April $\chi^2 = 60.84$, $N = 72$; May $\chi^2 = 46.24$, $N = 149$; June $\chi^2 = 46.24$, $N = 19$; and July $\chi^2 = 43.56$, $N = 6$) (Fig 4). On the dorsal surface, eggs were preferentially laid on the pronotum, followed by scutellum, head, and wings, in

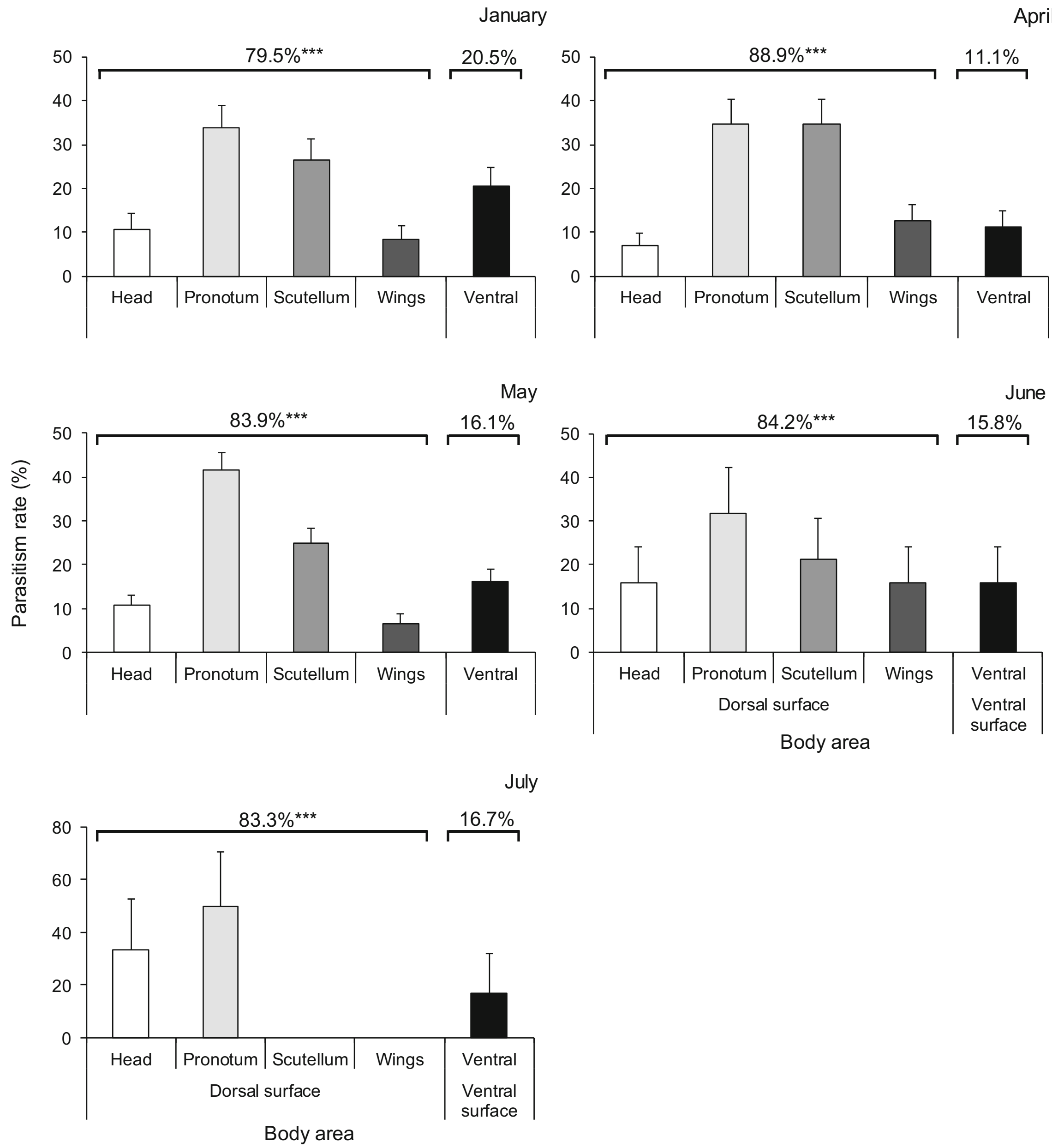

Fig 4 Allocation of eggs of tachinid flies (% ± SE) laid on different areas of the body of adult *Thyanta perditor* collected on jack black plants, *Bidens pilosa*, in Francisco Beltrão Co., Paraná state, Brazil (dorsal surface - head, pronotum, scutellum, and wings; and ventral surface). Based on examination of 301 parasitized individuals. *** Significant difference between dorsal vs. ventral surfaces using Pearson's chi-square test (χ^2) ($P < 0.001$).

decreasing order, except in July, when no eggs were laid on the scutellum or on the wings.

The mean cumulative percentage of the monthly pooled data (January to July) for parasitized *T. perditor* adults was significantly greater (over 5X) (t value = 32.09, df = 8, $P < 0.001$) on the dorsal compared to the ventral body surface. Considering the dorsal surface only, the pronotum was significantly ($F = 5.06$; df = 3, 16; $P < 0.05$) preferred and the wings the least preferred site. There was no difference in the number of adults with tachinid fly eggs deposited "under" versus "above" the wings (t value = − 2.12, df = 8, $P = 0.07$) (Table 1).

Plant structures explored by nymphs and adults

Nymphs and adults of *T. perditor* showed preferences for different parts of black jack plants. Nymphs were significantly ($P < 0.001$, df = 1) more abundant on reproductive compared to vegetative plant structures. This was consistent during all months that surveys were carried out (values of chi-square calculated were in January $\chi^2 = 70.56$, $N = 438$; April $\chi^2 = 88.36$, $N = 31$; May $\chi^2 = 88.36$, $N = 133$; June $\chi^2 = 81.00$, $N = 40$; and July $\chi^2 = 29.16$, $N = 13$). In general, over 90% of nymphs preferred reproductive parts of host plants,

Table 1 Mean cumulative (%) (January to July 2018) allocation of eggs of tachinid flies deposited on different areas of the body of adult *Thyanta perditor* collected on jack black plants, *Bidens pilosa*, in Francisco Beltrão Co., Paraná state, Brazil

Body area	Number of insects parasitized (mean cumulative % ± SE)	Number of total eggs
Dorsal surface	84.0 ± 1.5 a	276
Ventral surface	16.0 ± 1.5 b	53
Dorsal surface[1]		
Head	15.5 ± 4.7 ab	35
Pronotum	38.3 ± 3.4 a	124
Scutellum	21.4 ± 5.8 ab	88
Wings	8.7 ± 2.7 b	29
Wings		
Under	7.5 ± 2.6 a	24
Above	1.2 ± 0.6 a	5

Means (± SE) followed by the same letter between "dorsal vs. ventral surfaces" and "under vs. above wings" are not significantly different using Student's *t* test, $P < 0.05$. Means (± SE) followed by the same letter between dorsal surface areas (head, pronotum, scutellum, and wings) are not significantly different using Tukey's test, $P < 0.05$.

[1] Original data presented [for analysis, data were transformed in arcsine √(x/100)].

although slightly lower (ca. 77%) in July (Fig 5). Mature seeds were greatly preferred over immature seeds; on inflorescences, the number of nymphs were negligible. This significant preference was observed for all months, except in July (values of chi-square calculate were in January $\chi^2 = 17.39$, df = 1, $P < 0.001$; April $\chi^2 = 3.72$, df = 1, $P < 0.05$; May $\chi^2 = 20.88$, df = 1, $P < 0.001$; June $\chi^2 = 59.21$, df = 1, $P < 0.001$; and July $\chi^2 = 0.0$, df = 1, $P = 1$) (Fig 5).

As with nymphs, adults also significantly preferred (> 83%; $P < 0.001$, df = 1) reproductive compared to vegetative structures of black jack plants (Fig 6). The values of chi-square calculated were in January $\chi^2 = 60.84$, $N = 582$; April $\chi^2 = 46.24$, $N = 414$; May $\chi^2 = 77.44$, $N = 433$; June $\chi^2 = 73.96$, $N = 186$; and July $\chi^2 = 81.00$, $N = 126$). However, in contrast to nymphs, adults *T. perditor* greatly preferred immature seeds compare to mature seed; again, on inflorescences, the number of adults were negligible. This was observed for all months, as demonstrated by the significant values of chi-square calculated (January $\chi^2 = 40.91$, df = 1, $P < 0.001$; April $\chi^2 = 26.61$, df = 1, $P < 0.001$; May $\chi^2 = 64.72$, df = 1, $P < 0.001$; June $\chi^2 = 10.33$, df = 1, $P < 0.05$; and July $\chi^2 = 46.34$, df = 1, $P < 0.001$) (Fig 6).

When monthly data (January to July) were pooled (655 nymphs and 1,741 adults), the mean cumulative percentage of *T. perditor* indicated a significantly greater number ($F = 41.76$; df = 3, 16; $P < 0.001$) of nymphs on mature seeds (over 2X) compared to immature seeds, and ca. 8X more compared to leaves/stems. On the latter, nymphs were significantly more abundant than on the least preferred site, inflorescences (Table 2). Considering adults only, a similar distribution was observed, except that immature seeds were significantly ($F = 98.01$; df = 3, 16; $P < 0.001$) preferred (> 4X), compared to mature seeds (Table 2).

Discussion

In the Neotropics, adults of stink bug pests are usually attacked by tachinid flies (Table 3). Prior to the present investigation, however, only three tachinid fly species reportedly parasitized *T. perditor* adults: *Cylindromyia dorsalis* (Wiedemann), *Euthera barbiellinii* Bezzi, and *Trichopoda giacomelli* (Blanchard) (Table 3). Our survey of southern Brazil revealed a much higher diversity of tachinid *T. perditor* parasitoids, suggesting that tachinid parasitism is more intense and variable on the red-shouldered stink bug than previously reported (Panizzi & Herzog 1984, Nunes *et al* 1998). We obtained seven tachinid species from *T. perditor* adults collected from black jack plants in the field. Except for *C. dorsalis* and *E. barbiellinii*, the other five tachinids are new records the genus and/or species.

Some tachinids (members of the subfamilies Phasiinae and Dexiinae) deposit eggs externally on their hosts. However, other species, mostly of the subfamily Phasiinae (for example, members of the genus *Cylindromyia*) have an ovipositor adapted to introduce eggs directly into their hosts (Aldrich 1926, Dupuis 1963). Based exclusively on the presence or absence of external eggs, the parasitism rate on *T. perditor* adults was assessed by monthly surveys. During January to May (early-summer to mid-autumn), a large number of *T. perditor* adults were captured on black jack plants, mainly on immature seeds. While feeding upon developing seeds, the bugs are exposed to parasites; at this time, the tachinid parasitism reached nearly 29%.

At the end of autumn to early winter (June and July), captures of red-shouldered stink bugs substantially decreased as black jack plants became unavailable. These bugs seek shelters during this period and thereby escape parasitism by tachinid flies; at this time, tachinid parasitism was <

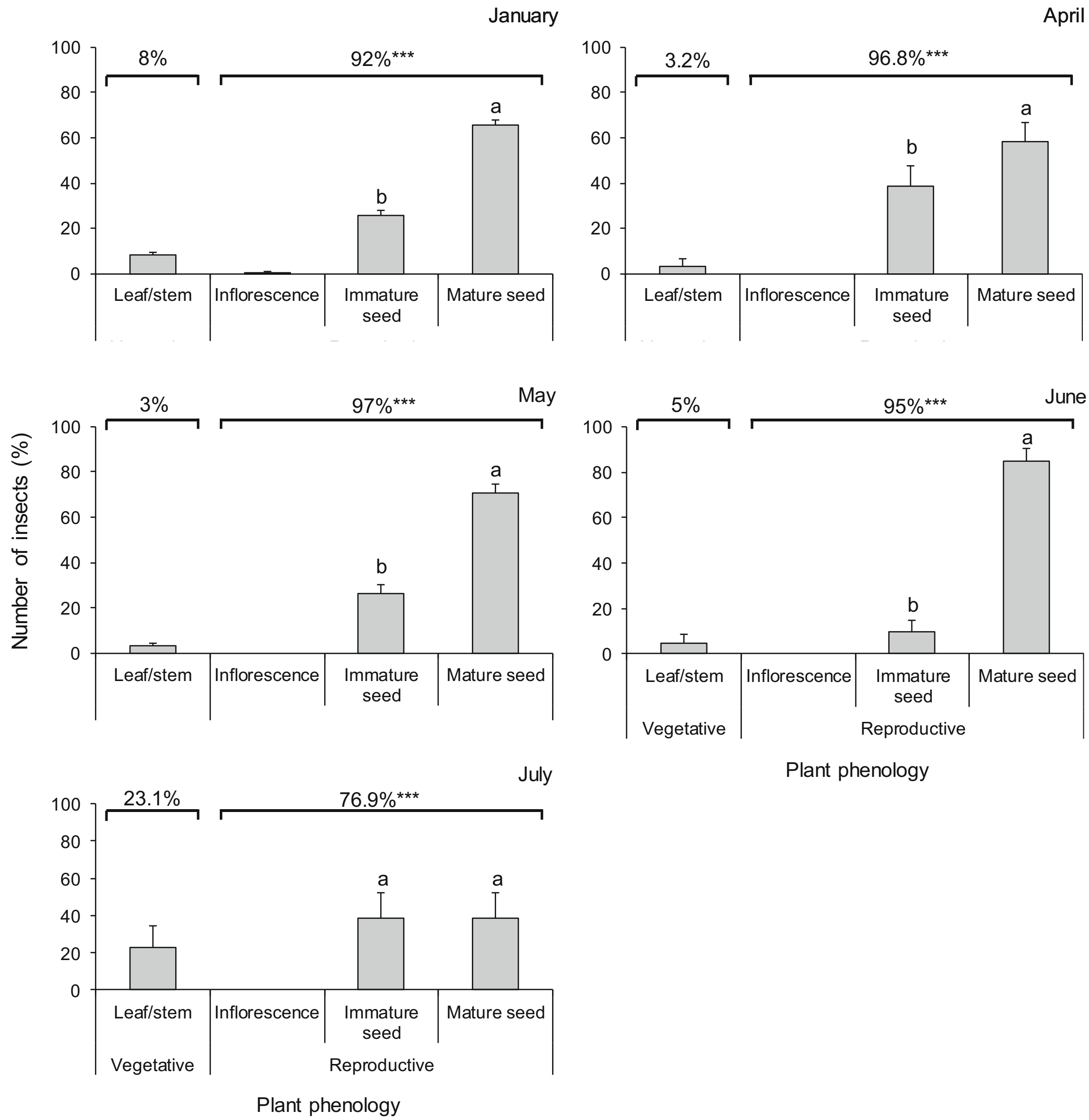

Fig 5 Preference ratios (%) of *Thyanta perditor* nymphs between vegetative vs. reproductive periods of black jack plants, *Bidens pilosa*, development. ***Significant different ($P < 0.001$) using Pearson's chi-square test (χ^2). Means (± SE) comparing the reproductive structures (immature vs. mature seeds—values for inflorescence were negligible) with different letters differ significantly ($P < 0.001$) using Pearson's chi-square test (χ^2), except in April ($P < 0.05$), and July (non-significant).

8%. A significant decrease in tachinid parasitism was also observed for the Neotropical brown-stink bug, *Euschistus heros* (F.), and the green-belly stink bug, *Dichelops furcatus* (F.), under unfavorable conditions (Panizzi & Oliveira 1999, Agostinetto *et al* 2018, respectively).

For *T. perditor* adults, the majority of fly eggs were deposited on the dorsal surface of the body, mostly on the pronotum, followed by scutellum, head and, the lowest rate above and under the wings. This result is different from those obtained for other pentatomids parasitized by different species of tachinids, where the majority of the fly eggs were deposited dorsally on hidden sites (e.g., abdominal tergites and underneath the wings) (Eger 1981, Aldrich *et al* 2006, Agostinetto *et al* 2018). However, our finding is in accordance with Salerno *et al.* (2002) who observed that majority of the eggs of *Trichopoda pennipes* F. were deposited on the thoracic region of *Nezara viridula* (L.).

The Neotropical red-shouldered stink bug *T. perditor* is reported to feed and reproduce on the wild plant black jack, *B. pilosa* (Panizzi & Herzog 1984, Tomacheski *et al.* 2019). The field surveys performed on this plant demonstrated that both nymphs and adults greatly preferred reproductive structures (mostly immature and mature seeds) of the plant compared to vegetative structures, although the preference for inflorescences of black jack was negligible for both nymphs and adults. However, nymphs showed a particular preference for

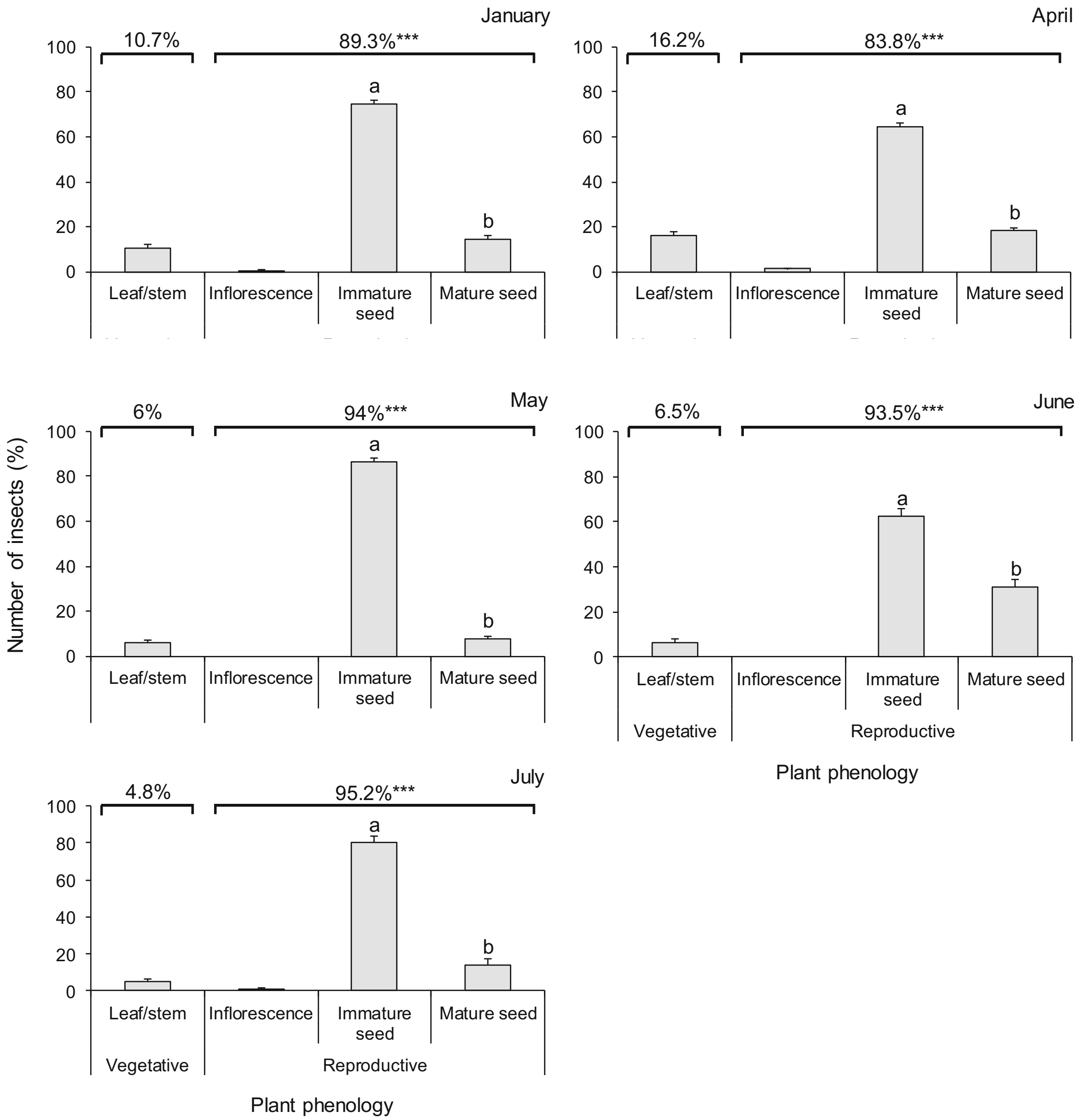

Fig 6 Preference ratios (%) of *Thyanta perditor* adults between vegetative vs. reproductive periods of black jack plants, *Bidens pilosa*, development. ***Significant different ($P < 0.001$) using Pearson's chi-square test (χ^2). Means (± SE) comparing the reproductive structures (immature vs. mature seeds—values for inflorescence were negligible) with different letters differ significantly ($P < 0.001$) using Pearson's chi-square test (χ^2), except in June ($P < 0.05$).

Table 2 Mean cumulative number (%) (January to July 2018) of *Thyanta perditor* observed colonizing black jack plants, *Bidens pilosa*, during the vegetative and the reproductive periods of development in the field in Francisco Beltrão Co., Paraná state, Brazil.

Plant phenology		Number of insects (mean cumulative % ± SE)[2]	
		Nymph	Adult
Vegetative	Leaf/stem	8.5 ± 3.8 c [45][1]	8.8 ± 2.1 b [173]
Reproductive	Inflorescence	0.1 ± 0.1 d [2]	0.5 ± 0.2 c [9]
	Immature seed	27.9 ± 5.3 b [169]	73.6 ± 4.6 a [1291]
	Mature seed	63.6 ± 7.7 a [439]	17.1 ± 3.9 b [268]

Means (± SE) followed by the same letter in columns are not significantly different using Tukey's test, $P < 0.05$.

[1] Total number of insects collected on each plant structure.

[2] Original data presented [for analysis, data were transformed in arcsine √(x/100)].

Table 3 Species of tachinid flies recorded parasitizing selected pest species of stink bugs from the Neotropics

Stink bug species	Tachinids species	References
Edessa meditabunda (F.)	*Dallasimyia bosqi* Blanchard *Homogenia* sp.	Liljesthröm & Avalos (2015)
	Trichopoda giacomelli (Blanchard)	Nunes *et al* (1998)
Euschistus heros (F.)	*Gymnoclytia paulista* Townsend	Corrêa-Ferreira (1984), Panizzi & Corrêa-Ferreira (1997)
	Gymnoclytia sp.	Aquino (2016)
	Strongygaster sp. (= *Hyalomyodes*)	Nunes *et al* (1998), Panizzi & Oliveira (1999)
	Phasia sp.	Corrêa-Ferreira *et al* (1998), Aquino (2016)
	Trichopoda giacomelli (Blanchard)	Nunes *et al* (1998), Panizzi & Oliveira (1999)
Dichelops furcatus (F.)	*Cylindromyia brasiliana* (Townsend)	Liljesthröm & Avalos (2015)
	Cylindromyia sp. *Ectophasiopsis gradata* (Wiedemann)	Agostinetto *et al* (2018)
	Ectophasiopsis gradata (= *Trichopoda argentinensis* [Blanchard])	Liljesthröm & Avalos (2015)
	Gymnoclytia sp.1 *Gymnoclytia* sp.2	Agostinetto *et al* (2018)
	Phasia sp.	Nunes *et al* (1998)
Dichelops melacanthus (Dallas)	*Cylindromyia brasiliana* (Townsend)	Panizzi & Corrêa-Ferreira (1997)
	Ectophasiopsis gradata (Wiedemann)	Dios & Nihei (2017)
	Trichopoda giacomelli (Blanchard)	Corrêa-Ferreira *et al* (2005)
Nezara viridula (L.)	*Gymnoclytia paulista* Townsend	Panizzi & Corrêa-Ferreira (1997)
	Ectophasiopsis arcuata (Bigot)	Jones (1988)
	Trichopoda giacomelli (Blanchard)	Nunes *et al* (1998), Liljesthröm & Avalos (2015)
Piezodorus guildinii (Westwood)	*Phasia* sp.	Corrêa-Ferreira *et al* (1998), Nunes *et al* (1998)
	Trichopoda giacomelli (Blanchard)	Nunes *et al* (1998)
Thyanta perditor (F.)	*Cylindromyia dorsalis* (Wiedemann) *Euthera barbiellinii* Bezzi	Corrêa-Ferreira *et al* (1998), Nunes *et al* (1998)
	Trichopoda giacomelli (Blanchard)	Panizzi & Herzog (1984), Nunes *et al* (1998)

mature seeds, whereas adults had a preference for immature seeds. This nymphal versus adult preference switch for seeds at different developmental stages is a common occurrence among phytophagous pentatomids (references in Panizzi 1997). Apparently, this change in food between phenological stages of development help bugs to achieve maximal reproductive performance.

In accordance with our field observations, Tomacheski *et al* (2019) observed that nymphs and adults *T. perditor* were unable to develop/reproduce when fed exclusively with inflorescences of black jack in laboratory studies. In addition, nymphs developed better on mature seeds compared to immature seeds of black jack. However, the authors observed that females exhibited a marked decrease in reproductive performance when fed with immature or mature seeds of black jack separately, but, when vegetative and reproductive structures were provided together, the performance substantially increased. Therefore, it is likely that *T. perditor* adults need plants of black jack carrying all vegetative and reproductive structures to provide all nutrients needed for them (Tomacheski *et al* 2019).

In conclusion, these laboratory studies, coupled with field observations, suggest that parasitism pressure tachinid flies play an important role in regulating populations of *T. perditor*, and that the red-shouldered stink bug relies on the presence of wild black jack plants, *B. pilosa* seeds to develop and reproduce.

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