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# Stink bug control at different stages of soybean development

## *Controle de percevejos em diferentes estádios de desenvolvimento da planta de soja*

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**ABSTRACT:** This study evaluates the effects of combinations of pyrethroids and neonicotinoids on the control of stink bugs at different stages of soybean crop development. The experiment was set up in a factorial randomized block design (4×6: 4 treatments and 6 stages) with 4 repetitions. The following treatments were tested during the V6/V7, R2, R4, R5.1, R5.5 and R 6 phenological stages: 1 – control (no application), 2 – thiamethoxam + λ-cyhalothrin, 3 – acetamiprid + α-cypermethrin, and 4 – dinotefuran + α-cypermethrin. Infestation, number of damaged seeds, number of pods, number of pods per plant, and yield (kg/ha) were evaluated. Stink bug infestations were smaller when applications commenced during the vegetative stages (V6-V8). Pod numbers and yields were highest in the dinotefuran + α-cypermethrin treatment with applications from V6/V8 to R4. The active ingredients dinotefuran + α-cypermethrin reduced stink bug populations and increased yields and could therefore be considered in integrated pest management (IPM) programs for soybean crops.

**KEYWORDS:** *Glycine max*; stink bugs; pentatomids; chemical control.

**RESUMO:** O objetivo deste trabalho foi avaliar o efeito de combinações de piretroides com neonicotinoides no controle de percevejos em diferentes estádios de desenvolvimento da cultura da soja. O delineamento experimental foi em blocos randomizados, em esquema fatorial 4×6 (4 tratamentos e 6 estádios) com 4 repetições. Os produtos utilizados foram: 1 – testemunha (sem aplicação), 2 – tiametoxam + λ-cialotrina, 3 – acetamiprida + α-cipermetrina, e 4 – dinotefuran + α-cipermetrina, e as aplicações foram realizadas a partir dos estádios fenológicos V6/V7, R2, R4, R5.1, R5.5 e R6. Avaliaram-se a infestação, número de grãos danificados, número de vagens, número de vagens por planta e produtividade (kg/ha). A infestação de percevejo foi menor quando se iniciou a aplicação precocemente nos estádios vegetativos (V6-V8). O número de vagens e produtividade foi superior no tratamento dinotefuran + α-cipermetrina nos estádios V6/V8 até R4. Os ingredientes ativos dinotefuran + α-cipermetrina apresentaram resultados positivos na redução da população de percevejo e proporcionaram incremento no rendimento de grão, podendo ser utilizado como opção em programa de manejo integrado de pragas (MIP) na cultura da soja.

**PALAVRAS-CHAVE:** *Glycine max*; percevejos; pentatomídeos; controle químico.

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# INTRODUCTION

Soybeans (*Glycine max* L.) are the most important crop in Brazil. Unfortunately, yields of this crop are significantly affected by phytosanitary problems. Soybeans are planted as a monoculture, which favors pests and diseases at all stages of development (FREITAS, 2011).

Phytophagous stink bugs (Hemiptera: Pentatomidae) are the most significant pest for soybean crops. The three main species of stink bugs, *Euschistus heros* (F.), *Nezara viridula* (L.) and *Piezodorus guildinii* (West.), are widely distributed throughout soybean croplands (SOUZA et al., 2016). Although *E. heros* is the most abundant of the three, *P. guildinii* is responsible for the greatest damage and physiological changes in soybeans (SOSA-GÓMEZ; SILVA, 2010; SOUZA et al., 2016).

Stink bugs damage soybeans directly. This damage reduces yield, decreases the physiological quality of seeds, and provides access to microorganisms such as the fungus *Nematospora coryli* that causes the yeast-spot disease. Damage can also cause abortion of seed and pods, reductions in germination, vigor, and oil content, and physiological disturbances, such as delayed plant maturation (DEPIERI; PANIZZI, 2011; LOURENÇÃO et al., 2010; JESUS et al., 2013; SOUZA et al., 2016).

Chemical control has been the most common method for reducing stink bug damage. Products with different combinations of neonicotinoids, pyrethroids, organophosphates and carbamates are available on the market (RIBEIRO et al., 2016). Wide use of organophosphates and endosulfan until 2004, led to the selection of resistant individuals (SOSA-GÓMEZ; SILVA, 2010).

The availability of different strategies for controlling stink bugs at appropriate stages of plant development allows soybean growers to choose more efficient strategies, especially since the use of pesticides alone may not always increase crop yields. Integrated pest management (IPM) provides the best alternative for controlling soybean pests (BUENO et al., 2011; 2015).

The objective of this study was to evaluate the effect of products with different combinations of pyrethroids and neonicotinoids on the control of pentatomid stink bugs at different stages of soybean plant development.

# MATERIAL AND METHODS

## Planting and treatments

The experiment was conducted in the Brazilian city of Uberlândia, Minas Gerais (18°54'187"S and 49°09'928"W). The Köppen-Geiger classification of the climate is Aw with average rainfall of 1474 mm and an average temperature of 23.6 °C (INMET, 2017).

The experiment was set up in a factorial randomized block design (4×6: 4 treatments and 6 stages) with 4 repetitions. The experimental units consisted of eight rows (5 m long, spaced 0.45 m apart) of which the four centermost rows were evaluated.

Foliar treatments were applied using a backpack sprayer (constant pressure – $CO_2$,) at 150 l/ha. The products used in the experiment were: thiamethoxam + λ-cyhalothrin – 247 g a.i./ha formulation – concentrated suspension; recommendation 61.75 mL/g/a.i./ha; acetamiprid + α-cypermethrin - 300g a.i./l or kg; formulation – concentrated suspension; recommendation 90 ml/g/a.i./ha; dinotefuran + α-cypermethrin – 360g a.i./l or kg; formulation – water-dispersible granules; recommendation 115.2 ml/g/a.i./ha. These treatments were applied at the following phenological stages: V6/V7, R2, R4, R5.1, R5.5 and R6.0.

## Evaluation

Infestations were monitored weekly from R4 to maturity (R8) (FEHR; CAVINESS, 1977) using the "beat sheet" method (HOFFMANN-CAMPO et al., 2012) at each stage and at one point per plot.

The following variables were measured: infestation (number of stink bugs per sheet per plot), number of damaged seeds (number of seeds with symptoms of stink bug attacks on pods in 10 plants per plot); number of pods (10 plants); number of pods per plant (averaged from 10 soybean plants); yield in kg·ha$^{-1}$ (49 m$^2$ of useful area and 13% seed moisture).

## Analyses and statistics

The data were evaluated by analysis of variance and means compared by the least significant difference (LSD) test at 5%. Multivariate analysis of variance was performed followed by canonical discriminant analysis. The results were presented as biplots containing the means of each combination of factors and confidence ellipses (95%) (R CORE TEAM, 2017).

# RESULTS

The stink bug infestations, pod numbers, yields and percentages of damaged seeds were statistically different at different phenological stages. Average stink bug infestations (INF) were greater when applications were made during R6 than during the V6/V8 stages. The number of pods (NPO) was lower when applications were performed from R5.3 to R6 and higher when applications commenced at R1. Percentages of damaged seeds (PDS) were lower when the applications commenced at R1 and greater when started at R5.3 and R5.5, while yield (YLD) was greater when the applications commenced during the vegetative phase V6/V8 and lower for later applications (R6) (Table 1).

Regarding active ingredients, the average INF was lowest in the dinotefuran + α-cypermethrin treatment and highest in the control. The number of pods (NPD) was lowest in the control and highest in the dinotefuran + α-cypermethrin treatment. The percentage of damaged seeds (PDS) was highest in the control and lowest in the dinotefuran + α-cypermethrin treatment while yield (YLD) was highest in the dinotefuran + α-cypermethrin treatment, followed by the thiamethoxam + λ-cyhalothrin treatment (Table 1).

There was significant interaction between active ingredients (treatments) and application times (phenological stages) regarding stink bug infestations (Table 2). Among active ingredients, significant differences were only found with thiamethoxam + λ-cyhalothrin and acetamiprid + α-cypermethrin. The infestation with thiamethoxam + λ-cyhalothrin was greatest when applications started at R6, but not statistically different from the infestations when commenced at R5.5 and R4. The greatest infestation for acetamiprid + α-cypermethrin was at R6 and R5.3 and lowest at V6/V8 and R1.

Stink bug infestations were significantly different at all developmental stages of the soybean plant. The greatest infestation was in the control and the smallest in the thiamethoxam + λ-cyhalothrin and dinotefuran + α-cypermethrin treatments. When each combination of active ingredients was analyzed separately, the highest average was found for thiamethoxam + λ-cyhalothrin applied from R4 and R5.5 and lowest when commenced at V6/V8. Regarding acetamiprid + α-cypermethrin applications, infestations did not differ when applications started at R6 and later, and were lowest when started at V6/V8 and R1, while no significant differences were found among the dinotefuran + α-cypermethrin applications (Table 2).

The number of pods per 10 plants showed no significant interaction between active ingredient and plant stage. The number of pods in the control did not differ statistically regarding plant stages, while the thiamethoxam + λ-cyhalothrin, acetamiprid + α-cypermethrin and dinotefuran + α-cypermethrin treatments differed. The thiamethoxam + λ-cyhalothrin, acetamiprid + α-cypermethrin and dinotefuran + α-cypermethrin treatments produced the highest numbers of pods when applied at V6/V8, R1 and R4. The highest numbers of pods were found when the treatments were applied at V6/V8, R1 and R4 (Table 2).

Significant interactions between active ingredients and development stages were found for the percentage of damaged seeds. PDS was highest in the control at V6/V8, R1, R4, R5.3 and R5.5. The thiamethoxam + λ-cyhalothrin, acetamiprid + α-cypermethrin and dinotefuran + α-cypermethrin treatments showed higher PDS at R5.3, R5.5 and R6. The highest PDS occurred when the treatments were applied at R5.3, R5 and R6 (Table 2).

**Table 1.** Number of stink bugs (m²), number of pods (10 plants), yield (kg·ha⁻¹) and percentage of damaged seeds (%) in soybean crops after applying various active ingredients at different phenological plant stages. Uberlândia, 2017.

| Stages (S) | INF[1] | NPD[2] | PDS[3] | YLD[4] |
|---|---|---|---|---|
| V6/V8 | 11.00 d | 604.94 b | 37.91 e | 3334.68 a |
| R1 | 12.88 c | 640.31 a | 39.54 d | 3065.70 b |
| R4 | 14.75 b | 594.44 b | 43.46 c | 3054.06 b |
| R5.3 | 14.88 b | 483.75 c | 71.81 a | 2817.04 c |
| R5.5 | 15.00 b | 477.00 c | 71.36 ab | 2631.49 d |
| R6 | 16.69 a | 463.19 c | 70.31 b | 2175.14 e |
| F (E) | 11.09 | 49.07 | 1347.39 | 57.01 |
| P (E) | P < 0.05 | P < 0.05 | P < 0.05 | P < 0.05 |
| **Treatment (T)** | **INF** | **NPD** | **PDS** | **YLD** |
| Control | 27.50 a | 2325.52 d | 71.375 a | 474.63 c |
| Thiamethoxam + λ-cyhalothrin | 7.88 c | 3060.93 b | 50.09 c | 573.46 a |
| Acetamiprid + α-cypermethrin | 14.96 b | 2657.06 c | 54.37 b | 535.50 b |
| Dinotefuran + α-cypermethrin | 6.46 d | 3341.90 a | 47.09 d | 592.17 a |
| F (T) | 392.95 | 103.14 | 822.95 | 32.81 |
| P (T) | P < 0.05 | P < 0.05 | P < 0.05 | P < 0.05 |
| F (SxT) | 1.88 | 6.63 | 176.34 | 8.29 |
| P (SxT) | P < 0.05 | P < 0.05 | P < 0.05 | P < 0.05 |
| CV (%) | 16.74% | 7.57% | 3.32% | 8.16% |

[1]INF = infestation (nº of stink bugs·plot⁻¹), [2]NPD = number of pods (10 plants), [3]PDS = percentage of damaged seeds (%) and [4]YLD = yield (kg·ha⁻¹). Means followed by the same letter within the same column do not differ by the LSD test (5%).

**Table 2.** Number of stink bugs (m²), number of pods (10 plants), percentage of damaged seeds (%) and yield (kg·ha⁻¹) in soybean crops after applying various active ingredients at different phenological plant stages. Uberlândia, 2017.

| Stages | Number of stink bugs (m²)[1] | | | | |
|---|---|---|---|---|---|
| | Control | Thiamethoxam + λ-cyhalothrin | Acetamiprid + α-cypermethrin | Dinotefuran + α-cypermethrin | P (S) |
| V6/V8 | 26.75 Aa | 3.75 Cc | 9.75 Cb | 3.75 Ac | P < 0.05 |
| R1 | 27.75 Aa | 6.75 BCc | 11.75 Cb | 5.25 Ac | P < 0.05 |
| R4 | 28.75 Aa | 8.25 Abc | 15.25 Bb | 6.75 Ac | P < 0.05 |
| R5.3 | 26.75 Aa | 7.50 Bc | 17.50 ABb | 7.75 Ac | P < 0.05 |
| R5.5 | 27.25 Aa | 9.50 Abc | 15.75 Bb | 7.50 Ac | P < 0.05 |
| R6 | 27.75 Aa | 11.50 Ac | 19.75 Ab | 7.75 Ad | P < 0.05 |
| P (T) | 0.8422 | P < 0.05 | P < 0.05 | 0.1083 | |
| **Stages** | **Number of pods (10 plants)** | | | | |
| | **Control** | **Thiamethoxam + λ-cyhalothrin** | **Acetamiprid + α-cypermethrin** | **Dinotefuran + α-cypermethrin** | **P (S)** |
| V6/V8 | 448.25 Ab | 675.50 Aa | 628.50 Aa | 667.50 Aa | P < 0.05 |
| R1 | 494.50 Ac | 686.75 Aab | 650.25 Ab | 729.75 Aa | P < 0.05 |
| R4 | 481.50 Ab | 667.25 Aa | 503.50 Bb | 725.50 Aa | P < 0.05 |
| R5.3 | 477.00 Aa | 482.25 Ba | 492.00 Ba | 483.75 Ba | P = 0.9714 |
| R5.5 | 480.50 Aa | 481.00 Ba | 465.75 Ba | 480.75 Ba | P = 0.9514 |
| R6 | 466.00 Aa | 448.00 Ba | 473.00 Ba | 465.75 Ba | P = 0.8743 |
| P (T) | 0.7685 | P < 0.05 | P < 0.05 | P < 0.05 | |
| **Stages** | **Percentage of damaged seeds (%)** | | | | |
| | **Control** | **Thiamethoxam + λ-cyhalothrin** | **Acetamiprid + α-cypermethrin** | **Dinotefuran + α-cypermethrin** | **P (S)** |
| 1 - V6/V8 | 71.25 Aa | 25.20 Cc | 31.80 Cb | 23.40 BCc | P < 0.05 |
| 2 - R1 | 72.78 Aa | 29.40 Bc | 33.33 Cb | 22.68 Cd | P < 0.05 |
| 3 - R4 | 72.05 Aa | 30.33 Bc | 45.80 Bb | 25.68 Bd | P < 0.05 |
| 4 - R5.3 | 72.05 Aa | 73.25 Aa | 72.28 Aa | 69.65 Aa | P = 0.0508 |
| 5 - R5.5 | 72.50 Aa | 70.80 Aa | 72.65 Aa | 69.48 Aa | P = 0.0553 |
| 6 - R6 | 67.63 Bb | 71.58 Aa | 70.35 Aa | 71.68 Aa | P < 0.05 |
| P (T) | P < 0.05 | P < 0.05 | P < 0.05 | P < 0.05 | |
| **Stages** | **Yield (kg·ha⁻¹)** | | | | |
| | **Control** | **Thiamethoxam + λ-cyhalothrin** | **Acetamiprid + α-cypermethrin** | **Dinotefuran + α-cypermethrin** | **P (S)** |
| V6/V8 | 2367.33 Ac | 3689.28 Aab | 3411.20 Ab | 3870.93 Aa | P < 0.05 |
| R1 | 2336.08 Ad | 3250.58 Bb | 2827.40 Bc | 3848.75 Aa | P < 0.05 |
| R4 | 2304.58 Ad | 3298.80 Bb | 2850.33 Bc | 3762.53 Aa | P < 0.05 |
| R5.3 | 2402.35 Ac | 3014.23 BCb | 2492.83 Cc | 3358.75 Ba | P < 0.05 |
| R5.5 | 2290.90 Ab | 2876.43 Ca | 2477.38 Cb | 2881.25 Ca | P < 0.05 |
| R6 | 2251.88 Aa | 2236.25 Da | 1883.23 Db | 2329.20 Da | P < 0.05 |
| P (T) | 0.9357 | P < 0.05 | P < 0.05 | P < 0.05 | |

[1]Means followed by the same upper-case letters in columns and lower-case letters in rows, do not differ by the LSD test (5%).

Yield also showed significant interactions between the active ingredients and development stages. Yield was lowest in the control regardless of developmental stage and highest in the thiamethoxam + λ-cyhalothrin in V6/V8, dinotefuran + α-cypermethrin treatments at V6/V8, R1 and R4. The lowest average was in the acetamiprid + α-cypermethrin treatment at R6 (Table 2).

Multivariate analysis showed that the treatments responsible for variation in the percentage of damaged seeds (GRD) were 4:3

(application at R5.3 and acetamiprid + α-cypermethrin); 3:3 (application at R4 and acetamiprid + α-cypermethrin), and 6:2 (application at R6 and thiamethoxam + λ-cyhalothrin). Infestation was highest in the 6:1 treatment (application at R6 and the control). The greatest variation in the number of pods (NVA) occurred in 2:3 (application at R1 and acetamiprid + α-cypermethrin), 1:3 (application at V6/V8 and acetamiprid + α-cypermethrin), 3: 2 (application at R4 and thiamethoxam + λ-cyhalothrin), and 2:2 (application at R1 and thiamethoxam + λ-cyhalothrin) (Fig. 1).

## DISCUSSION

Pentatomid stink bugs are the most important pest group for soybean pods and seeds and require IPM programs that apply efficient insecticides at appropriate phenological stages (FIORIN et al., 2011).

In general, when controls were applied at later stages of soybean development (R4 to R6) stink bug infestations were higher, which resulted in lower NPD, higher PDS and lower YLD. Larger pest populations at later plant stages may be explained by greater food availability and overlapping generations of pests, which increase pest densities and lead to greater soybean pod and seed results (GORE et al., 2006).

While stink bugs can feed on various plant organs, they prefer soybean pods and seeds. Infestations at earlier developmental stages lead to pod abortion and lower seed weight. Stink bug populations tend to grow as soybean pods develop due to the greater availability of food (CORRÊA-FERREIRA, 2005). The current study showed that applications from V6/V8 to R4 of thiamethoxam + λ-cyhalothrin and dinotefuran + α-cypermethrin were associated with greater numbers of pods, which may have resulted from smaller stink bug infestations during vegetative and early reproductive stages. Reductions in NPD from R3 to R6 may be related to pod abortion caused by the salivary activity of stink bugs during feeding (MILES, 1972; BOETHEL et al., 2000).

The lowest average stink bug infestation occurred in the thiamethoxam + λ-cyhalothrin and dinotefuran + α-cypermethrin treatments. Similarly, KAMMINGA et al. (2009) found that neonicotinoid and dinotefuran provided efficient control of the stink bug species *Acrosternum hilare* and *Euschistus servus* (Hemiptera: Pentatomidae) in soybeans.

Smaller infestations in the thiamethoxam + λ-cyhalothrin treatment may have resulted from positive interactions between the pyrethroid λ-cyhalothrin and the neonicotinoid thiamethoxam. Here, the active ingredient λ-cyhalothrin is very lipophilic and therefore does not readily permeate the plasma membrane or translocate through phloem. It also does not move through xylem easily because it lacks water

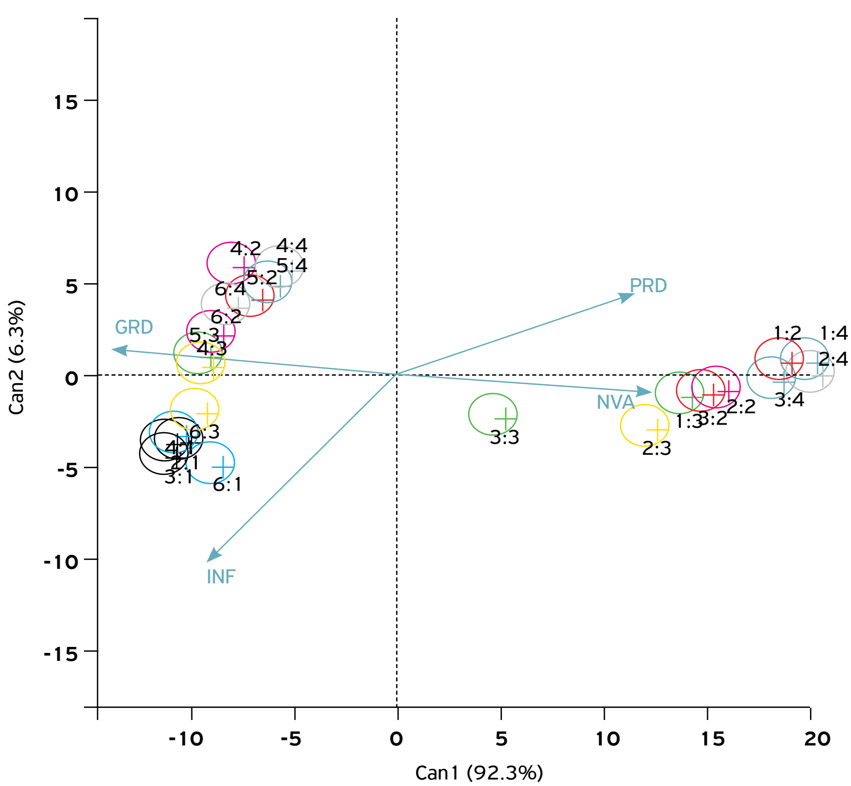


**Figure 1.** Multivariate analysis of the principle components responsible for variation in mean numbers of damaged seeds (GRD), infestation (INF), number of pods damaged (NVA) and yield (PRD).

solubility. Consequently, it is most effective at the point of contact. Conversely, thiamethoxam is polar and therefore moves quickly through xylem, which prolongs its effect since it can reach areas that the other active ingredient is unable to reach. Thus, one active ingredient complements the other and expands the overall spectrum of activity (FARIAS et al., 2006; MILHOME et al., 2009). These characteristics demonstrate the advantage of mixing neonicotinoids and pyrethroids in controlling stink bugs. CULLEN; ZALOM (2007) showed that a mixture of these two chemical groups was more efficient at controlling the stink bug *Euschistus conspersus* (Uhler) (Hemiptera: Pentatomidae) than when used separately.

At the end of the vegetative period, stink bugs leave quiescence and/or alternative host plants and start to migrate to soybeans (CORRÊA-FERREIRA, 2005). Therefore, infestations during early developmental stages are less intense, but increase over time. Peak infestations occur during the reproductive stage when food is more abundant. Nevertheless, treatments that start at R1 in the current study provided efficient control since average infestations were lowest during this phase. However, none of the treatments provided complete control, which may be due to possible reinfestations, natural fluctuations or other hatches occurring in the field (KAMMINGA et al., 2009).

Stink bug dispersion occurs naturally in soybean crops, with populations growing until the end of the seed filling stage (R6) and decreasing thereafter. After this stage, the pest seeks alternative host plants and/or diapause niches, where they remain until the next soybean crop (CORRÊA-FERREIRA; PANIZZI, 1999). In the present study, the infestation did not follow this pattern and, instead, persisted through the final crop development stages.

The lowest percentage of damaged seeds occurred in the dinotefuran + α-cypermethrin treatment started in R1. This may have resulted from the higher yield in this treatment, in which the affected seeds were smaller, wrinkled, and hollow, which reduced their final weight (CORRÊA-FERREIRA, 2005). Several authors have identified pentatomid stink bug infestations as a factor that limits soybean yields (JESUS et al., 2013; SOUZA et al., 2016).

These results indicate that combinations of chemical groups applied at optimal stages of soybean growth are important factors to be considered in the IPM control of stink bugs. However, these alternatives alone do not guarantee the successful control of pests in soybean crops. Instead, various strategies must be available so that soybean growers can choose the most effective and environmentally responsible methods for controlling soybean pests (BUENO et al., 2015). Indiscriminate use of insecticides does not guarantee greater soybean yields. Instead, IPM practices provide the best alternative for controlling soybean pests (BUENO et al., 2011).

## CONCLUSION

Stink bug infestations were lowest when applications commenced during the vegetative stages (V6-V8). The number of pods and yields were higher, and the percentage of damaged seeds was lower in the dinotefuran + α-cypermethrin treatment when applications were started between V6/V8 and R4.

Since dinotefuran + α-cypermethrin reduced stink bug populations and increased yields, it can be considered as alternative in IPM programs for soybeans.

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**AVAILABILITY OF DATA AND MATERIAL:** The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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