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Effect of seed treatment with insecticides on the control of *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) in soybean

Efeito do tratamento de sementes com inseticidas no controle de **Spodoptera frugiperda** *(J. E. Smith) (Lepidoptera: Noctuidae) na cultura da soja*

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ABSTRACT: Fall armyworm is one of the main insect pests in Brazil. Thus, the present work aimed to evaluate the seed treatment effect on the control of *Spodoptera frugiperda* in initial infestations of soybean crops. The experimental design was completely randomized with four replicates of six insecticide treatments applied through seed treatment: imidacloprid plus thiodicarb at the dose of 52.5 plus 105 g a.i. (active ingredient) 100 kg^{-1} of seed (Cropstar® 0.350 L 100 kg^{-1} of seed); thiamethoxam at 105 g a.i. 100 kg^{-1} of seed (Cruiser 350 FS® 0.3 L 100 kg^{-1} of seed); chlorantraniliprole at 62.5 g a.i. 100 kg^{-1} of seed (Dermacor® 0.1 L 100 kg^{-1} of seed); cyantraniliprole at 120 g a.i. 100 kg^{-1} of seed (Fortenza 600 FS® 0.2 L 100 kg^{-1} of seed); fipronil plus pyraclostrobin and thiophanate-methyl 50 + 5 + 45 g a.i. 100 kg^{-1} of seed (Standak Top® 0.2 L 100 kg^{-1} of seed), and a control treatment. The experiment was carried out in a greenhouse. Diamide insecticides (chlorantraniliprole and cyantraniliprole) presented the best results among all treatments, with lower consumption of the treated leaves by the caterpillars and greater control efficacy of this insect. We verified that seed treatment is a viable alternative for controlling *S. frugiperda* at the beginning of crop development, when the caterpillar presents the behavior of cutting the seedlings and/or the consumption of leaf area, causing a reduction in the plant population and a consequent yield loss.

KEYWORDS: chemical control; diamide; fall armyworm; mortality.

RESUMO: A lagarta-do-cartucho é um dos principais insetos-praga no Brasil. Assim, o presente trabalho teve por objetivo avaliar o efeito do tratamento de sementes no controle de *Spodoptera frugiperda* nas infestações iniciais da cultura da soja. O delineamento experimental foi inteiramente casualizado, com quatro amostras replicadas de seis tratamentos inseticidas aplicados via tratamento de sementes: imidacloprida mais tiodicarbe na dose de 52,5 mais 105 g i.a. (ingrediente ativo) 100 kg^{-1} de sementes (Cropstar® 0,350 L 100 kg^{-1} de sementes); tiametoxam a 105 g i.a. 100 kg^{-1} de sementes (Cruiser 350 FS® 0,3 L 100 kg^{-1} de sementes); clorantraniliprole a 62,5 g i.a. 100 kg^{-1} de sementes (Dermacor® 0,1 L 100 kg^{-1} de sementes); ciantraniliprole a 120 g i.a. 100 kg^{-1} de sementes (Fortenza 600 FS® 0,2 L 100 kg^{-1} de sementes); fipronil mais piraclostrobina e tiofanato-metílico 50 + 5 + 45 g i.a. 100 kg^{-1} de sementes (Standak Top® 0,2 L 100 kg^{-1} de sementes) e um tratamento controle. O experimento foi conduzido em uma vegetação. Dentre todos os tratamentos, os inseticidas do grupo químico das diamidas (clorantraniliprole e ciantraniliprole) apresentaram os melhores resultados, com consumo inferior pelas lagartas das folhas tratadas e maior eficiência de controle deste inseto. Foi constatado que o tratamento de sementes é uma alternativa viável para o controle de *S. frugiperda* no início do desenvolvimento da cultura, quando a lagarta apresenta o comportamento de cortar as plântulas e/ou consumir área foliar, ocasionando uma redução da população de plantas e uma consequente perda de produtividade.

PALAVRAS-CHAVE: controle químico; diamidas; lagarta-do-cartucho; mortalidade.

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INTRODUCTION

Soybean cultivation is responsible for several changes in the Brazilian agriculture and agribusiness since the mid-1970s, and soybeans are the main agricultural product for export (ESPÍNDOLA, 2015). Currently, soybeans are cultivated in the most unlike geographical regions of the country, and the states of Mato Grosso, Paraná, Rio Grande do Sul and Goiás are considered the largest national producers. During the last crop season, Brazil cultivated approximately 33 million hectares, producing the equivalent to 114 million tons and remaining the second largest producer and exporter in the world, only behind the United States of America (CONAB, 2018).

Crop cultivation intensification in agricultural areas, climate change, development of resistance mechanisms in phytopathogenic agents, introduction of exotic pests, and indiscriminate use of pesticides have led to an imbalance in agroecosystems, making the rational use of several management strategies necessary in food production (DEL BEM JÚNIOR, 2017).

Planting crops with different phenologies, such as corn and cotton (grown in the summer), and cover plants, such as millet (grown in the period between harvests), close to one another facilitates the movement of *Spodoptera frugiperda* among plant species (NAGOSHI, 2009). This may be the cause of the more frequent occurrence of this pest in crops where it was previously considered sporadic or secondary (BARROS et al., 2010). In soybean, *S. frugiperda* attacks are more frequent among seedlings due to the presence of caterpillars in the straw, with higher occurrence in fields of the Cerrado biome, which is usually associated with periods or years of low rainfall.

Therefore, seed treatment with insecticide is recommended for producers who adopt good agricultural practices and as part of integrated pest management, since it ensures the rational use of products, reduction of environmental impact, and maintenance of the population of natural enemies at adequate levels. It also regulates the population fluctuations of the most important pests. According to BALARDIN et al. (2011), this practice is efficient since it assures an adequate population of plants when edaphoclimatic conditions during sowing are unfavorable to germination and rapid emergence. DHINGRA (1985) affirms that seed treatment is an important process and the first effective step for plant protection. The absence of this initial form of protection may have a direct impact on crop yield, with a significant reduction in farmer profitability (BUZZERIO, 2010).

In Brazil, there are several chemical groups used in seed treatment to control different soybean pests, such as methylcarbamate, pyrazole, abamectin, and diamides. These insecticides are found in the market independently or in association with other products that may or may not influence caterpillars (CHIESA et al., 2016). According to the author of such study, by analyzing each active ingredient in isolation, it is possible to evaluate the contribution in terms of efficacy of each one for use as a background to elaborate the most efficient strategies for pest management and control.

Therefore, the goal of this study was to evaluate the seed treatment effect with insecticides on the control of *S. frugiperda* in initial infestations of soybean crops under environmentally controlled conditions.

MATERIALS AND METHODS

Experimental characterization

The experiment was carried out in a greenhouse at the Crop Protection Department, School of Agronomical Sciences, *Universidade Estadual Paulista "Júlio de Mesquita Filho"* (Unesp), Botucatu, São Paulo, Brazil. The soybean seeds were sown on February 10, 2017, using five seeds of the BMX Turbo RR cultivar (germination estimated at 80%) per pot and maintaining three plants per pot after thinning. For this purpose, 24 plastic pots with a capacity of 1.0 kg were filled with Tropstrato® substrate composed of pine bark, peat, vermiculite, simple superphosphate, and potassium nitrate.

For the seed treatment, 2-L plastic bags were used, in which water and insecticides were added for each treatment at the correct doses for treating 0.5 kg of seed of the BMX Turbo RR cultivar. The seeds were then transferred to the plastic bags and vigorously agitated until complete coverage with the respective products, according to the methodology proposed by CUNHA et al. (2015).

The experimental design was completely randomized with six treatments and four replicates, and each plot consisted of one pot. The following treatments were used: T1 – imidacloprid plus thiodicarb at 52.5 + 105 g a.i. 100 kg^{-1} of seed (Cropstar® at 0.350 L 100 kg^{-1} of seed); T2 – thiamethoxam at 105 g a.i. 100 kg^{-1} of seed (Cruiser 350 FS® at 0.3 L 100 kg^{-1} of seed); T3 – chlorantraniliprole at 62.5 g a.i. 100 kg^{-1} of seed (Dermacor® at 0.1 L 100 kg^{-1} of seed); T4 – cyantraniliprole at 120 g a.i. 100 kg^{-1} of seed (Fortenza 600 FS® at 0.2 L 100 kg^{-1} of seed); T5 – fipronil plus pyraclostrobin plus thiophanate-methyl at 50 + 5 + 45 g a.i. 100 kg^{-1} of seed (Standak Top® at 0.2 L 100 kg^{-1} of seed); T6 – control treatment without seed treatment according to Table 1.

Caterpillar infestation

Third-instar *S. frugiperda* larvae were acquired from the Promip® biofactory, located in Engenheiro Coelho city, São Paulo, and transported to the laboratory in 300 mL plastic cups containing 100 larvae with a specific diet developed by the company laboratory and with cooled gel plates for appropriate temperature maintenance.

The release of third-instar *S. frugiperda* larvae occurred ten days after seedling emergence by applying one caterpillar per plant for a total of three caterpillars per pot. These caterpillars were transferred with a brush to the soybean leaflets, and the pots were then covered with voile fabric (anti-fly fabric). The evaluations were conducted at 24, 48, and 72 hours after caterpillar transference, all at the same time, by measuring the consumed leaf area and the mortality of the caterpillars in each treatment.

On the last day of the leaf area consumption evaluation, all the leaves that showed visible damage were collected and separated according to the treatment and replicate. The damaged leaf area was determined with the digital image analysis software from the American Phytopathological Society (APS), the Assess Image Analysis Software for Plant Disease Quantification, version 2.0 (Lamari, Department of Plant Science, University of Manitoba, Winnipeg, Manitoba, Canada). Data regarding the number of dead caterpillars were $(x + 1)^{1/2}$ transformed and subjected to analysis of variance according to the F test using the Sisvar® program, version 5.6 (FERREIRA, 2011). The mean values were compared by Tukey's test ($p < 0.05$).

RESULTS AND DISCUSSION

Data obtained in this study show that the insecticidal treatments thiamethoxam (T2), fipronil plus pyraclostrobin and thiophanate-methyl (T5), and imidacloprid plus thiodicarb (T1) did not differ statistically from the control (T6). It indicates the low efficiency of these insecticides in controlling *S. frugiperda* (Fig. 1). These results corroborate those obtained by BUENO et al. (2010), who observed low efficiency in the control of third- and fourth-instar *S. frugiperda* larvae with the insecticide thiodicarb at 600 g a.i. (less than 40%).

The products that showed low efficiency are not officially registered to control this insect pest, but they are used in mixtures intended for not only the seed treatment according to the on-farm method, but also the industrial seed treatment (IST).

The chlorantraniliprole (T3) and cyantraniliprole (T4) insecticidal treatments differed statistically from the other treatments, presenting smaller leaf areas consumed by the caterpillars of 1.75 and 1.87%, respectively. These treatments are, therefore, important management tools for decreasing leaf area losses that consequently reduce crop yield (Figs. 1 and 2). The anthranilic diamide insecticide group, to which T3 and T4 belong, has high insecticidal activity and low toxicity to mammals as main characteristics (LAHM et al., 2007). These insecticides bind to ryanodine receptors of the insect in muscle cells, promoting the uncontrolled exit of calcium from the sarcoplasmic reticulum caused by channel opening, thereby resulting in muscle paralysis and insect death (CORDOVA et al., 2006).

In terms of caterpillar mortality, the cyantraniliprole (T4) insecticidal treatment differed from the other treatments,

Table 1. Characterization of the insecticides and their respective dosages used in the seed treatment.

Treatment	Trade name	Active ingredient	Dosage (mL 100 kg^{-1} of seed)
1	Cropstar®	Imidacloprid + Thiodicarb	500
2	Cruiser®	Thiamethoxam	200
3	Dermacor®	Chlorantraniliprole	100
4	Fortenza®	Cyantraniliprole	200
5	Standak Top®	Fipronil + Pyraclostrobin + Thiophanate-Methyl	200
6	Control	-	-

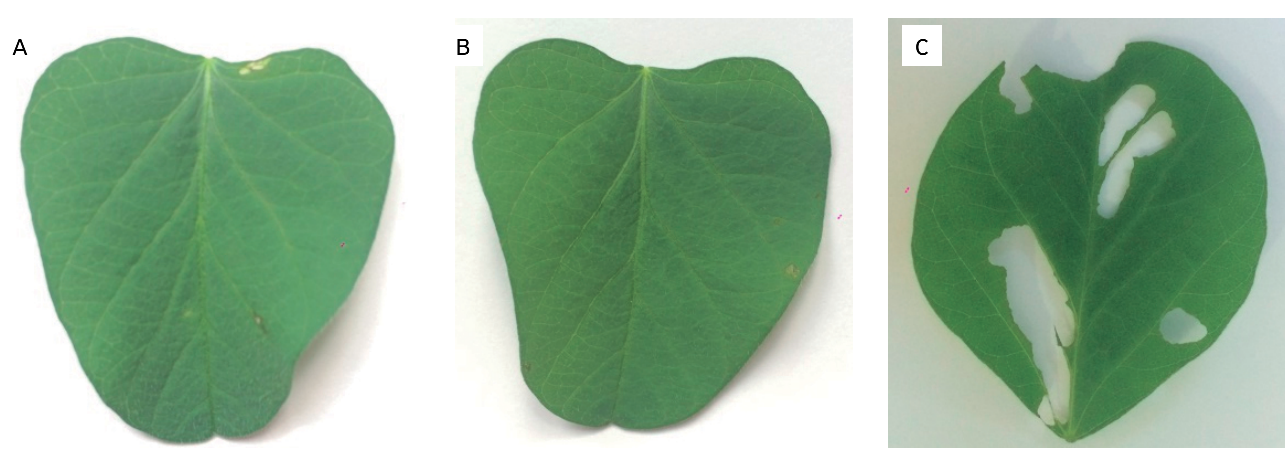

Figure 1. Soybean leaflet after seed treatment with chlorantraniliprole (A) and cyantraniliprole (B) and control without treatment (C).

with higher control efficiency in the first 24 hours after the release of caterpillars onto the plants (90.91%). In contrast, the chlorantraniliprole (T3) and imidacloprid plus thiodicarb (T1) insecticidal treatments did not differ statistically from T4, but they showed lower control efficiency on the first day of evaluation, with efficacy values of 72.73 and 54.55%, respectively (Table 2). Thiamethoxam (T2) showed the lowest efficiency (9.09%), which is not different from the untreated control. KUSS et al. (2016), using second instar *Helicoverpa armigera* larvae that received leaves harvested 24 hours after spraying, observed better control efficiency associated with the chlorantraniliprole and flubendiamide (diamides) insecticidal treatments, with 100% accumulated insect mortality three days after caterpillar exposure. Thus, the capacity

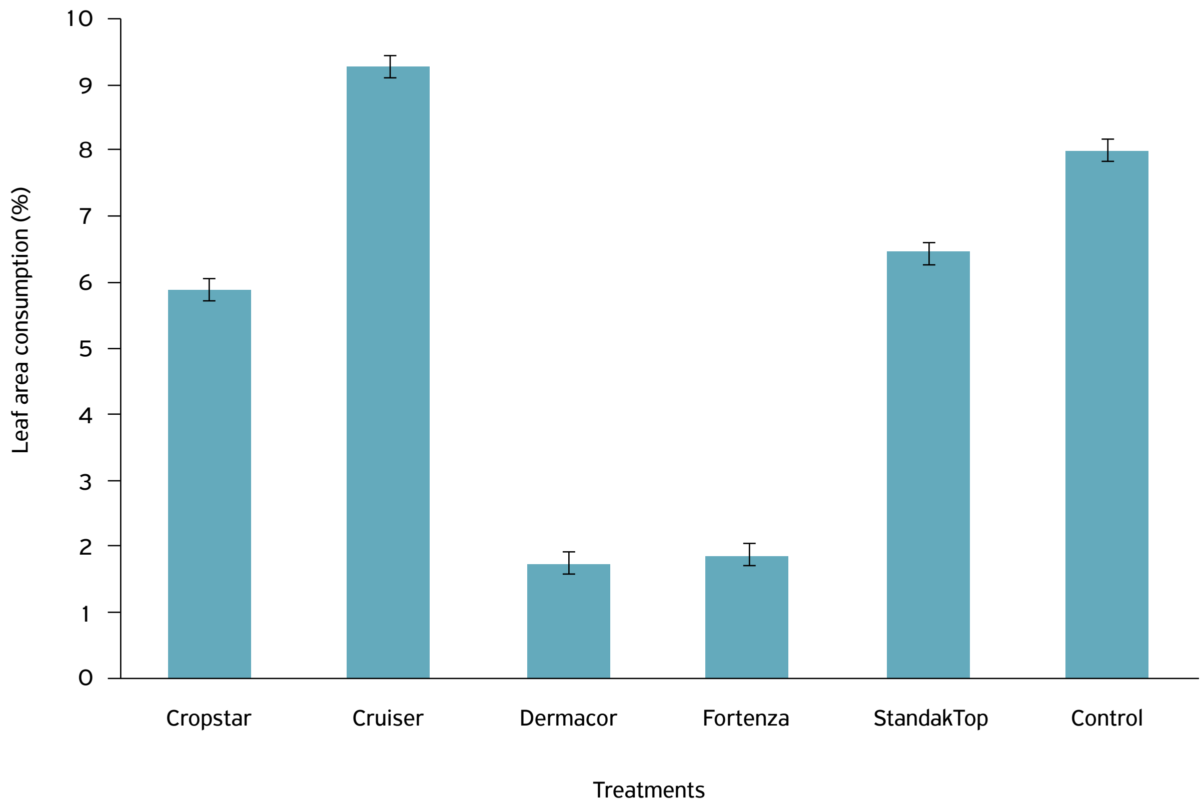

Figure 2. Effect of seed treatment with insecticides on the percentage of leaf area consumed by third instar *Spodoptera frugiperda* larvae (Coefficient of Variation in %: 13.73; Least significant difference: 0.78).

Table 2. Mortality and control efficiency (%) of insecticides applied in the seed treatment against *Spodoptera frugiperda* one, two, and three days after caterpillar release among soybean plants.

Treatment	Trade name	Time after release of caterpillars (hours)					
		24		48		72	
		M¹	EF (%)	M¹	EF (%)	M¹	EF (%)
T1	Cropstar	1,75 ab*	54,55	2,00 a	60,00	2,00 a	60,00
T2	Cruiser	0,50 cd	9,09	0,75 b	10,00	0,75 b	10,00
T3	Dermacor	2,25 ab	72,73	3,00 a	100,00	3,00 a	100,00
T4	Fortenza	2,75 a	90,91	3,00 a	100,00	3,00 a	100,00
T5	Standak Top	1,50 bc	45,45	2,00 a	60,00	2,50 a	80,00
T6	Control	0,25 d	-	0,50 b	-	0,50 b	-
CV (%)		10,64	-	10,65	-	9,98	-
F value		15,90**	-	14,49**	-	17,01**	-

*Means followed by the same letters in a column do not differ according to Tukey's test ($p < 0.05$); M[1]: caterpillar mortality; EF(%): treatment efficiency calculated according to Abbott formula (ABBOTT, 1925); **significant values according to the F test.

for diamide translocation allowed a greater contribution of the insecticide to the apical leaves from the spray treatment intercepted by the other parts of the plant, contributing to better control of second instar larvae 72 hours after spraying (CAMERON et al., 2015).

In the second evaluation, 48 hours after caterpillar release, the treatments with insecticides belonging to the diamide chemical group (T3 and T4) reached 100% caterpillar control. The imidacloprid and thiodicarb (T1) and fipronil plus pyraclostrobin and thiophanate-methyl (T5) treatments did not differ statistically from those that obtained greater control, but they presented a 60% efficacy compared to that of the control. The insecticide thiamethoxam showed the poorest increase in mortality of these insects over time, from 9.09% on the first day to 10% on the second (Table 2).

As a result of poisoning by diamides, the insect undergoes the sudden cessation of feeding, lethargy, paralysis and finally death (HANNIG, 2009). This insecticide presents high activity against *Lepidopteran* species, as well as species of *Coleoptera, Diptera and Hemiptera* (KUHAR et al., 2008; TEMPLE et al., 2009). LAI; SU (2011) reported that the greatest mortality of *Spodoptera exigua* caused by chlorantraniliprole occurred within the first four days of exposure, because it is a slow-acting insecticide that acts primarily via ingestion. The delayed mortality observed for diamides (1-4 days) can be attributed, at least in part, to the fact that diamides need to be ingested to initiate their insecticidal activity. However, diamides act quickly on the target pest, and less than 24 hours of feed disruption, which contrasts with what occurs following the application of other newly developed insecticides (HANNIG et al., 2009).

In the third evaluation, 72 hours after exposure, the insecticidal treatments maintained their control efficiency values in all cases except for T5 (fipronil + pyraclostrobin + thiophanate-methyl), which showed a 20% increase over the final product efficiency. Thus, the insecticidal activity against the caterpillars occurred, for the most part, within 48 hours (Table 2). Therefore, for treatments that did not attain 100% mortality, the alternative to complement the insecticidal effect on the insect targets is to consider the time interval between crop seasons (fallow). This consideration combined with the chemical control performed by the seed treatment may reduce the initial attack of pests on subsequent crops (PEDIGO, 2002).

To improve *S. frugiperda* management in early soybean planting, seed treatment with insecticides of the diamide chemical group should be considered as a control option. Therefore, seed treatment may not only be used to control older instars of *S. frugiperda* caterpillars, but may also be used as a technique that has a relatively low impact on natural enemies, providing greater balance to the agroecosystem.

CONCLUSIONS

Treatment of soybean seeds with insecticides of the diamide chemical group was shown to be the best option for controlling *Spodoptera frugiperda*, significantly reducing the consumed leaf area and quickly increasing caterpillar mortality.

The application of the insecticide thiamethoxam (Cruiser®) through seed treatment showed the lowest control efficiency of *Spodoptera frugiperda* during the evaluation period in soybean plants.

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