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IPM in soybeans: how to reduce crop damage and increase profit for the farmer

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ABSTRACT

The objective of the present work was to implement integrated pest management (IPM) in the soybean crop, comparing it with the management carried out by the farmer during two consecutive seasons. The monitoring of adult lepidopterans was also evaluated using Delta-type traps baited with the sexual pheromones of *Spodoptera frugiperda* (Bio Spodotera®), *Helicoverpa armigera* (Bio Helicoverpa®) and *Chrysodeixis includens* (Bio Pseudoplusia®). Incidence of caterpillars and stinkbugs in soybeans was weekly determined, both in the IPM area and in the farmer, area using the beat cloth method. Insecticide applications in the IPM area were carried out when pest population densities reached the control level, while in the area managed by the farmer, sprayings were carried out at his discretion. Based on the results obtained, we found that adoption of IPM enabled better control of the pests in soybeans, especially for stink bugs, and the number of insecticide applications in soybeans could be reduced, which provides economic and environmental benefits for the farmer. In addition, we found that the sexual pheromones of the three evaluated pest species are effective in capturing their moths.

Keywords: Caterpillars, Stink bugs, Insecticide, Sexual pheromone, Entomopathogens fungi.

MIP na soja: como reduzir os danos à cultura e aumentar o lucro do agricultor

RESUMO

Objetivou-se neste trabalho implementar o manejo integrado de pragas (MIP) na cultura da soja, comparando-se com o manejo realizado pelo produtor, durante duas safras consecutivas. Avaliou-se também o monitoramento de lepidópteros adultos, utilizando armadilhas do tipo Delta iscadas com os feromônios sexuais de *Spodoptera frugiperda* (Bio Spodotera®), *Helicoverpa armigera* (Bio Helicoverpa®) e *Chrysodeixis includens* (Bio Pseudoplusia®). Determinou-se a incidência semanal de lagartas e de percevejos na soja, tanto na área do MIP quanto na área do produtor, utilizando-se o pano de batida. As aplicações de inseticidas na área do MIP foram realizadas quando as densidades populacionais das pragas atingiam o nível de controle, enquanto na área manejada pelo produtor, as pulverizações foram realizadas a seu critério. Diante dos resultados obtidos, foi constatado que a adoção do MIP possibilitou melhor controle dos insetos-praga na soja, especialmente de percevejos fitófagos e que o número de aplicações de inseticidas na cultura da soja poderia ser reduzido, o que traz benefícios econômicos e ambientais para o produtor. Em adição constatamos que os feromônios sexuais das três espécies de pragas avaliadas são eficazes na captura das suas mariposas.

Palavras-chave: Lagartas, Percevejos, Inseticida, Feromônio sexual, Fungos entomopatógenos.

1. Introduction

The soybean *Glycine max* (L.) crop can be attacked by insect pests from sowing to the grain maturation phase, characterizing itself as one of the main factors limiting its economic production. (Tomquelski and Martins, 2011; Panizzi et al., 2012).

The initial pests that occur in soybean crops are soil pests, such as different species of whitgrubs (Scarabaeoidea) (Coleoptera) and the brown stink bug (*Scaptocoris castanea*) (Perty, 1830) (Hemiptera: Cydnidae). Next, surface pests appear that attack soybean seedlings, such as the black cutworm (*Agrotis ipsilon*) (Hufnagel, 1766) (Lepidoptera: Noctuidae), lesser cornstalk borer (*Elasmopalpus lignosellus*) (Zeller, 1848) (Lepidoptera: Pyralidae), snails and slugs (Oliveira et al., 2012; Hoffmann-Campo et al., 2012) and the larvae and adults of stalk weevil (*Sternechus subsignatus*) (Boheman 1836) (Coleoptera: Curculionidae), which cause injuries to plants and stand reduction in the crop (Hoffmann-Campo et al., 2012).

Starting at the V3 growth stage (3rd open trefoil), normally the presence of defoliating insects such as rootworm (*Diabrotica speciosa*) (Germar, 1824) and *Cerotoma* sp. (Coleoptera: Chrysomelidae) and later, caterpillars that feed on leaves, flowers and pods, such as the velvetbean (*Anticarsia gemmatalis*) (Hübner, 1818) (Lepidoptera: Erebidae), soybean looper (*Chrysodeixis includens*) (Walker, 1858), *Helicoverpa armigera* (Hübner, 1808) and the *Spodoptera* complex (Lepidoptera: Noctuidae) (Moscardi et al., 2012). Already in the reproductive phase, phytophagous insects appear that attack the grains in formation, such as the *Nezara viridula* (Linnaeus 1758), *Piezodorus guildinii* (Westwood, 1837), *Euschistus heros* (Fabricius, 1798), *Diceraeus melacanthus* (Dallas, 1851) and *Edessa meditabunda* (Fabricius, 1794) (Hemiptera: Pentatomidae) (Panizzi et al., 2012; Ávila and Grigolli, 2014). At this time, other insects such as whitefly may also occur (*Bemisia tabaci*) (Gennadius, 1889) (Hemiptera: Aleyrodidae), which sucks the sap from plants, causes sooty mold and transmits viruses (Moscardi et al., 2012).

At the beginning of the 1980s, an average of five insecticide applications was carried out on soybeans/crops to control pests, decreasing to less than two per crop when integrated pest management (IPM) was implemented in the cultivation (Bueno et al., 2012). However, the benefits provided by the IPM in the soybean cultivation suffered a major setback in the last decade since the producer practically abandoned the principles of the IPM, returning to carrying out up to six insecticide applications per season (Morales and Silva, 2006). Currently, insecticide applications in crops have been carried out preventively, together with the post-emergent desiccant herbicide or with fungicides, aiming to take advantage of operations, especially in the initial phase of crop development and generally using broad-spectrum products (Bueno et al., 2012). Therefore, it is important that the IPM-Soy bean program is resumed, following its basic principles applied in the cultivation (Hoffmann-Campo et al., 2000).

The IPM's main objective is to adopt control strategies that aim to keep the insect pest population below the level of economic damage to crops. (Kogan, 1998). The success of implementing IPM in soybeans will depend on the information and control tactics available to be used. (Ávila and Santos, 2018). For example, in pest control, insect-resistant or tolerant cultivars, selective chemical insecticides and biological insecticides can be used, always considering economic, ecological and social criteria. (Carvalho and Barcellos, 2012; Corrêa-Ferreira et al., 2013). In view of the above, the objective of the present work was to implement the management of insect pests present in soybean crops following the principles and philosophy of IPM.

2. Material and Methods

The study was conducted in the field at the “Pica Pau” Farm (S 22º10'41”, W 54º31'27”), located in the municipality of Dourados/MS during the 2018/2019 and 2019/2020 seasons in two distinct areas of management. In an area of 20 hectares, pest management was carried out following the principles of IPM, while in another area of 25 hectares, management was carried out according to the producer's criteria. In the 2018/2019 season, the two soybean areas (IPM and producer) were sown with the Bt cultivar (BMX Garra IPRO), while in the 2019/2020 season, the conventional Syn 1163 RR cultivar was used.

Soybean seeds, sown in both areas, were previously treated with *Bradyrhizobium japonicum*, in addition to the fipronil insecticide at a dose of 62.5 g a.i./100 kg of seeds to control the initial pests. Soybean crops were sown in direct planting areas with a spacing of 0.5 m between rows. In the 2018/2019 season, the area destined for the implementation of the IPM contained crop residues of second-crop corn, while in the producer's area of responsibility, the crop residues present were wheat, both cultivated in 2018. In the 2019/2020 season, both the IPM and producer areas had been cultivated with corn from the second season in 2019.

To monitor the adult Lepidoptera in soybean crops, Delta-type traps were installed, supplied by the Biocontrole®company at three distinct points within the IPM and producer area, which contained the sexual pheromones of *Spodoptera frugiperda* (Bio Spodotera®), *Helicoverpa armigera* (Bio Helicoverpa®)

and *Chrysodeixis includens* (Bio Pseudoplusia®), separately in each trap. The septa containing the sex pheromone were replaced every 21 days and the adhesive floors used to capture the moths were collected weekly, at which point the captured moths were quantified and identified by species.

After the V3 phenological stage (3 trefoils), weekly monitoring of caterpillars and stink bugs in the crop began in both the IPM and producer areas. For this, a beating cloth with dimensions of 1m x 1m was used, carrying out 10 random beats in each environment, totaling 13 evaluation periods until the soybean maturation phase. If the population density of caterpillars reached 20 caterpillars (large + small) or 2 stink bugs (adults + nymphs > 5 mm) per meter of soybean row (control levels), insecticides were applied in the IPM area.

In the area managed by the producer, insecticide applications on soybeans were carried out according to the farm's criteria. Insecticide applications in both areas (IPM and producer) were carried out with a drag bar sprayer driven by a tractor equipped with fan nozzles, spaced 50 cm apart on the bar and releasing a volume of spray solution of 90 L/ha. The sampling values of caterpillars and stink bugs from the IPM area and the producer were statistically compared using the T test with a 5% probability of error since there were only two treatments.

For the economic analysis of pest management in the two areas studied (IPM and producer area), the prices of chemical and biological insecticides/hectare used in the two management systems were quoted. In addition to the costs of insecticides, there are currently also the costs of labor and product spraying on crops. The economic analysis was carried out by comparing the costs/hectare in the two management areas and, subsequently, extrapolating the benefits to the total area of soybeans cultivated on the producer's farm.

3. Results and Discussion

Regarding the collection of moths in traps, it turns out that in the 2018/2019 season, moths of the three species in which their sexual pheromones were used were collected, both in the IPM and producer areas (Figure 1). However, there was a predominance of capture of *S. frugiperda* in comparison to *C. includens* and *H. armigera* in the IPM area, observing two peaks of occurrence of this pest during the capture period (Figure 1). This probably occurred due to the previous cultivation of second-crop corn in the area, which led to a greater occurrence of fall armyworm moths that would previously have been developing in this crop. The largest population of *H. armigera* moths at the beginning of the 2018/2019 season in the producer's area (Figure 1), probably occurred because this pest was developing in the wheat grown before the soybeans. The lower incidences of *C. includens* and *H. armigera* moths compared to the *S. frugiperda* during soybean cultivation in the 2018/2019 season were presumably due to the toxic action of Bt soybean plants on the caterpillars of these two species, while for the fall armyworm, this effect was not observed because this species is resistant to this Bt toxin (Farias et al., 2014).

During the 2019/2020 season, there was again a significant predominance of *S. frugiperda* adults in relation to the other two moth species, both in the IPM area and in the area managed by the producer, however, without the occurrence of typical capture peaks (Figure 1). During the collection period, around 600 moths were captured in pheromone traps in the IPM and producer areas. This greater occurrence of *S. frugiperda* moths is probably explained by the previous occurrence of this pest in corn grown before soybean sowing, as well as by the lack of effect of Bt soybeans on the caterpillars of this species. (Bernardi et al., 2014; Bueno and Silva, 2016). A low occurrence of *C. includens* and *H. armigera* moths was found in this soybean season, although a conventional soybean cultivar was used in this season (Figure 1).

Monitoring moth adults with sex pheromone traps constitutes an alternative that can be used as an indicator of the presence or even to estimate the population density of the immature stages (eggs and caterpillars) of the pest in the field (Arn, 1990). Regarding the occurrence of insect pests in soybean crops, during the 2018/2019 and 2019/2020 seasons, it was found that the population densities of caterpillars did not reach the NC of 20 caterpillars/m² of soybean row, both in the IPM area and soybean managed by the producer (Figure 2).

In the 2018/2019 season, the caterpillars of the *A. gemmatalis*, *C. includens* and *H. armigera* species found in the samples were small and had a low occurrence, probably due to the toxic action of Bt soybean plants. Ávila and Santos (2018) also found that the adoption of Bt soybean plants, associated with natural biological control, reduced the incidence of caterpillars in soybean crops. Conte et al. (2016) also argued that the first generation of Bt soybeans (Intacta RR2 PRO TM) controls the false gauge caterplillar (*C. includens*), the soybean caterpillar (*A. gemmatalis*), the cotton apple caterpillar (*C. virescens*) and causes suppression in *H. armigera*. However, that technology does not control the caterpillars of the *Spodoptera* spp. group (Bueno and Silva, 2016), as was also found in the present work.

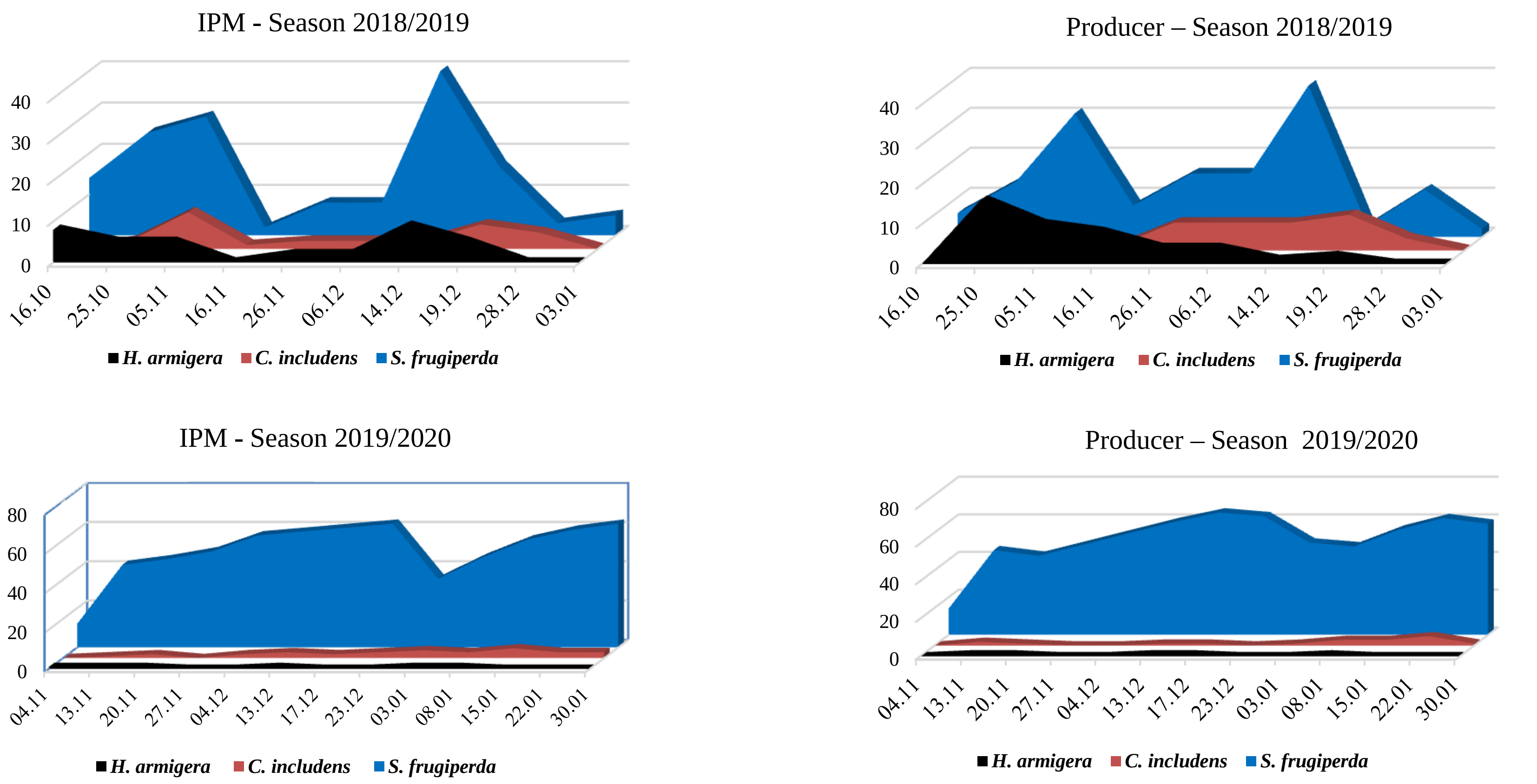

Figure 1. Average number of moths captured in traps baited with sexual pheromones from *Helicoverpa*, *Chrysodeixis includens* and *Spodoptera frugiperda* in the IPM and Producer soybean areas during the 2018/2019 and 2019/2020 Seasons. Dourados, MS

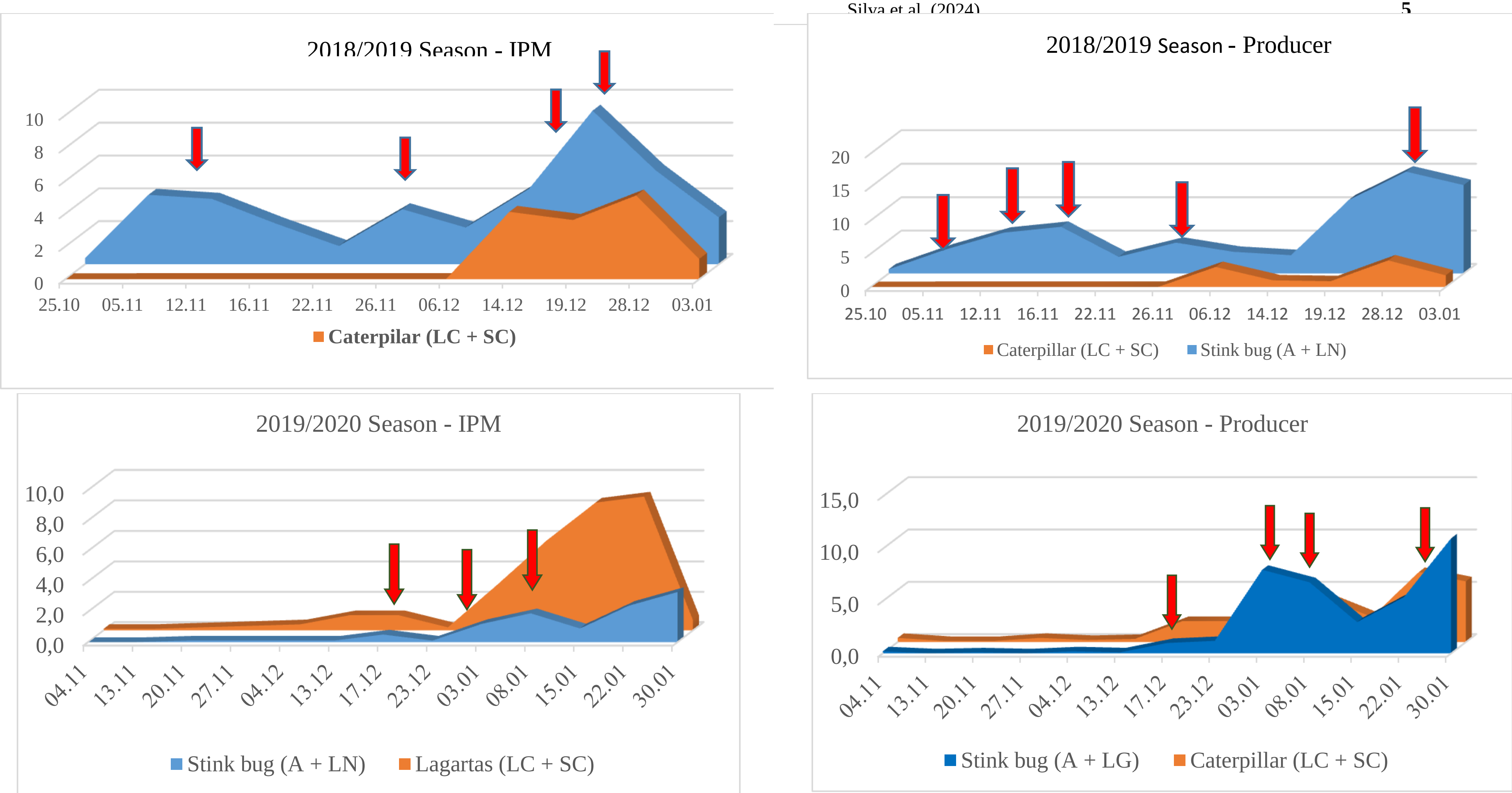

Figure 2. Occurrence of stink bugs (adults-A + large nymphs-LN) and caterpillars (large-LC + small-SC) per meter of soybean row at different evaluation times in the IPM-Soy and Producer area. Seasons of 2018/19 and 2019/20. Dourados, MS. ⬇ = Applications of insecticides in soybeans to control insect pests.

In the 2019/2020 season in which conventional soybeans were used, the low incidence of caterpillars in the crop (Figure 2) can probably be explained by the accentuated use of Bt soybeans in crops in the Dourados region since producers in their almost totality, use soybean cultivars with intact technology. Most of the remaining caterpillars (small and large) were of *S. frugiperda*, which also corroborates the higher incidence of moths captured both in the IPM and producer areas (Figure 1). The highest incidence of caterpillars this season was once again the *S. frugiperda*, which confirms the high population of moths of this species captured in the pheromone traps.

Ávila and Souza (2017) also found that *A. gemmatalis* and *C. includens* caterpillars occurred in soybean monitoring work, with the first observed with greater intensity in the vegetative phase of soybeans and the second with greater predominance in the reproductive phase. Conte et al. (2015) observed in their soybean IPM area that the *C. includens* species had a higher occurrence than the *A. gemmatalis*, while Conte et al. (2016) observed a higher incidence of *A. gemmatalis* in soybean crops compared to the *C. includens* caterpillars and the *Spodoptera* spp. complex.

The population density of phytophagous stink bugs reached the NC (2 stink bugs/m of soybean row), in five evaluation periods in the IPM area during the 2018/2019 season (Figure 2). As a result, four applications of chemical insecticides were carried out on soybeans with the addition of salt (NaCl). In the first application, acephate was used (1 kg/ha + 0.5% salt), in the second and third thiamethoxam + lambdacyhalothrin (0.3 L/ha + 0.5% salt) and in the fourth fenpropathrin (0.4 L/ha + 0.5% salt), ending the last assessment carried out for stink bugs below the NC (Figure 2). In the area managed by the producer, the population density of stink bugs reached NC in six periods during the evaluations (Figure 2).

As a result, the producer carried out five insecticide applications on soybeans this season, the first with thiamethoxam + lambdacyhalothrin (0.3 L/ha), the second with acetamiprid + fenpropathrin (0.7 L/ha), the third with thiamethoxam + lambdacyhalothrin (0.3 L/ha), the fourth with acephate (1.1 kg/ha + 0.5% salt) and the fifth with fenpropathrin (0.4 L/ha + 0.5% salt), finishing the last two assessments with a stink bug population density well above the NC (Figure 2).

In the 2019/2020 season, the population of phytophagous stink bugs in the IPM area was close to or reached the NC in two assessment periods. However, three applications of microbial insecticides were carried out, the first being sprayed with the entomopathogenic fungus *Beauveria bassiana* (isolate IBCB 66 with 1.0 x 1010 cfu/g), at a dose of (200 g/ha) with only 0.2 stinkbug/beat cloth (Figure 2). The second application was with *Metarhizium anisopliae* (isolate IBCB 425 with 1.32 x 109 cfu/g), at a dose of (200 g/ha) and the third again with *B. bassiana* (isolate PL 63 with 2.0 x 109 cfu/ g), at a dose of (200 g/ha). In the producer's area, the population density of stink bugs exceeded the NC in five sampling periods (Figure 2), with the most pronounced occurrences observed in the latest assessments during the month of January 2020.

The producer carried out four applications of chemical insecticides on soybeans to control stink bugs and whiteflies, the first two with diflubenzuron (0.03 kg/ha), the third with the mixture acephate (1.2 kg/ha) + cypermethrin (0.25 L/ha) and the fourth with the mixture thiamethoxam + lambdacyhalothrin (0.20 L/ha) + methomyl (1.00 L/ha).

Silva et al. (2014) found that the population of *E. heros* reached the NC only once when the pest was monitored by the pheromone and twice when it was monitored with the beating cloth, thus requiring one and two applications of insecticides in the respective areas. Ávila and Santos (2018) found two NCs of stink bugs in the area managed with IPM and three NCs in the area managed by the producer during the 2014/2015 season, resulting in both studies in lower quantities of insecticide applications on soybeans than in those verified in the present work.

Corrêa-Ferreira et al. (2013), evaluating the influence of different control tactics on the population of the main soybean pests in the states of Paraná and Goiás, found that in the biological control and IPM areas, two to three insecticide applications/crop were needed, while in the areas managed by producers without the adoption of IPM, six to eight applications/season during the 2005/2006 and 2006/2007 seasons were necessary. The number of applications carried out by producers in these regions also exceeds that observed by rural producers in the present work.

Conte et al. (2014) carried out work in partnership between Emater and Embrapa Soja with the objective of resuming IPM-soy bean actions in the State of Paraná, noting that in the areas where they carried out IPM and IPM + biological control, on average, 2, 6 and 2.0 insecticide applications, respectively, for stink bug control. Regarding caterpillar control, insecticides were applied in the IPM area, while in areas with IPM + biological control, there was no need to apply insecticides to the soybeans. The total number of caterpillars present in the sampling of the IPM and producer areas during the 2018/2019 season did not differ statistically from each other (Figure 3).

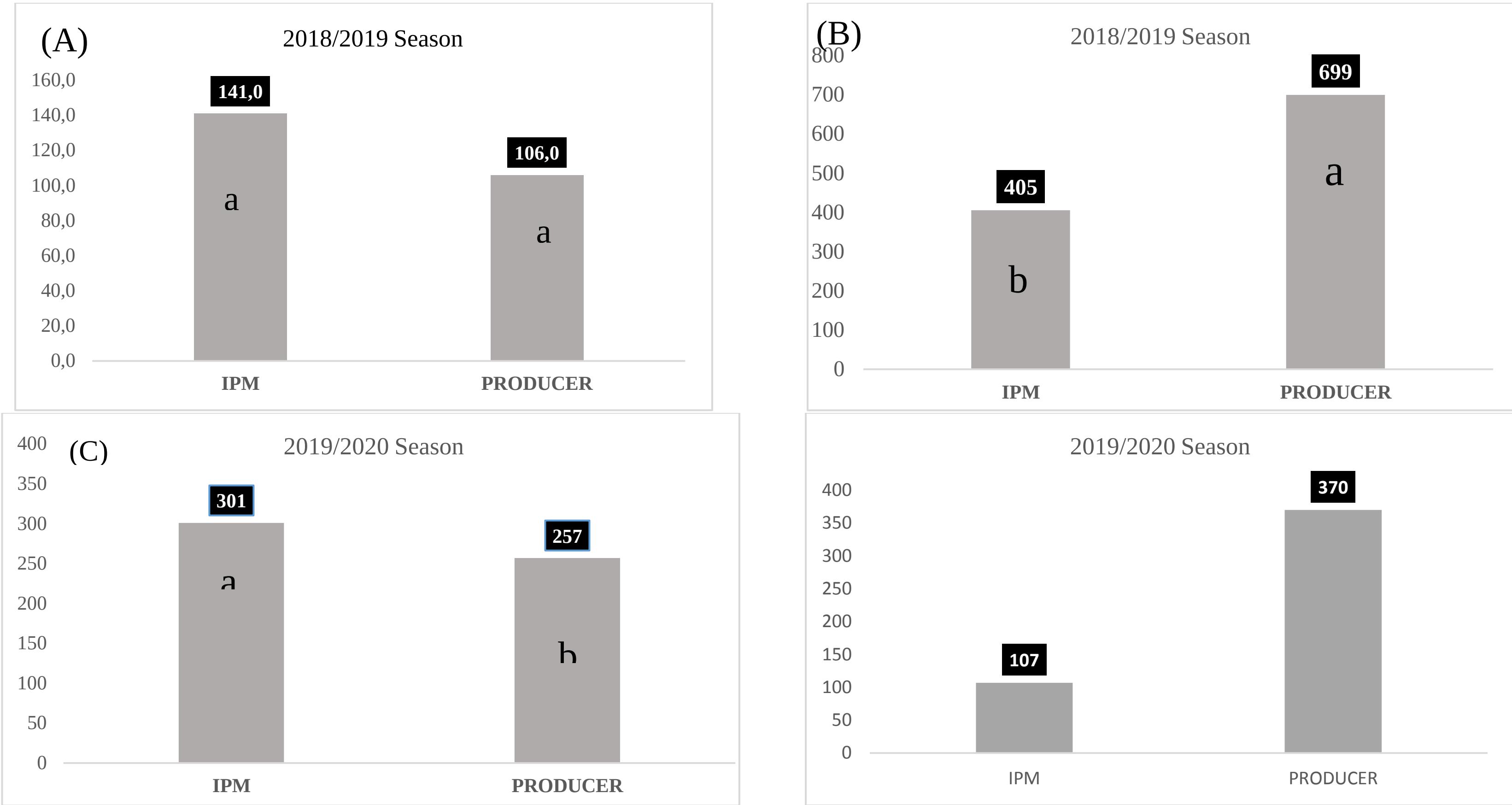

Figure 3. Total number of large + small caterpillars (A and C) and adult stink bugs + large nymphs (B and D) per beating cloth in the different sampling seasons in the IPM-Soybean and producer areas. Dourados, MS. Columns followed by the same letter, the values do not differ statistically using the T test ($p < 0.05$).

The remaining surviving caterpillars (large and small) were basically composed of *S. frugiperda*, a pest in which the Bt soy toxin has low control efficiency. (Bernardi et al., 2014; Farias et al., 2014). Regarding the total incidence of stink bugs in soybeans, during the 2018/2019 season (Figure 3), a much lower number of insects were observed in the IPM area than in the soybean area managed by the producer (Figure 3B). The fact that more stink bugs occurred in the producer's area may be due to the reason that insecticide application to soybeans began before that carried out in the IPM area and/or because the products or the sequence of application to the soybeans had a negative impact on the control effectiveness of this pest.

Given the results obtained, it was evident that the control of stink bugs in the IPM area was more effective than in the area managed by the producer, although fewer insecticide applications were carried out on the soybeans (Figure 2). In the 2019/2020 season, the total density of caterpillars sampled in the soybean crop differed between the IPM and producer areas, being higher in the former (Figure 3C). The total densities of stinkbugs found in the two sampling areas also differed from each other, with the producer's area having more than three times the quantity found in the IPM area (Figure 3D). When implementing adequate IPM management, it is necessary to monitor pests, choose the appropriate insecticide and apply it at the correct time.

This higher incidence of stinkbugs and lower incidence of caterpillars in the producer's area was probably due to inadequate management of insecticides in this area. The first two sprays that the producer made on soybeans contained only the product diflubenzuron, which has no effect on stink bugs. In addition, when the producer carried out the third and fourth spraying with specific products for stink bugs, the population density of this pest was already very high (Figure 2), with more than six stink bugs/m of soybean row, thus not allowing effective control in the cultivation.

As a result, the stink bug population increased at the end of the soybean cycle when compared to the IPM area (Figure 2), which could cause a serious problem for second-crop corn that would be cultivated in succession to the soybeans. The lower population of caterpillars in the producer's area is explained by the first two applications of diflubenzuron made in the area since this insecticide is considered a good lizardicide. However, these applications of diflubenzuron were unnecessary since the density of soybean caterpillars in the area was still below the NC at this time (Figure 2).

Conte et al. (2015 e 2016) implemented IPM-Soy reference units in different producing regions of the State of Paraná during the 2014/2015 and 2015/16 seasons, verifying that on average, 1.7 and 1.9 insecticide applications/season were needed for the stink bugs and 2.5 and 2.1 applications for the caterpillars/crops, respectively. The number of insecticide applications in these two studies for caterpillars are higher than those observed in the present work in the IPM area where there was no need to apply insecticides for the caterpillars, while applications for stinkbugs are inferior since four stink bug applications were required in the present work.

Another factor that may explain this difference in the incidence of stink bugs in these two pest management environments may be related to the different selectivity of insecticides applied to soybean crops. The biological products *M. anisopliae* and *B. bassiana*, applied in the IPM area, are considered selective for non-target organisms such as predators and parasitoids of insect pests, which play an important role in the natural control of phytophagous stink bugs in soybeans. (Oliveira et al., 2011; Bueno et al., 2012; Batisti et al., 2022).

The products applied to soybeans by the producer have low to moderate selectivity for predators and practically zero for stink bug egg parasitoids, such as *Telenomus podisii* Ashmead 1893 (Hymenoptera: Scelionidae) (Carmo et al., 2009; Carmo et al., 2010). Probably, in the IPM area, natural enemies, especially predators and parasitoids, were preserved and thus acted better in the natural control of phytophagous stink bugs in the IPM area, thus reducing their population in this environment. However, it is worth noting that the main natural enemies of phytophagous stink bugs found in soybeans in Mato Grosso do Sul are represented by egg parasitoids (Godoy et al., 2005), which were not quantified in the present research. Biological control in the agroecosystem can reduce dependence on chemical control to control soybean pests since it reduces the number of chemical insecticide applications on the crop (Ávila and Santos 2018). In the 2018/2019 season, the total cost for controlling insect pests/hectare in the IPM area was 67.99 (sixty-seven dollars and ninety-nine cents), while in the producer's area it was 86.88 (eighty-seven dollars and eighty-eight cents) (Table 1).

As a result, it was possible to save 18.88 (eighteen dollars and eighty-eight cents)/hectare using IPM (Table 2). In the 2019/2020 season, the total cost for controlling insect pests/hectare was 32.89 (thirty-two dollars and eighty-nine cents) and 56.92 (fifty-six dollars and ninety-two cents) for the IPM and producer area, respectively (Table 1), resulting in this season saving/hectare of 125.44 (one hundred and twenty-five reais and forty-four centavos) with the use of IPM (Table 2).

Table 1. Economic analysis of the costs of insecticide applications carried out to control stink bugs in the IPM and rural producer soybean areas during the 2018/2019 and 2019/2020 seasons. Dourados, MS.

	Insecticide	Dose/ha	Total cost(US$)/ha[1]
IPM Area - 2018/2019 Season			
1ª	Acephate	1.0 Kg	24.76
2ª	Thiamethoxam + lambdacyhalothrin	0.30 L	15.56
3ª	Thiamethoxam + lambdacyhalothrin	0.30 L	15.56
4ª	Fenpropathrin	0.40 L	12.11
		Total (US$)	67.99
Producer Area - 2018/2019 Season			
1ª	Thiamethoxam + lambdacyhalothrin	0.30 L	15.56
2ª	Acetamiprid + Fenpropathrin	0.70 L	16.59
3ª	Thiamethoxam + lambdacyhalothrin	0.30 L	15.56
4ª	Acephate	1.10 Kg	27.06
5ª	Fenpropathrin	0.40 L	12.11
		Total (US$)	86.88
IPM Area - 2019/2020 Season			
1ª	*Beauveria bassiana*	0.20 Kg	11.73
2ª	*Metarhizium anisopliae*	0.20 Kg	9.43
3ª	*Beauveria bassiana*	0.20 Kg	11.73
		Total (US$)	32.89
Producer Area - 2019/2020 Season			
1ª	Diflubenzuron	0.033 Kg	15.56
2ª	Diflubenzuron	0.033 Kg	16.59
3ª	Acephate	1.200 Kg	15.56
3ª	Cypermethrin	0.250 L	27.06
4ª	Thiamethoxam + lambdacyhalothrin	0.200 L	12.11
4ª	Methomyl	1.00 L	15.56
		Total (US$)	102.44

[1]Cost of the insecticide + its application on soybeans.

Table 2. Financial benefits arising from the possibility of using IPM-Soy across the producer's entire area cultivated with soybean considering the 2018/2019 and 2019/2020 seasons. Dourados, MS.

2018/2019 Season		
Analyzed parameter	Unit	Savings with IPM (US$)
Savings (US$) IPM x Producer	1 ha	98.58
Producer area	380 ha	7,176.32
2019/2020 Season		
Analyzed parameter	Unit	Savings with IPM (US$)
Savings (US$) IPM x Producer	1 ha	125.44
Producer area	380 ha	9,131.64

Analyzing the costs of insecticide applications to control caterpillars and stink bugs in soybeans, Ávila and Santos (2018) found that in the IPM area, the cost of pest control/hectare was US$56.97, while in the area conducted for the producer the cost/hectare was US$67.24, that is, with a savings of US$10.26 per hectare. Corrêa-Ferreira et al. (2013) studying the influence of different control tactics on the population of the main soybean pests, also found that the application of IPM or biological could markedly reduce the cost of pest control in the crop. Conte et al. (2014) argued that chemical control of soybean pests based on the IPM criteria and principles reduced the number of applications on the crop by up to 50%, and consequently, the producer's production costs, similar to what was observed in the present work.

Conte et al. (2015) evaluated pest control in soybean crops in the state of Paraná, finding that in IPM areas, the cost/hectare on average was 2 bags of soybeans, while in the area managed by the producer, it was 5 bags of soybeans. Similarly, Conte et al. (2016) implementing IPM-Soy reference units in different producing regions of the State of Paraná during the 2015/2016 season, found that the pest IPM areas had a cost of two bags/hectare, while in the areas managed by the producer, it was five bags/hectare.

The producer, owner of the area where the work was carried out cultivates 380 hectares of soybeans annually. If the producer had implemented the IPM across his entire property area in the 2018/2019 season, he would have saved 7,176.32 (seven thousand one hundred and seventy-six dollars and thirty-two cents) (Table 2). In the 2019/2020 season, the producer would have saved 9,131.64 (nine thousand one hundred and thirty-one dollars and sixty-four cents) (Table 2). This extrapolation of the results of using IPM in soybean cultivation provides not only economic benefits, but also environmental benefits since fewer chemicals are applied to crops, which contributes to the preservation of the environment and non-target insects, such as natural enemies and pollinators. The use of biological products to control pests, as occurred in the 2019/20 season of the present research, further maximizes the environmental and ecological benefits of IPM in the soy agroecosystem

4. Conclusions

Adoption of IPM guarantees better control of insect pests in soybean crops, especially in relation to phytophagous stink bugs. The number of insecticide applications in soybean crops can be reduced by using IPM, which brings economic and environmental benefits to the producer. In addition, the sexual pheromones Bio Spodotera®, Bio Helicoverpa®, Bio Pseudoplusia® are effective in capturing moths of the *S. frugiperda*, *H. armigera* and *C. includens*, species, respectively. Finally, it is possible to obtain effective control of phytophagous stink bugs in soybeans using only the microbial products *B. bassiana* and *M. anisopliae* applied by spraying on the crop.

Authors' Contribution

Izabela Vessoni, Elizete Cavalcanti, Andressa Mariani and Suélen Moreira carried out the field experiment, collected and processed the data. Crébio José Ávila elaborated and coordinated the planning, execution of the study and experimental design and conducted the statistical analysis. Crébio José Ávila and Ivana Fernandes da Silva checked the planning and evaluation of the data and revised the manuscript.

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