Insect incidence and soybean yield under sustainable and conventional production systems in midwestern Santa Catarina

Cirio Parizotto[1] and Rodolfo Vargas Castilhos[2]

Abstract – Brazil is the world's largest soybean producer and exporter, a promising scenario that can last by adopting sustainable production systems that meet current consumer needs. This work compared the incidence of pest insects and natural enemies, the number of insecticide sprays and grain yield in soybean areas under sustainable and conventional production systems in midwestern Santa Catarina for the agricultural years of 2018, 2019, 2020 and 2021. The sustainable system adopted integrated pest management (IPM), with insecticide spray applied when pest population reached the economic threshold. As for the conventional system, pest management was achieved with prophylactic use of insecticides (sprays every 15 days). Pest insects and natural enemies were sampled weekly in both systems using a beat cloth from V4 to pre-harvest and yield was measured at physiological maturation. Incidence of *Spodoptera* spp. and stinkbugs was higher in the sustainable system for the 2018/19 and 2020/21 agricultural years; however, occurrence of natural enemies was also higher in three of the four agricultural years evaluated due to an 86% reduction in insecticide spray in the referred system. Yield under the sustainable system was similar or superior to the conventional system in three of the four agricultural years evaluated, showing that sustainable production systems with IPM adoption can provide satisfactory yields combined with less environmental impact.

Keywords: *Glycine max* L.; sustainability; Integrated Pest Management.

Incidência de insetos e produtividade de soja em sistemas de produção sustentável e convencional no Meio-Oeste Catarinense

Resumo – O Brasil é o maior produtor e exportador mundial de soja, e esse cenário promissor pode ser mantido caso sejam adotados sistemas sustentáveis de produção, que atendam as necessidades do mercado consumidor atual. Este trabalho objetivou comparar a incidência de insetos-praga e inimigos naturais, o número de aplicações de inseticidas e o rendimento de grãos em áreas de soja conduzidas em sistemas de produção sustentável e convencional, no Meio-Oeste Catarinense. O estudo foi realizado nos anos agrícolas de 2018, 2019, 2020 e 2021. No sistema sustentável foi adotado o Manejo Integrado de Pragas (MIP), com aplicação de inseticidas quando as pragas atingiram o nível de controle, enquanto que no sistema convencional o manejo de pragas foi realizado de maneira profilática (pulverizações de inseticidas a cada 15 dias). Insetos-praga e inimigos naturais foram monitorados semanalmente nos dois sistemas com pano de batida do estágio V4 até a pré-colheita, e a produtividade mensurada na maturação fisiológica. A incidência de *Spodoptera* spp. e percevejos foi maior no sistema sustentável nas safras 2018/19 e 2020/21, no entanto a ocorrência de inimigos naturais também foi superior em três das quatro safras avaliadas em consequência da redução de 86% na pulverização de inseticidas verificada no referido sistema. A produtividade obtida no sistema sustentável se mostrou similar ou superior ao convencional em três das quatro safras avaliadas, demonstrando que sistemas sustentáveis de produção, onde é adotado o MIP, podem prover rendimentos satisfatórios, aliado à menor impacto ambiental.

Palavras-chave: *Glycine max* L.; sustentabilidade; Manejo Integrado de Pragas.

Introduction

Soybean [*Glycine max* (L.)] is one of the main crops of global economic importance, with production destined for human consumption and production of vegetable oil, animal feed, biodiesel, among others (Nair *et al.*, 2023). Brazil is the world's largest soybean producer, followed by the USA, Argentina, China and India (Fatima and Jan, 2023). Estimates indicate that the soybean plantation area in Brazil will reach 47.36 million hectares in the 2024/25 agricultural year, with a production of 166.14 million tons (CONAB, 2025).

Among the crop production limiting factors, phytosanitary problems like the incidence of key pests such as the caterpillars *Chrysodeixis includens*, *Anticarsia gemmatalis* and *Spodoptera* spp. (Lepidoptera: Noctuidae), which cause defoliation and consequent reduction of the photosynthetic area, and stink bugs *Nezara viridula*, *Euschistus heros* and *Piezodorus guildinii* (Hemiptera: Pentatomidae), which cause direct damage to the grains by feeding stylet insertion stand out (Pozebon *et al.*, 2020). Using sustainable agricultural practices in soybean crops is a necessity since the global market demand for safe, quality and sustainably produced food has grown in recent years. One way to achieve sustainability

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in soybean crops is adopting integrated pest management (IPM), essential for reducing the indiscriminate use of insecticides in crops, becoming the most efficient way to achieve sustainable production systems (Panizzi, 2013; Bueno *et al.*, 2021). IPM in soybeans includes monitoring pest populations with a beating cloth and adopting economic threshold for decision-making, in addition to identifying pest species and natural enemies (Bortolotto *et al.*, 2015; Bueno *et al.*, 2021). Established in the 1970s, IPM was widely adopted by soybean farmers, causing a reduction in insecticide application by around 50%. However, in the last two decades there has been low adherence to IPM due to changes in the production scenario including: high adoption of no-tillage planting, which favored soil-dwelling pests; multiple crops throughout the year with an abundant supply of hosts for pests; low cost of conventional insecticides; emergence of secondary pests and deleterious effect of fungicides used for Asian rust on entomopathogens (Panizzi, 2013). Consequently, producers began to use prophylactic insecticide applications on crops indiscriminately, disregarding the economic threshold (Bueno *et al.*, 2021).

An IPM "rebirth" and adaptation to the current reality of farmers are necessary to achieve sustainability combined with satisfactory productivity in soybean crops. Thus, this study compared the incidence of insect pests and natural enemies, the number of insecticide applications, and grain yield in soybean areas managed under a sustainable production system (pest monitoring and spraying based on economic threshold) and a conventional system (without pest monitoring and spraying by calendar) in midwestern Santa Catarina.

Material and methods

The study was conducted in the agricultural years of 2018, 2019, 2020, and 2021 at the Experimental Station of the Agricultural Research and Rural Extension Company of Santa Catarina (Epagri) in Campos Novos (27°23'11" S and 51°13'19" W). Altitude of the study site is 933 m, the soil is classified as Eutrophic Red Nitosol (Embrapa, 2013) and its climate is humid subtropical (Dufloth *et al.*, 2005).

An experimental crop was installed in an area of 17.11 ha with a history of soybean and corn cultivated by no-tillage farming with succession of crops and kept fallow in the winter for 25 years. A conventional (Conv.) and a sustainable (Sust.) system were evaluated. For this purpose, we divided the area into four plots so that soybeans could be grown under both systems each year, as follows: T1 sustainable system with 5.25 ha; T2 conventional system with 4.85 ha; T3 conventional system with 3.88 ha; T4 sustainable system with 3.13 ha. The sustainable and conventional plots were located next to each other, with soybeans being grown in rotation with corn to meet the environmental, social and economic precepts of production. All cultivars used in each year — 2018: TMG 7262; 2019: NS 5258 IPRO; 2020: BMX 58I60 RSF IPRO and 2021: NS 5258 IPRO — are resistant to glyphosate (RR), with no resistance to pests, and were chosen due to their adaptation to midwestern Santa Catarina. Row spacing was set at 0.5 m in all years and the plant population varied between 242,000 and 280,000 plants ha^{-1}, as recwommended for each cultivar.

The sustainable production system used green covers in the soybean off-season, such as black oat (*Avena strigosa* Schreb), white oat (*Avena sativa* L.), rye (*Secale cereale* L.), forage radish (*Rafhanus sativus* L.) and buckwheat (*Fagopyrum esculentum* Moench) alone or in consortium. The green covers were desiccated using glyphosate (2.5 L ha^{-1}) at sowing. Regarding pest management, IPM precepts were followed by monitoring insects with a beating cloth, and using insecticides only when the following economic thresholds were reached: 20 caterpillars ≥1.5 cm/m for *C. includens* and *A. gemmatalis*; 10 caterpillars ≥1.5 cm/m for *Spodoptera* spp.; 2 stink bugs/m (Corrêa-Ferreira *et al.*, 2017). In the conventional system, the area was kept fallow in the off-season and desiccated with glyphosate (2.5 L ha^{-1}) + clethodim (0.45 L ha^{-1}) 30 days before sowing. Insect management used preventive insecticide sprays every 15 days (calendar system). Fertilization in both systems was similar and followed the technical standards recommended for soybean crop (Martin *et al.*, 2022).

Incidence of insects in each plot for each agricultural year was assessed by randomly listing 10 points which were georeferenced and evenly distributed throughout the area for weekly monitoring of insect pests and natural enemies using a beating cloth, with monitoring always taking place at the same points during the evaluations. Measuring 1 m long, the beating cloth was inserted between the soybean rows, with one side facing the base of the plants and the other side extended above the plants in the adjacent row. The sampled plants were shaken above the cloth and the following insects were counted on monitoring sheets (Corrêa-Ferreira *et al.*, 2017): "green caterpillars" (*A. gemmatalis* and *C. includens*), *Spodotera* spp., phytophagous stink bugs (Hemiptera: Pentatomidae) and predatory natural enemies in general. Monitoring was conducted from stage V4 until pre-harvest, according to the period recommended for said monitoring instrument (Corrêa-Ferreira *et al.*, 2017).

After physiological maturity, grain yield was assessed by collecting 10 samples in each plot, with each sample representing a useful area of 10m x 1.5m (15m²). All pods in the useful area were harvested. After harvest, the grains were mechanically threshed. Moisture content was determined and grains were weighed to estimate yield (13% moisture content) in kg ha^{-1}.

Data were analyzed by Student's t-test (p≤0.05), using the "t-test" function for independent samples to compare the means obtained in the two production systems available on R version 4.1.0 (R Core Team, 2021).

Results and discussion

Figure 1 shows the incidence of insect pests and natural enemies in soybeans grown under sustainable and conventional systems during the four agricultural years evaluated. Velvet bean caterpillar *A. gemmatalis* and soybean looper *C. includens* had higher occurrence in the 2018/19 harvest, whereas the occurrence of "black" caterpillars *Spodoptera* spp. was lower. In turn, the stink bug population was below the economic threshold, with some peaks during the reproductive period (due to the availability of pods for feeding) in the 2021/22 harvest, in soybeans grown under the sustainable system. Natural enemies presented greater abundance in soybeans grown under the sustainable production system in the 2020/21 harvest.

Considering the overall average of insects captured per beating cloth during the entire monitoring period, and comparing the two production systems, the incidence of "green" caterpillars was similar in both systems during the four years evaluated (Table 1). *Spodoptera* spp. showed a significant difference between the production systems in the 2018/19 harvest, with a higher occurrence in the sustainable system. Stink bugs had higher incidence in the sustainable system in the 2018/19 and 2021/22 harvests. Excepting the 2021/22 harvest, the sustainable production system exhibited a higher occurrence of natural enemies (Table 1).

This higher incidence of *Spodoptera* spp., stink bugs and natural enemies observed in the sustainable system is strongly related to the supply of hosts for shelter and food during the entire off-season, since green covers were sown and desiccated on sowing day. Moreover, in the conventional system the spontaneous vegetation established in the fallow area was desiccated 30 days before sowing, creating a "food gap" for potential pests and natural enemies.

The number of insecticide sprays in the conventional system varied between five and six, whereas the sustainable system performed no more than one spray per harvest, resulting in an 86% reduction (Table 2).

Grain yield showed significant difference between the systems in the 2018/19 and 2020/21 harvests, with higher productivity observed in the sustainable and conventional systems, respectively (Figure 2). In the 2019/20 and 2021/22 harvests, production in both systems was similar.

Despite the higher incidence of black caterpillars and stink bugs in the sustainable system for the 2018/19 harvest, it showed higher productivity due to effective pest control once the economic threshold was reached, combined with the low incidence of other pests and better soil conditions due to the implementation of off-season plant cover. Likewise, the sustainable system exhibited a higher incidence of stink bugs in the 2021/22 harvest; however, yield did not differ between systems, showing that more sustainable

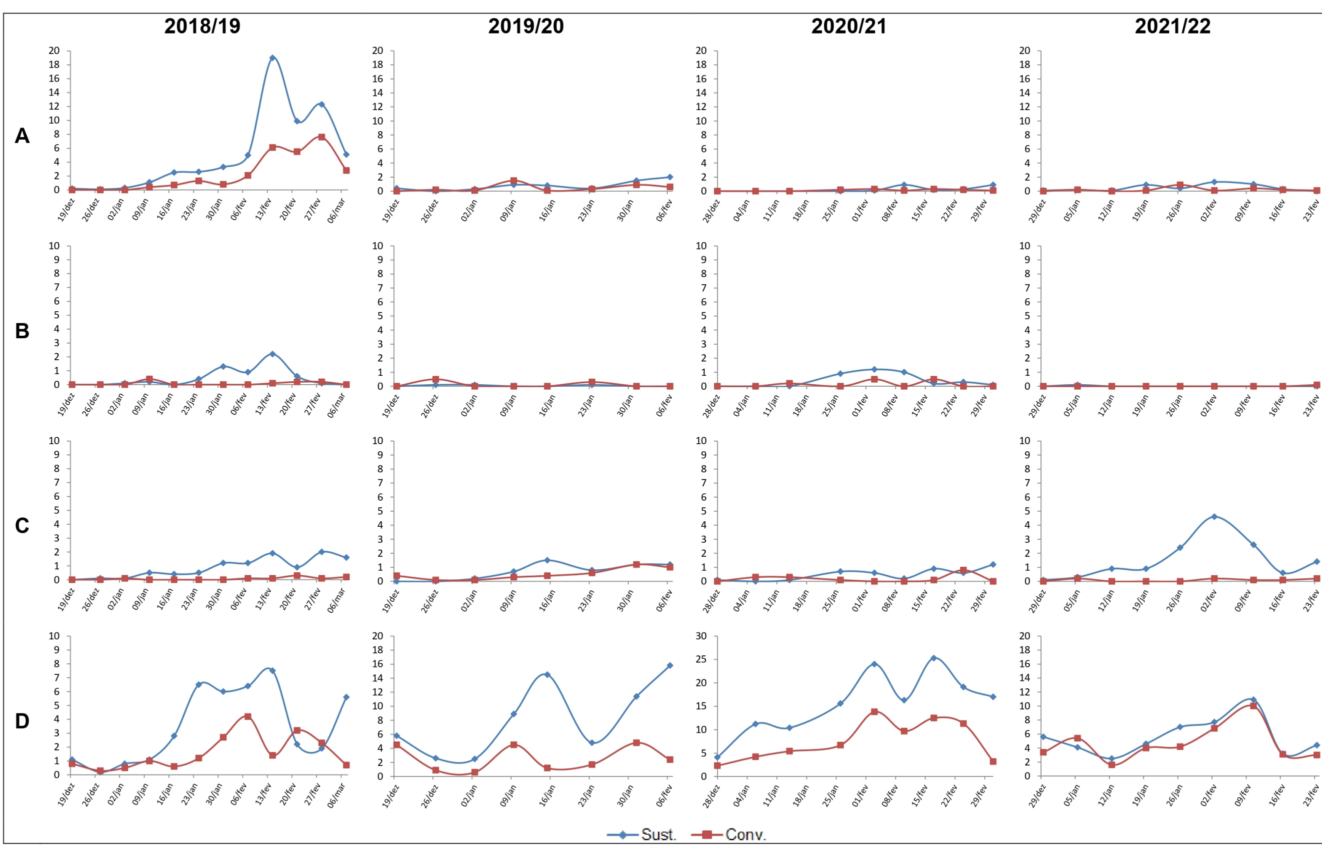

Figure 1. Incidence of insects (average number of individuals / m) in sampling with beat cloth on soybean crop cultivated under conventional and sustainable system, during four agricultural years in the municipality of Campos Novos, SC. (A) Green caterpillars (*Anticarsia gemmatalis* and *Chrysodeixis includens*) >1.5cm; (B) *Spodoptera* spp. >1.5cm; (C) stink bugs; (D) Natural enemies.
Figura 1. Incidência de insetos (número médio de indivíduos / m) em monitoramento com pano de batida na cultura soja, conduzida em sistemas convencional e sustentável, em quatro anos agrícolas, no município de Campos Novos, SC. (A) Lagartas "verdes" (Anticarsia gemmatalis e Chrysodeixis includens) >1,5cm; (B) Spodoptera spp. >1,5cm; (C) Percevejos; (D) Inimigos naturais

Fonte: Elaborado pelos autores (2025)
Source: elaborated by the authors (2025)

Table 1. Average occurrence of insects (number of individuals / m) in soybean crop cultivated under conventional and sustainable system, during four agricultural years in the municipality of Campos Novos, SC
Tabela 1. Média geral de ocorrência de insetos (número de indivíduos / m) na cultura da soja conduzida em sistemas convencional e sustentável, em quatro anos agrícolas, no município de Campos Novos, SC

Insects	System	2018/19	2019/20	2020/21	2021/22
Green caterpillars (*A. gemmatalis* and *C. includens)*	Sust.	5.12 ± 1.68^{ns}	0.79 ± 0.24^{ns}	0.27 ± 0.12^{ns}	0.48 ± 0.16^{ns}
	Conv.	2.28 ± 0.77	0.46 ± 0.18	0.13 ± 0.04	0.22 ± 0.09
Spodoptera spp.	Sust.	0.48 ± 0.19*	0.04 ± 0.02^{ns}	0.41 ± 0.16^{ns}	0.01 ± 0.01^{ns}
	Conv.	0.08 ± 0.04	0.10 ± 0.07	0.13 ± 0.07	0.01 ± 0.01
Stink bugs	Sust.	0.87 ± 0.20*	0.70 ± 0.21^{ns}	0.48 ± 0.14^{ns}	1.53 ± 0.48*
	Conv.	0.08 ± 0.03	0.51 ± 0.15	0.18 ± 0.08	0.09 ± 0.03
Natural enemies	Sust.	3.51 ± 0.77*	8.29 ± 1.84*	15.89 ± 2.23*	5.56 ± 0.87^{ns}
	Conv.	1.58 ± 0.36	2.57 ± 0.62	7.68 ± 1.42	4.61 ± 0.84

ns=not significant; *significant difference by Student's t-test (p≤0.05).

Green caterpillars - 2018/19: t=1.54; p=0.14; 2019/20: t=1.77; p=0.29; 2020/21: t=1.02; p=0.33; 2021/22: t=0.78; p=0.44. Spodoptera spp. - 2018/19: t=2.03; p=0.032; 2019/20: t=0.88; p=0.4; 2020/21: t=1.57; p=0.14; 2021/22: t=0.78; p=0.44. Stink bugs - 2018/19: t=3.83; p=0.0027; 2019/20: t=0.75; p=0.46; 2020/21: t=1.90; p=0.08; 2021/22: t=3.00; p=0.017. Natural enemies: 2018/19: t=2.27; p=0.037; 2019/20: t=2.94; p=0.016; 2020/21: t=3.11; p=0.008; 2021/22: t=0.78; p=0.45.

Source: Elaborated by the Authors (2025)

*ns=diferença não significativa; *diferença significativa pelo teste t de Student (p≤0,05).*

Lagartas verdes - 2018/19: t=1,54; p=0,14; 2019/20: t=1,77; p=0,29; 2020/21: t=1,02; p=0,33; 2021/22: t=0,78; p=0,44. Spodoptera spp. - 2018/19: t=2,03; p=0,032; 2019/20: t=0,88; p=0,4; 2020/21: t=1,57; p=0,14; 2021/22: t=0,78; p=0,44. Percevejos - 2018/19: t=3,83; p=0,0027; 2019/20: t=0,75; p=0,46; 2020/21: t=1,90; p=0,08; 2021/22: t=3,00; p=0,017. Inimigos naturais: 2018/19: t=2,27; p=0,037; 2019/20: t=2,94; p=0,016; 2020/21: t=3,11; p=0,008; 2021/22: t=0,78; p=0,45.

Fonte: Elaborado pelos autores (2025)

Table 2. Use of insecticides in soybean on sustainable (Sust.) and conventional (Conv.) plots from 2018 to 2021 agricultural years
Tabela 2. Utilização de inseticidas na soja nos talhões de produção sustentável (Sust.) e produção convencional (Conv.), nos anos agrícolas de 2018 a 2021

Agricultural year	System	Insecticides sprayed	Num.
2018	Sust.	- imidacloprid+beta-ciflutrina / 1L ha^{-1} + lambda-cialotrina+clorantraniliprole / 1L ha^{-1}	1
	Conv.	- lambda-cialotrina+clorantraniliprole / 1L ha^{-1}	6
		- tiametoxam+lambda-cialotrina / 0.2L ha$^{'}$	
		- imidacloprid+beta-ciflutrina / 1L ha^{-1}	
		- lambda-cialotrina+clorantraniliprole / 1L ha^{-1}	
		- imidacloprid+beta-ciflutrina / 1L ha^{-1}	
		- tiametoxam+lambda-cialotrina / 0.2L ha^{-1}	
2019	Sust.	- *Bacilus thuringiensis*, Var. kurstaki / 0.5L ha^{-1}	1
	Conv.	- tiametoxam+lambda-cialotrina / 0.2L ha^{-1}	5
		- lambda-cialotrina+clorantraniliprole / 1L ha^{-1}	
		- imidacloprid+beta-ciflutrina / 1L ha^{-1}	
		- lambda-cialotrina+clorantraniliprole / 1L ha^{-1} + imidacloprid+beta-ciflutrina / 1L ha^{-1}	
		- abamectina / 0.075 L ha^{-1} + imidacloprid+beta-ciflutrina / 1L ha^{-1}	
2020	Sust.	--	0
	Conv.	- tiametoxam+lambda-cialotrina / 0.2L ha^{-1}	5
		- tiametoxam+lambda-cialotrina / 0.2L ha^{-1}	
		- tiametoxam+lambda-cialotrina / 0.2L ha^{-1}	
		- tiametoxam+lambda-cialotrina / 0.2L ha^{-1}	
		- tiametoxam+lambda-cialotrina / 0.2L ha^{-1}	
2021	Sust.	- tiametoxam+lambda-cialotrina / 0.2L ha^{-1}	1
	Conv.	- tiametoxam+lambda-cialotrina / 0.2L ha^{-1}	6
		- lambda-cialotrina + tiametoxam / 0.2L ha^{-1}	
		- tiametoxam+lambda-cialotrina / 0.2L ha^{-1}	
		- tiametoxam+lambda-cialotrina / 0.2L ha^{-1}	
		- imidacloprid+beta-ciflutrina / 1L ha^{-1}	
		- tiametoxam+lambda-cialotrina / 0.2L ha^{-1}	

Source: Elaborated by the Authors (2025)
Fonte: Elaborado pelos autores (2025)

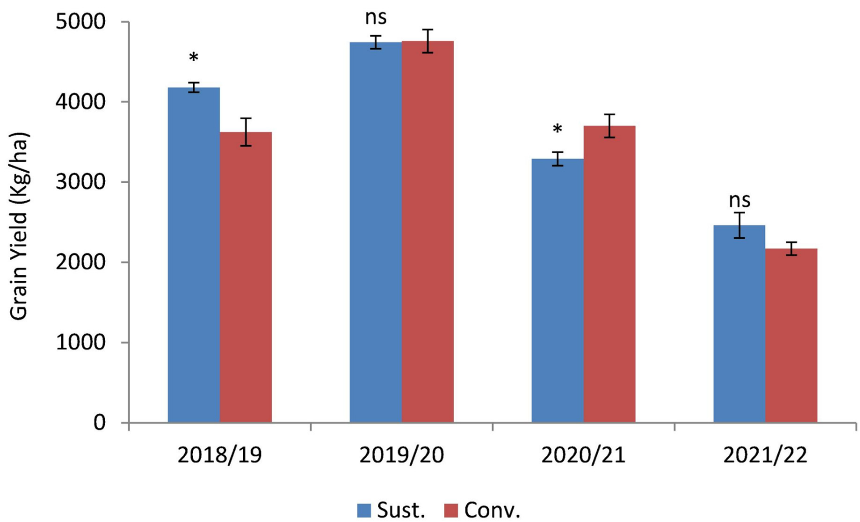

Figure 2. Average yield (kg ha^{-1}) of soybean cultivated in sustainable and conventional system, during four agricultural years

* significant difference by Student's t-test. 2018/19: t=2.20; p=0.01; 2019/20: t=2.14; p=0.93; 2020/21: t=2.13; p=0.027; 2021/22: t= 2.16; p= 0.12.

^{ns} not significant

Source: Elaborated by the Authors (2025)

Figura 2. Produtividade média (Kg ha^{-1}) de soja conduzida em sistema sustentável e convencional, em quatro anos agrícolas.

** diferença significativa pelo teste t de Student. 2018/19: t=2,20; p=0,01; 2019/20: t=2,14; p=0,93; 2020/21: t=2,13; p=0,027; 2021/22: t= 2,16; p= 0,12.*

^{ns} sem diferença significativa

Fonte: Elaborado pelos autores (2025)

production systems in which drastic pest control is not adopted can also produce satisfactorily (Table 1, Figure 2). Similar to our study, Bueno *et al.* (2011), when evaluating different pest management strategies in soybean production, found in some cases a higher occurrence of caterpillars and stink bugs in crops managed by biological control (within the IPM perspective) compared with the prophylactic use of insecticides. However, the yields obtained were overall similar between the systems, showing that the preventive use of insecticides does not always result in higher yields. In the state of Paraná, in the 2023/24 harvest soybean crops managed by IPM produced around five more bags of soybeans per hectare, combined with a lower number of insecticide applications (Carnevalli *et al.*, 2024). According to the authors, in crops managed by IPM the cost of pest control represented 4.6% of productivity; in crops where IPM was not adopted this cost represented 8.6%, highlighting the importance of adopting sustainable production systems that provide not only economic gains for producers, but also environmental benefits.

This substantial reduction in insecticide use under the sustainable system is reflected on the incidence of natural enemies, which was higher in said system in three of the four harvests evaluated. Monitoring of natural enemies by beating cloth identified predatory ladybugs (Coleoptera: Coccinelidae), *Callida scutellaris* (Coleoptera: Carabidae), *Lebia concinna* (Coleoptera: Carabidae), *Doru* spp. (Dermaptera: Forficulidae), predatory ants (Hymenoptera: Formicidae) and spiders as the predominant species. Conservation of natural enemies is a strategy within IPM in soybean since natural biological control contributes to regulate the pest population, acting in combination with other control measures (Bueno *et al.*, 2023).

The sustainable system showed satisfactory yield combined with lower use of insecticides. Grain yield was higher than 3,200 kg ha^{-1} excepting the 2021/22 harvest, which was seriously compromised by the low rainfall recorded in the state from December 2021 onward (Giehl *et al.*, 2022).

Our results indicate that monitoring pests and using insecticides only when reaching the economic threshold are important strategies for achieving sustainability in soybean crops to help keep soybean farmers competitive in the market while ensuring satisfactory productivity.

Conclusion

- Incidence of *Spodoptera* sp. caterpillars, stink bugs and natural enemies was higher in the sustainable production system in some specific harvests.
- IPM adoption in soybean led to a significant reduction in insecticide applications.
- Soybean yield in the sustainable system equaled to that obtained in the conventional system.

Authors' contributions

Cirio Parizotto: Conceptualization, Project administration, Investigation, Data curation, Supervision, Writing-review & editing; Rodolfo Vargas Castilhos: Investigation, Data curation, Formal analysis, Visualization, Writing-first draft, Writing-review & editing

Conflicts of interest

We hereby declare that this study has no form or type of conflict of interest.

Research data

The data are available from the authors upon direct request.

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