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Efficacy of *Telenomus podisi* Ashmead, 1893 (Hymenoptera: Platygastridae) release for the control of *Euschistus heros* (Fabricius, 1794) (Hemiptera: Pentatomidae) eggs in soybean, in Brazil

Eficacia de la liberación de Telenomus podisi *Ashmead, 1893 (Hymenoptera: Platygastridae) para el control de huevos de* Euchistus heros *(Fabricius, 1794) en soja, en Brasil*

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ABSTRACT

This study aimed to assess the effectiveness of releases of different *amounts of Telenomus podisi* for the control of *Euchistus heros* in soybean crops. In addition, productivity was determined between treatments. The experiments were conducted in commercial areas of soybean production during the 2017/2018 crop season. The experiments were installed in three experimental areas in different locations of São Paulo state, Brazil; Pardinho (Farm Santa Fe), Tatuí (Farm Dos Lagos), and Angatuba (Farm Santa Irene). The experimental design was that of random blocks with five treatments and five repetitions. The statistical analysis of the experimental data applied was of variance homogeneity (Hartley Test), variance analysis (ANOVA), and Tukey's average discrimination test, at 5% of probability. The treatments evaluated were: T1- 2,000 eggs/ha; T2- 3,500 eggs/ha; T3- 5,000 eggs/ha; T4- 6,500 eggs/ha; T5- Control (Without *T. podisi* release). The release of adult parasitoids was carried out manually in the center of the plots. The parasitoid release interval was made from the presence of two nymphs or average adults *of E. heros* per linear meter, considering the end of the vegetative phase and physiological maturation. The sampling of nymphs and adults *of E. heros* were performed at weekly intervals (1, 7, 14, and 21 days) prior to the releases of *T. podisi.* The reduction in the number of nymphs and adults *of E. heros,* following the release of parasitoids was assessed.
Additionally, productivity between treatments was evaluated. The release of 6,500 *adults of T. podisi* significantly reduced the number of nymphs and *adults of E. heros* and showed to be more effective regarding other treatments. The productivity between the treatments evaluated did not show significant statistical differences.

Keywords: Applied biological control, egg parasitoids, integrated management of pests.

RESUMEN

Este estudio tuvo como objetivo evaluar la eficacia de las liberaciones de diferentes cantidades de Telenomus podisi *para el control de* Euschistus heros *en el cultivo de soya. Además, se determinó la productividad entre los tratamientos. Los experimentos fueron conducidos en áreas comerciales de producción de soya, durante el año agrícola 2017/2018. Los experimentos fueron instalados en tres áreas experimentales en diferentes localidades del estado de São Paulo, Brasil; Pardinho (Hacienda Santa Fé), Tatuí (Hacienda Dos Lagos) y Angatuba (Hacienda Santa Irene). El diseño experimental fue de bloques al azar con cinco tratamientos y cinco repeticiones. El análisis estadístico de los datos experimentales aplicado fue la homogeneidad de varianzas (Prueba de Hartley), el análisis de varianza (ANOVA) y la prueba de discriminación de medias de Tukey, al 5% de probabilidad. Los tratamientos evaluados fueron: T1- 2.000 huevos /ha; T2- 3.500 huevos/ha; T3- 5.000 huevos/ha; T4- 6.500 huevos/ha; T5- Control (Sin liberación de* T. podisi*). La liberación de los parasitoides adultos fue realizada manualmente, en el centro de las parcelas. El intervalo de liberación de los parasitoides se realizó a partir de la presencia de dos ninfas y/o adultos promedio de*

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E. heros por metro lineal, entre el final de la fase vegetativa y la maduración fisiológica. Los muestreos de ninfas y adultos de E. heros*, fueron realizados en intervalos semanales (1, 7, 14 y 21 días) previamente a las liberaciones de* T. podisi*. Se evaluó la reducción del número de ninfas y de adultos de* E. heros*, posterior a la liberación de los parasitoides. Además, se evaluó la productividad entre los tratamientos. La liberación de 6,500 adultos/ha de T. podisi redujo significativamente el número de ninfas y adultos de E. heros y fue más eficaz en relación a los otros tratamientos. La productividad entre los tratamientos evaluados, no presentaron diferencias estadísticas significativas entre sí.*

Palabras Clave: *Control biológico aplicado, parasitoides de huevos, manejo integrado de plagas.*

Introduction

In the sucking insect pest complex of the Pentatomidae family, *Euschistus heros* Fabricius, 1794 (Hemiptera: Pentatomidae) is considered vital, as it is the most abundant species in this complex and is found in all soybean-producing areas of Brazil, Argentina, Paraguay, Panama, Uruguay, and Bolivia (Bueno *et al*., 2015; Panizzi, 2013, 2015).

The main method employed by soybean farmers to control stink bug pests involves the use of synthetic pesticides. However, it is crucial to adopt integrated pest management (IPM) strategies (Higley and Peterson, 1996; Panizzi, 2013; Song and Swinton, 2009; Zalucki *et al*., 2009).

It is necessary to estimate the population levels of insects through reliable field sampling, based on which management decisions can be made to reduce the use of pesticides. The beating sheet method, which samples two adult stink bugs per linear meter for grains and one stink bug per linear meter for seeds, is recommended for monitoring the extent of stink bug infestation in soybean crops (Bueno *et al*., 2013; Pacheco and Corrêa-Ferreira, 1998; Panizzi and Oliveira, 1998; Panizzi and Slansky Jr., 1985; Peres and Corrêa-Ferreira, 2004; Tuelher *et al*., 2018).

For pest control, one should opt for an inter-and multidisciplinary view that integrates several methods of control that are less harmful to humans and the environment. Therefore, complementary tactics for successful insect pest control can be incorporated into the IPM system. One of the methods that has shown promising results in pest control is the use of biological control agents (Broglio-Micheletti *et al*., 2007; Bueno *et al*., 2011).

Among the various biological control agents for stink bug species, the species *Telenomus podisi* Ashmead, 1893 (Hymenoptera: Platygastridae) has been reported as the most effective egg parasitoid (Moreira and Becker, 1986; Medeiros *et al*., 1997; Sharkey, 2007; Stecca *et al*., 2017). Biological control of stink bugs in soybean crops has thus been considered through the release of *T. podisi* egg parasitoids.

Because of its high host search capacity *T. podisi* is a very promising biological control agent for stink bugs. It responds to different host cues in *E. heros*, such as *E. heros* sex pheromones, traces left on the substrate by *E. heros* females, herbivore-induced volatiles produced by soybean plants, vibratory signals produced during the sexual communication of *E. heros*, and the volatile phytorium (Z)-jasmone released by soybean plants. *T. podisi* is among the most abundant species, associated with greater than 80% parasitism of stink bug eggs in the field. In addition, it has other beneficial biological characteristics significant for biological control agents, such as having a low impact on human health, no interval between the release and harvest, no resistance to its parasitoid action, no phytotoxic damage, and no waste released into the environment (Corrêa-Ferreira, 1993; Michereff *et al*., 2014; Pazini *et al*., 2016; Sales *et al*., 1978; Tognon *et al*., 2014; van Lenteren *et al*., 2018).

In the United States, *T. podisi* has a higher demographic distribution than other parasitoids of pentatomid eggs, besides possessing the largest number of hosts, including *Euschistus* spp.; *Euchistus servus* Say, 1832; *Thyanta custator* accera McAtee, 1919; *Acrosternum hilare* Say, 1832; and *Nezara viridula* Linnaeus, 1758; pests in soybean and *Tibraca limbativentris* Stål, 1860: *Oebalus pugnax* Fabricius, 1775 and *Oebalus insularis* Stål, 1872 (Hemiptera: Pentatomidae) in rice (Ehler, 2002; Pacheco and Corrêa-Ferreira, 1998; Sudarsono *et al*., 1992; Tillman, 2010; Zachrisson *et al*., 2014a, 2014b).

In Brazil, several species are hosts of *T. podisi*. In addition to *E. heros*, *Piezodorus guildinii* (Westwood, 1837), and *N. viridula*, *T. podisi* was also reported to parasitize the eggs of *Tibraca limbativentris* Stål, 1860 (Riffel *et al*., 2010), *O. insularis* (Zachrisson *et al*., 2014b), *Dichelops melacanthus* (Dallas, 1851), *Dichelops furcatus* (Fabricius, 1775) (Paz-Neto *et al*., 2015), *Acrosternum aseadum* Rolston, 1983

(Sujii *et al*., 2002), the predatory stink bug *Podisis nigrispinus* (Dallas, 1851) (Medeiros *et al*., 1998), *Edessa meditabunda* (Fabricius, 1794) (Favetti *et al*., 2013), and *Podisus connexivus* Bergroth, 1891 (Hemiptera: Pentatomidae) (Corrêa-Ferreira and Moscardi, 1995).

Despite evidence indicating the potential of using egg parasitoids for controlling stink bugs, their use in biological control programs is still very limited due to the lack of studies aimed at understanding the efficacy of the large-scale release and use of these parasitoids in soybean plantations (Medeiros *et al*., 1997; Nascimento, 2011; Peres and Corrêa-Ferreira, 2004; Stecca *et al*., 2017).

Few studies have reported the use of *T. podisi* in the field and evaluated and created awareness about the natural parasitism of the parasitoid. Similar studies have been conducted on the parasitoid *Trissolcus basalis* (Wollaston, 1858) (Hymenoptera: Scelionidae), to control the *N. viridula* stink bug in soybean crops (Corrêa-Ferreira and Moscardi, 1996; Pacheco and Corrêa-Ferreira, 2000; Zachrisson *et al*., 2017).

Therefore, improving the use of *T. podisi* in managing the stink bug complex is of fundamental importance for the effective control of this pest in soybean crops. To this end, it is necessary to evaluate the effectiveness of releasing different quantities of *T. podisi* into soybean fields since release is a fundamental step in the commercial development of technological packages for using *T. podisi* in the biological control of pest stink bug complexes in soybean crops. The objective of this study was thus to evaluate the efficacy of releasing different amounts of *T. podisi* in the biological control of *E. heros* in soybean.

Materials and methods

Agronomic management and location of experimental areas

This work was carried out in commercial soybean production fields during the 2017/2018 harvest, with three experimental set-ups installed at three different locations in São Paulo, Brazil. Each set-up had an area of 25 ha, divided into five blocks of 5 ha, with a 1 ha plot of a block for each treatment, having 30 m borders. The Farm Santa Fe is located in the municipality of Pardinho, with an altitude of 930 m and coordinates 23º00'44.6 "S 48º22'51.5" W; Farm Dois Lagos is located in the municipality of Tatui, with an altitude of 660 m and coordinates 23º19'21.1" S 47º56'28.4" W; and the Farm Santa Irene is located in the municipality of Angatuba, with an altitude of 685 m and coordinates 23º31'27.4 " S 48º 33'46.1" W. Sowing was carried out in all areas using the no-tillage system, with management based on the IPM guidelines. The experimental areas are classified as basal subtropical wetland life zones and are predominantly located in the State of São Paulo, Brazil.

In the planting and management at Farm Santa Fe, sowing was carried out on October 20, 2017, using seeds of cultivar NS 5959 IPRO, with INTACTA RR2 PRO technology, under the trademark Nidera®. Industrially treated seeds (TSI) were inoculated with the Atmo® inoculant at an amount of 2.29 l ha^{-1} of the commercial product in the furrow at the time of sowing. The spacing was 0.50 m, with 13 seeds per linear meter. Fertilization was carried out at the time of sowing, with 17 kg ha^{-1} of the commercial formulation 07-40-00 (NPK) and 163 kg ha^{-1} of potassium chloride (KCl) for all treatments, depending on the soil chemical analysis. Four sprays were used for nutrition, disease management, control of invasive plants, and soybean desiccation at a flow rate of 40 l ha^{-1}.

In the planting and management at Farm Dois Lagos, sowing was carried out on October 18th, 2017, using seeds of cultivar M 5917 IPRO with INTACTA RR2 PRO technology, under the trademark Monsoy®. Industrially treated seeds (TSI) were inoculated with the Masterfix® inoculant, Stoller®, at an amount of 0.5 l ha^{-1} of the commercial product in the furrow at the time of sowing. The spacing was 0,50 m, with 14 seeds per linear meter. Fertilization was carried out at the time of sowing, with 250 kg ha^{-1} of the commercial formulation 08-40-00 (NPK) and 150 kg ha^{-1} of KCl for all treatments, depending on the soil chemical analysis. Five sprays were used for nutrition, disease management, control of invasive plants, and soybean desiccation at a flow rate of 200 l ha^{-1}. In the Farm Santa Irene, the planting, management, and sowing were carried out on November 15th, 2017, using seeds of cultivar DM 5958 IPRO with INTACTA RR2 PRO technology, under the trademark DonMario®. Industrially treated seeds (TSI) were inoculated with the Atmo® inoculant at an amount of 0.5 l h^{-1} of the commercial product in the furrow at the time of sowing. The spacing was 0.50 m, with 15 seeds

per linear meter. Fertilization was carried out at the time of sowing, with 160 kg ha^{-1} of the commercial formulation 10-48-00 (NPK), 150 kg ha^{-1} of KCl, and 60 kg ha^{-1} of urea for all treatments, depending on the soil chemical analysis. Five sprays were used for nutrition, disease management, control of invasive plants, and soybean desiccation at a flow rate of 200 l ha^{-1}.

Multiplication of the parasitoids for release in soybean fields

The *E. heros* adults were kept in plastic bins (35×25×15 cm) lined with filter paper. A piece of cloth (raw cotton) was placed in the bin to serve as a substrate for the stink bugs. For adult feeding, bean pods (*Phaseolus vulgaris Linnaeus*), horse peanuts (*Arachis hypogaea* Linnaeus), sunflower seeds (*Helianthus annuus* Linnaeus), and ligustro fruits (*Ligustrum lucidum* Ainton) were renewed each week. The pest eggs were withdrawn daily and offered to *T. podisi* females for parasitism. After parasitization, the eggs with 90% parasitism and 80% sex ratio of females were stored at 18 ºC ± 1 ºC, 70 ± 10% relative humidity, and 14 h photophase until the time of release.

One week before each release, parasitoids were removed from the heated chamber. The eggs were then transferred to plastic bags (25×35 cm) that had received droplets (0.05 mL) of 100% honey via a brush to feed the adults. For separation of the released parasitoids, the eggs were measured by volume, such that a 1 mL volume containing 1,000 parasitized eggs of *E. heros* was divided into plastic bags, representing the various treatments. The treatments were divided into five groups: (1) T1 with 2,000 eggs ha^{-1}; (2) T2 with 3,500 eggs ha^{-1}; (3) T3 with 5,000 eggs ha^{-1}; (4) T4 with 6,500 eggs ha^{-1}; and (5) T5 as the control without release. After separation of treatments, the parasitoids were kept in an air-conditioned room at 25 ± 1 ºC, 70 ± 10% relative humidity, and a 14 h photophase to allow for the emergence of adults before field release.

Release of *Telenomus podisi* for the control of *Euchistus heros*

The release of parasitoids occurred when the first *E. heros* individuals were found in the samples. To follow this release, the population of stink bugs was monitored in the three experimental set-ups from the end of the vegetative phase until physiological maturation (R6).

Sampling was conducted using the beating sheet method (1×1 m) to count stink bug nymphs and adults. In each plot of the experimental set-ups, four samplings were performed before the release at 7, 14, and 21 days after the first release through zigzag walking to cover 20 points. In each sample, the total number of nymphs and adults of *E. heros* was recorded. When an average of two stink bugs were sampled per meter in all plots of the experimental areas, the adult parasitoids were released.

The release of the adult parasitoids was performed manually by walking across the center of the plots, forming a circumference with a 15 m radius. The release was concentrated toward the centers of the plots, at which a flag was fixed for signaling each plot after considering the dispersion capacity of *T. podisi*. Three releases were performed at 0, 7, and 14 days after the previous round of one release per plot/treatment.

Productivity of the treatments in experimental areas

Harvesting was performed manually along the central lines upon the maturation of soybean crops. Two samplings of 1 m^2 each for a total of six linear meters were performed with the aid of a polyvinyl chloride board to delineate the harvest area. The soybean was threshed with the aid of a forklift attached to the power cord of a tractor and manually separated from the rest of the straw by sifting. The final yield (kg ha^{-1}) and mass of 1,000 grains were adjusted for 13% humidity according to the following equation: $Pc = Pb\ (100 - Ur)/100^{-13}$. Where: Pc = Corrected sample weight at 13% moisture, Pb = Gross weight of the sample, and Ur = Sample moisture at the time of weighing.

Sample masses were measured using a digital scale (Toledo®) with 0.002 kg precision and humidity using the "Gehaka AGRI" model G929®.

Experimental design and statistical analysis

The experimental design consisted of randomized blocks with five treatments and five replicates. The results were subjected to exploratory analysis to evaluate the normality assumptions of the residues, homogeneity of the treatment variance (Hartley test), and the additivity of the model to allow an analysis

of variance. Subsequently, means were compared using Tukey's test ($P < 0.05$). The control efficacy was also calculated for each treatment using the Abbott mean (1945).

Results

Efficacy of the release of *Telenomus podisi* for the biological control of *Euchistus heros* in experimental soybean-containing areas

The treatments and the control did not differ statistically among the three evaluated areas, with initial sampling between 0.16 and 0.33 stink bug/m^2. From these results, it can be seen that the Farm Santa Fe crop had an upward trend in the *E. heros* population from the beginning till the end of the sampling period. In one month, the population of the pest increased threefold, from 0.25 stink bug/m^2 at the beginning of soybean filling to 4.72 stink bug/m^2 at the end of physiological maturation.

One week after the first release, only treatment with 6,500 parasitoids presented a statistical difference compared to the control. The efficacy of the parasitism caused by the *T. podisi* species in *E. heros* was constant in the first three samplings and reached 91.12% in the second sampling; 82.63% coincided with the stink bug population in the area of 4.72 stink bug/m^2. The other treatments were insufficient to keep the stink bug population below the control level (Table 1).

At Farm Dois Lagos, the population levels of stink bugs were lower than those at Farm Santa Fe, but an increase in the population of stink bugs from the beginning of the sampling period till the end was observed. The insect pest population increased from 0.23 stink bug/m^2 at the R5 stage of soybean to 3.38 stink bug/m^2 at the end of the R6 stage. One week after the first release, there was no significant difference between treatments involving 5,000 and 6,500 parasitoids ha^{-1}, but these treatments differed from the other treatments, with parasitism efficacies of 78.29% and 85.39%, respectively. However, from the second release until the last evaluation, only the treatment with 6,500 *T. podisi* parasitoids ha^{-1} differed significantly from the other treatments, with a parasitism efficacy of 85.39% (Table 1).

The tendency seen in the previous areas was also observed at Farm Santa Irene; however, despite the population growth of the stink bugs, the infestation was lower, with 0.30 stink bug/m^2 at the beginning of the evaluation and at the end 2.81 stink bug/m^2. After the first release, all treatments presented significant differences compared to the control but did not differ significantly from each other. However, this observation was not repeated in the evaluation after the second release, in which only the treatments with 5,000 and 6,500 parasitoids ha^{-1} differed statistically from the other treatments, with control efficacies of 77.60% and 85.20%, respectively (Table 1).

In the last evaluation, only the treatment with 6,500 parasitoids ha^{-1} differed significantly from the other treatments, while the efficacy of the control was maintained above 75%, thus reproducing the observation that was seen in the previous areas.

Productivity in experimental areas during the 2017/18 crop season

The productivity in kg ha^{-1} and bags ha^{-1} for the treatments was similar, with no significant differences among them (Table 2). However, despite the productivity of the treatments, the yields were quite satisfactory. At Farm Santa Fe and Santa Irene, the average productivity was shown to be similar to that of the State of Sao Paulo, which was 3,676 kg ha^{-1} and 61.25 bags ha^{-1} (CONAB, 2018). At Farm Dois Lagos, the average productivity surpassed that of the State of São Paulo, at 5,365 kg ha^{-1} and 9,065 bags ha^{-1} (Table 2).

Discussion

The differences in the efficacy of the *T. podisi* parasitoid in the different areas assessed in this study can be explained by the behavior of *T. podisi* in parasitizing the eggs of several species of bugs. However, the efficacy of 6,500 parasitoids ha^{-1} for controlling the *E. heros* population was below that for controlling the populations of other stink bugs, such as *D. furcatus*, *P. guildinii*, and *E. servus*, which were present in all the areas assessed, with an incidence of 75% (91%) (Table 1) (Abreu *et al*., 2015; Pacheco and Corrêa-Ferreira, 1998).

In general, treatment with 6,500 parasitoids ha^{-1} can control stink bugs and was the only treatment that presented differences in all analyzed parameters and between all the areas evaluated under different edaphoclimatic conditions. This finding confirmed that this number of parasitoids is suitable for soybean-IPM.

Table 1. Mean number of nymphs and adults of *Euschistus heros* and total number of bugs prior to release, 1SAL[1]; 2SAL[2]; 3SAL[3], one week after the release of *Telenomus podisi* in soybean crop.

	Farm Santa Fe			Farm Dois Lagos			Farm Santa Irene		
Treatments ha^{-1}	Nymphs Pr	Adults Pr	Total Pr	Nymphs Pr	Adults Pr	Total Pr	Nymphs Pr	Adults Pr	Total Pr
2.000 *T. podisi*	0.01 ± 0.01 ns	0.18 ± 0.02 ns	0.19 ± 0.02 ns	0.03 ± 0.02 ns	0.11 ± 0.02 ns	0.16 ± 0.04 ns	0.02 ± 0.01 ns	0.31 ± 0.03 ns	0.33 ± 0.03 ns
3.500 *T. podisi*	0.03 ± 0.03	0.13 ± 0.04	0.17 ± 0.05	0.09 ± 0.09	0.11 ± 0.03	0.22 ± 0.09	0.03 ± 0.03	0.24 ± 0.04	0.27 ± 0.05
5.000 *T. podisi*	0.03 ± 0.02	0.19 ± 0.04	0.23 ± 0.04	0.10 ± 0.08	0.10 ± 0.04	0.22 ± 0.07	0.02 ± 0.02	0.26 ± 0.08	0.32 ± 0.06
6.500 *T. podisi*	0.01 ± 0.01	0.17 ± 0.01	0.19 ± 0.02	0.04 ± 0.01	0.13 ± 0.05	0.18 ± 0.04	0.01 ± 0.01	0.24 ± 0.04	0.27 ± 0.05
Control wr	0.05 ± 0.04	0.15 ± 0.05	0.17 ± 0.06	0.13 ± 0.06	0.14 ± 0.06	0.23 ± 0.08	0.03 ± 0.03	0.29 ± 0.08	0.30 ± 0.07
CV (%)	4.98	6.27	6.31	10.8	7.36	10.2	4.57	8.62	7.78

Farm Santa Fe

Treatments ha^{-1}	Nymphs 1SAL	E%	Adults 1SAL	E%	Total 1SAL	E%	Nymphs 2SAL	E%	Adults 2SAL	E%	Total 2SAL	E%	Nymphs 3SAL	E%	Adults 3SAL	E%	Total 3SAL	E%
2.000 *T. podisi*	1.66 ± 0.25 b	2.35	1.09 ± 0.23 c	48.34	2.76 ± 0.34 bc	22.91	1.87 ± 0.10 b	–38.52	1.47 ± 0.36 b	28.29	3.50 ± 0.35 bc	18.22	2.43 ± 0.20 b	1.62	2.95 ± 0.22 c	6.35	5.38 ± 0.34 b	–13.98
3.500 *T. podisi*	1.70 ± 0.24 b	0.00	1.92 ± 0.15 c	9.00	3.62 ± 0.32 c	–1.12	1.63 ± 0.20 b	–20.74	1.99 ± 0.15 b	2.93	3.71 ± 0.25 c	13.32	2.32 ± 0.13 b	6.07	2.84 ± 0.25 bc	9.84	5.17 ± 0.38 b	–9.53
5.000 *T. podisi*	1.05 ± 0.06 b	38.24	1.15 ± 0.10 b	45.50	2.22 ± 0.13 b	37.99	1.20 ± 0.11 b	11.11	1.38 ± 0.07 b	32.68	2.66 ± 0.18 b	37.85	1.81 ± 0.14 b	26.72	2.02 ± 0.27 b	35.87	3.83 ± 0.34 b	18.86
6.500 *T. podisi*	0.17 ± 0.06 a	90.00	0.21 ± 0.05 a	90.05	0.38 ± 0.08 a	89.39	0.22 ± 0.02 a	83.70	0.08 ± 0.05 a	96.10	0.38 ± 0.06 a	91.12	0.60 ± 0.10 a	75.71	0.22 ± 0.05 a	93.02	0.82 ± 0.09 a	82.63
Control wr	1.70 ± 0.39 b		2.11 ± 0.18 d		3.58 ± 0.55 c		1.35 ± 0.35 b		2.05 ± 0.52 b		4.28 ± 0.16 c		2.47 ± 0.21 b		3.15 ± 0.15 c		4.72 ± 1.11 b	
CV (%)	15.03		10.19		11.77		14.01		20.21		7.4		7.58		8.48		17.35	

Farm Dois Lagos

Treatments ha^{-1}	Nymphs 1SAL	E%	Adults 1SAL	E%	Total 1SAL	E%	Nymphs 2SAL	E%	Adults 2SAL	E%	Total 2SAL	E%	Nymphs 3SAL	E%	Adults 3SAL	E%	Total 3SAL	E%
2.000 *T. podisi*	0.84 ± 0.04 b	32.26	1.37 ± 0.08 d	11.61	2.22 ± 0.06 b	32.11	1.31 ± 0.07 b	8.39	1.25 ± 0.03 c	19.35	2.64 ± 0.11 c	25.84	1.42 ± 0.03 b	25.26	1.52 ± 0.02 c	28.64	3.03 ± 0.09 b	10.36
3.500 *T. podisi*	0.75 ± 0.06 b	39.52	0.98 ± 0.04 c	36.77	1.75 ± 0.08 b	46.48	1.15 ± 0.11 b	19.58	1.04 ± 0.09 bc	32.90	2.32 ± 0.12 bc	34.83	1.48 ± 0.10 b	22.11	1.62 ± 0.15 cd	23.94	3.11 ± 0.17 b	7.99
5.000 *T. podisi*	0.17 ± 0.03 a	86.29	0.52 ± 0.02 b	66.45	0.71 ± 0.04 a	78.29	0.48 ± 0.13 a	66.43	0.30 ± 0.07 ab	80.65	0.92 ± 0.17 ab	74.16	0.35 ± 0.06 a	81.58	0.97 ± 0.11 b	54.46	1.42 ± 0.20 ab	57.99
6.500 *T. podisi*	0.13 ± 0.04 a	89.52	0.29 ± 0.05 a	81.29	0.46 ± 0.04 a	85.93	0.23 ± 0.05 a	83.92	0.24 ± 0.06 a	84.52	0.52 ± 0.05 a	85.39	0.25 ± 0.06 a	86.84	0.42 ± 0.07 a	80.28	0.75 ± 0.13 a	77.81
Control wr	1.24 ± 0.26 b		1.55 ± 0.10 d		3.27 ± 0.46 c		1.43 ± 0.28 b		1.55 ± 0.41 c		3.56 ± 0.17 c		1.90 ± 0.09 c		2.13 ± 0.20 d		3.38 ± 0.87 b	
CV (%)	12.18		4.84		9.6		12.65		16.41		19.08		5.28		7.38		19.29	

Farm Santa Irene

Treatments ha^{-1}	Nymphs 1SAL	E%	Adults 1SAL	E%	Total 1SAL	E%	Nymphs 2SAL	E%	Adults 2SAL	E%	Total 2SAL	E%	Nymphs 3SAL	E%	Adults 3SAL	E%	Total 3SAL	E%
2.000 *T. podisi*	0.01 ± 0.01 a	98.11	0.85 ± 0.14 ab	18.27	0.86 ± 0.14 ab	42.28	1.34 ± 0.21 b	–22.94	1.48 ± 0.20 c	–40.95	2.82 ± 0.38 b	–12.80	0.70 ± 0.26 a	61.26	0.86 ± 0.27 b	50.32	1.61 ± 0.53 ab	42.82
3.500 *T. podisi*	0.02 ± 0.02 a	96.23	0.68 ± 0.10 ab	34.62	0.70 ± 0.12 a	53.02	0.96 ± 0.20 b	11.93	1.07 ± 0.12 bc	–1.90	2.03 ± 0.29 b	18.80	1.20 ± 0.24 a	33.70	1.18 ± 0.19 ab	32.47	2.39 ± 0.37 ab	15.04
5.000 *T. podisi*	0.01 ± 0.01 a	98.11	0.50 ± 0.13 a	51.92	0.52 ± 0.13 a	65.10	0.13 ± 0.06 a	88.07	0.41 ± 0.08 ab	60.95	0.56 ± 0.10 a	77.60	0.66 ± 0.29 a	63.54	0.49 ± 0.15 ab	71.84	1.19 ± 0.41 ab	57.65
6.500 *T. podisi*	0.01 ± 0.01 a	98.11	0.42 ± 0.03 a	59.62	0.45 ± 0.04 a	69.80	0.10 ± 0.02 a	90.83	0.26 ± 0.04 a	75.24	0.37 ± 0.04 a	85.20	0.39 ± 0.05 a	78.45	0.28 ± 0.05 a	83.91	0.70 ± 0.09 a	75.09
Control wr	0.53 ± 0.15 b		1.04 ± 0.13 b		1.49 ± 0.30 b		1.09 ± 0.35 b		1.05 ± 0.30 bc		2.50 ± 0.38 b		1.81 ± 0.13 b		1.74 ± 0.11 c		2.81 ± 0.71 b	
CV (%)	9.59		10.11		12.75		18.66		14.81		13.26		16.85		12.44		25.41	

[ns] Non-significant according to Tukey test (P <0.05), [1]Pr Preview beforehand (before release), [2]wr without release, [3]1SAL one week after 1st release, [4]2SAL one week after 2nd release, [5]3SAL one week after 3rd release, [6]Means followed by the same letters in the column do not differ statistically from each other by Tukey test (P <0.05), E% Abbott control efficacy.

Table 2. Mean values of productivity of soybean at different management tactics and different amounts of *T. podisi* release. Experimental areas from the 2017/18 harvest, Farm Santa Fe (Pardinho), Farm Dois Lagos (Tatui), and Farm Santa Irene (Angatuba), São Paulo, Brazil, 2018.

Treatments há$^{-1}$	Farm Santa Fe		Farm Santa Irene		Farm Dois Lagos	
	Productivity Kg ha^{1}	Bags ha^{1}	Productivity Kg ha^{1}	Bags ha^{1}	Productivity Kg ha^{1}	Bags ha^{1}
2.000 *T. podisi*	3654.32 ± 187.08 ns	64.91 ± 2.50 ns	3909.91 ± 228.60 ns	68.50 ± 3.94 ns	5520.47 ± 241.28 ns	91.61 ± 0.94 ns
3.500 *T. podisi*	3814.15 ± 164.52	64.90 ± 2.88	3985.82 ± 248.06	60.43 ± 5.96	5341.91 ± 380.92	91.83 ± 1.78
5.000 *T. podisi*	3954.16 ± 108.31	65.90 ± 1.81	3989.68 ± 134.60	65.49 ± 2.45	5365.30 ± 86.29	90.75 ± 0.87
6.500 *T. podisi*	3729.14 ± 123.11	62.15 ± 2.05	3677.91 ± 159.17	61.30 ± 2.65	5353.09 ± 300.60	90.55 ± 4.51
Control wr	3889.04 ± 177.85	62.82 ± 1.99	3916.42 ± 366.12	73.61 ± 2.73	5459.57 ± 490.22	90.99 ± 8.17

ns Non-significant according to F test ($P < 0.05$), wr- without release.

For choosing the numbers of parasitoids for this study, we considered the logistics for parasitoid production and delivery in the production areas. According to previous studies, the amount of *T. podisi* recommended for controlling *E. heros* in soybean crops is 5,000 parasitoids ha^{-1} in three releases (Simonato *et al*., 2014; Broglio-Micheletti *et al*., 2007). However, the highest efficacy of this recommendation was not confirmed in this study, which indicated that the appropriate number of parasitoids to be released is 6,500.

The productivity between the treatments evaluated did not show significant statistical differences between them. The agronomic management used to install experimental plots could explain the results, mainly the control treatment (without parasitoid release). In field conditions, it is difficult to control the variables that can influence the productivity of experimental plots, considering the possible migration of the insect-pest complex and egg parasitoid species from the shelter areas located on the edges of the crop to the soybean.

Recognizing the potential of *T. podisi* in the biological control of *E. heros* in soybean crops still needs validation to enable registration with the Ministry of Agriculture, Livestock and Food Supply (MAPA) to justify and legalize the use of this relevant biological control agent in soybean crops for the control of *E. heros*.

Conclusion

The release of 6,500 parasitoid ha^{-1} of *T. podisi* has a significant impact on the control of *E. heros*. Thus, this amount of this parasitoid egg release confirmed the efficacy of keeping the population of stink bugs below the action level proposed by the soybean-IPM.

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