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Assessment of a more conservative stink bug economic threshold for managing stink bugs in Brazilian soybean production

Adeney de Freitas Bueno [a,*], Orcial Ceolin Bortolotto [b], Aline Pomari-Fernandes [c], José de Barros França-Neto [a]

[a] Embrapa Soybean, P.O. Box 231, Londrina County, State of Paraná, Postal Code 86001-970, Brazil
[b] Federal University of Paraná, Setor de Ciências Biológicas, Departamento de Biologia, P.O. Box 19020, Postal Code: 81531-980, Curitiba, Paraná, Brazil
[c] Instituto Agronômico do Paraná, Setor de Entomologia Agrícola, Rod. Celso Garcia Cid, km 375, Postal Code 86047-902, Londrina, Paraná, Brazil

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A B S T R A C T

The objective of this study was to assess the stink bug economic threshold for soybean integrated pest management decisions. For this purpose, a replicated experiment was implement in a commercial soybean crop located in Arapongas, Parana State, Brazil, during two crop seasons: 2010/2011 and 2011/12. Treatments consisted of different stink bug densities triggering the application of insecticides, ¼ of the economic threshold (ET) (= 0.5 stink bugs m^{-1}) and ET (= 2 stink bugs m^{-1}), and without applying an insecticide (control). The stink bugs were quantified weekly and all specimens were identified to the species level. At harvest, yield and quality of the seeds were also measured. In all crops, *Euschistus heros* was the most abundant species. The highest yield and percentage of viable seeds were found in the 'BMX Power RR′ cultivar (indeterminate growth cultivar), indicating a better seed quality. At the end of the experiment, there was no observed difference in yield between different stink bug management thresholds, indicating the effectiveness of the control when adopting ET. This study demonstrates that decreasing the economic threshold increased the number of required insecticide applications, but did not increase yield or bean quality neither the net income when an economic analysis was performed.

1. Introduction

Currently, soybeans [*Glycine max* (L.) Merrill] are one of the world's major crops, accounting for half of the global demand for oil and vegetable protein, with an annual production of around 262 million tons (Oerke and Dehne, 2004; Faostat, 2013). However, this production could be even greater if the loss from pests was minimized (Oerke, 2006). Among the different insects that attack the crop, piercing-sucking bugs are noteworthy for feeding directly from the pods, seriously affecting crop yields beyond the physiological and sanitary quality of the seeds (Corrêa-Ferreira and Azevedo, 2002). In this complex of stink bugs belonging to the family Pentatomidae, there have been at least 54 species reported from soybean-growing areas (Panizzi and Slansky, 1985). The Neotropical brown stink bug, *Euschistus heros* (Fabricius, 1794) (Hemiptera: Pentatomidae), is the most abundant species in South America, mainly in the central region of Brazil at latitudes between 0° and 23° (Panizzi and Corrêa-Ferreira, 1997).

In order to mitigate losses caused by pests and consequently increase profits, growers control these phytophagous arthropods (Zalucki et al., 2009). Currently, the primary method of pest control adopted by soybean growers is the use of chemical insecticides, often applied erroneously and excessively (Song and Swinton, 2009; Panizzi, 2013). However, for sustainable crop management, it is crucial to adopt strategies for pest control within the context of integrated pest management (IPM). IPM is based on the premise that certain levels of plant pests are tolerable without reducing economic production (Higley and Peterson, 1996). In this context, Stern et al. (1959) defined the smallest population of pests that can cause economic damage to plants as the economic injury level (EIL). However, to avoid reaching the EIL, causing a yield loss, management is supposed to be undertaken a little earlier, at the economic threshold (ET), which is the economically correct time for initiating a measure of control and thus preventing the population of insects

* Corresponding author. Embrapa Soybean, Rod. Carlos João Strass, Distrito de Warta, Caixa Postal 231, CEP 86001-970, Londrina, Paraná, Brazil.
E-mail addresses: adeney.bueno@embrapa.br (A.F. Bueno), bortolotto.orcial@gmail.com (O. Ceolin Bortolotto), alinepomari@gmail.com (A. Pomari-Fernandes), jose.franca@embrapa.br (J.B. França-Neto).

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from exceeding the EIL (Pedigo et al., 1986; Prokopy and Kogan, 2003; Bueno et al., 2013.).

The current recommended ET for controlling stink bugs in Brazil is 2 insects per meter for grain production and only 1 per meter for crop seeds (Bueno et al., 2013). In Mississippi, for example, the ET for the control of stink bugs in soybeans is higher than the one adopted in Brazil, at 3.3 per meter (Catchot, 2008). However, in recent years, new strategies have been adopted in the cultivation of soybeans, such as the planting of higher yielding cultivars (Chocorosqui and Panizzi, 2004; Panizzi, 2013). Most of these new cultivars are of indeterminate growth habit. Thus, in the last 40 years the soybean yield has doubled, moving from an average yield of less than 1500 kg ha^{-1} in the 1970's to about 3000 kg ha^{-1} today. This yield increase, along with higher prices for soybeans and the low cost of many insecticides, has fostered questions about the validity of the economic thresholds. Regarding defoliators, Bueno et al. (2011a) found that the ET remains safe, and that the indeterminate habit cultivars are even more tolerant and productive than those cultivars with determinate growth. In contrast to peanut crops (*Arachis hipogaea* L.), Prasad et al. (2007) argued that cultivars with indeterminate growth may be more sensitive to loss of production because of directional translocation of assimilates to compensate for the loss of leaf area. However, there is no study that has reassessed the ET for decision making regarding the management of stink bugs. Thus, the aim of this study was to assess the stink bug economic threshold for soybeans in IPM decisions.

2. Materials and methods

An experiment was carried out under field conditions during two consecutive soybean seasons (2010/2011 and 2011/2012) in the municipality of Arapongas (23°25′12″S, 51°25′31″W) in the northern state of Paraná (PR), Brazil. It was conducted during the growing year (crop season) of 2011/2012 using an experimental design with randomized blocks, with 2 cultivars (different growth habits - determinate and indeterminate growth) × 3 levels of action for stink bug management (untreated control and economic thresholds of 0.5 and 2 stink bugs per meter), with four replicates (plots). Plots were 50 rows wide (0.45 m row spacing) by 25 m long for a total plot area of 562.5 m^2. In the first harvest (2010/2011), the experiment was conducted only on cultivars with indeterminate growth ('BMX Power RR′), but assessing the same levels of action and using the same methodology.

2.1. Soybean sowing and cultivars

In the first season (2010/2011), the area was sown on Oct 25, 2010 with the cultivar 'BMX Power RR' (maturity group 6.7, indeterminate growth) at 15 seeds per meter. In the second season (2011/2012), the area was sown on Oct 24, 2011 with the cultivars 'BMX Power RR' (maturity group 6.7, indeterminate growth) and 'BRS 294 RR' (maturity group 6.3, determinate growth) at 15 seeds per meter.

2.2. Plant protection management

Applications of insecticides for caterpillars (*Bacillus thuringiensis* 13.44 g.a.i. ha^{-1}; Dipel® 400 mL ha^{-1}), herbicides (glyphosate 1440 g.a.i. ha^{-1} Roundup 3L ha^{-1}), and fungicides (azoxystrobin + cyproconazol 93.33 g.a.i. ha^{-1}; Priori Xtra® 300 mL ha^{-1}) were also made in all treatments (including the control), to isolate the effect of stink bug infestation in the experiment. During the soybean season, herbicides were applied twice (2 and 5 weeks after soybean emergence) in association with the application of *B. thuringiensis*. The fungicides were applied three times, the first application in the early stage of R$_3$ (Fehr et al., 1971) and the other applications following at intervals of 21 days.

The insecticide used for controlling stink bugs was thiamethoxam + lambda-cyhalothrin 26.5 + 35.25 g.a.i. ha^{-1} (Engeo Pleno® 250 mL ha^{-1}), always applied when the economic threshold of each treatment had been reached. All pesticides (herbicides, fungicides, and insecticides) were applied with a CO_2 pressurized backpack sprayer (Herbicat®) adjusted to a spray volume of 150 L ha^{-1} using hollow cone, model TXVK-8 tip. Spraying was carried out under appropriate environmental conditions (winds below 6 km h^{-1}, relative humidity above 50%, and a maximum temperature of 25 °C).

2.3. Economic threshold evaluation

The management of stink bugs consisted of different thresholds for initiating insecticide application. In this work, the application thresholds were ¼ ET (= 0.5 stink bugs per meter) and ET (= 2 stink bugs per meter), and there was a third treatment without any applications (control).

2.4. Population assessment of stink bugs in soybeans

Samples were taken weekly starting from stage V$_1$ until soybean maturation. For this, a ground cloth (1.0 m long × 1.2 m large) positioned horizontally on the ground, parallel to soybean rows, was used for sampling. Ground cloth was large enough to cover all ground and also the adjacent soybean row. In each treatment, four random samples were taken from 1 m sections of rows, counting stink bugs longer than 0.5 cm (corresponding to the adults and nymphs from 3rd to 5th instars), and all individuals were identified to species.

Upon the full maturity of soybean grains (R$_8$ phenological stage) (Fehr et al., 1971), plants were collected from 5-m sections of the two central rows of each replicate. These samples were then threshed individually and evaluated. The weight and moisture content of each sample were recorded, and these values were then corrected for yield adjusted to 13% seed moisture.

2.5. Tetrazolium test

Tetrazolium test was conducted accordingly to the methodology described by França-Neto et al. (1998). Briefly this procedure includes two sub-samples of 50 seeds per plot which were wrapped in a paper substrate filter moistened with sterile H_2O equivalent to 2.5 times the weight of the seeds. The samples were placed in controlled environmental conditions (environment chambers) for 16 h at 25 ± 2 °C. The seeds were then immersed in a solution of 0.075% tetrazolium salts (2,3,5-triphenyl tetrazolium chloride) and placed in an oven at 40 °C for 2 h and 30 min in the dark. This procedure differentiates living tissues from dead tissues in embryos of seeds on the basis of the dehydrogenase enzyme (enzyme breathing) activity. After the hydration of a seed, the activity of dehydrogenase enzymes increases, resulting in the release of hydrogen ions, which reduces the solution of colorless tetrazolium salt into a red formazan compound called Formazan. Bright red spots indicate living cells, whereas dead cells remain colorless. After a defined period, the seeds were washed in running water and individually inspected for stink bug damage. A scale of 6–8 (%) indicates the percentage of seeds with sufficiently severe damage to make them unviable.

2.6. Data analysis

Applying soybean values of US$ 0.43/soybean kilogram in 2010/