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Efficacy of chlorantraniliprole applied in sugarcane planting furrow and foliar spray to control of sugarcane borer

Eficácia de clorantraniliprole aplicado no sulco de plantio e em pulverização no controle da broca da cana

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Abstract

Sugarcane borer (*Diatraea saccharalis*) is one of the most important insect pests in sugarcane crops in Brazil. Historically, this insect has been controlled with releases of parasitoid *Cotesia flavipes*. However, chemical control with diamides and insect growth regulators has been used to help in control of this pest. In this study, the effectiveness of the diamide chlorantraniliprole applied in the sugarcane planting furrow and foliar spray on sugarcane borer damage and production were assessed. The experiment was carried out in an experimental area of SP80-3280 sugarcane variety, planted in November 2016 in Uberaba (Brazil), followed a randomized block design with four treatments: control, chlorantraniliprole foliar (21 g ha^{-1}), chlorantraniliprole furrow (105 g ha^{-1}), and chlorantraniliprole furrow (105 g ha^{-1}) + foliar (21 g ha^{-1}), with five replicates (plots). Each experimental plot had six planting lines of 10 m long spaced 1.5 m (90 m^2). One chlorantraniliprole application in the planting furrow and foliar spray was performed in November 2016 and in March 2017, respectively. All plots were infested with *D. saccharalis* eggs in February and March 2017. In May 2017, the plant height, stalk diameter, and number of tillers were assessed. In October 2017, the mass of stalks, sugarcane borer holes, number and percentage of damaged internodes were evaluated. Chlorantraniliprole applied in the planting furrow did not reduce the damage caused by *D. saccharalis*. The spray of chlorantraniliprole reduced the damage of the sugarcane borer in about 52%. The chlorantraniliprole application did not affect the initial sugarcane development or its production. One chlorantraniliprole spray in sugarcane was not enough to avoid the *D. saccharalis* damage and other additional control measures should be used.

Additional keywords: diamide; *Diatraea saccharalis*; insecticide; systemic.

Resumo

A broca da cana-de-açúcar *Diatraea saccharalis* é uma das mais importantes pragas da cultura no Brasil. Historicamente, esta praga tem sido controlada com liberações do parasitoide *Cotesia flavipes*. No entanto, o controle químico com diamidas e com reguladores de crescimento de insetos tem sido usado para auxiliar o controle da praga. Objetivou-se com este estudo avaliar a eficiência da diamida clorantraniliprole aplicada no sulco de plantio da cana e em pulverização foliar, no dano da broca e na produção da cultura. O experimento foi realizado em uma área experimental de cana-de-açúcar da variedade SP80-3280, plantada em novembro de 2016, em Uberaba (Brasil), seguindo um delineamento de blocos com parcelas casualizadas, com quatro tratamentos: controle, clorantraniliprole foliar (21 g ha^{-1}), clorantraniliprole no sulco (105 g ha^{-1}) e clorantraniliprole sulco (105 g ha^{-1}) + foliar (21 g ha^{-1}), com cinco repetições (parcelas). Cada parcela tinha seis linhas de plantio de 10 m de comprimento, espaçadas em 1,5 m (90 m^2). Uma aplicação de clorantraniliprole no sulco de plantio e foliar foi realizada em novembro de 2016 e em março de 2017, respectivamente. As parcelas foram infestadas com ovos de *D. saccharalis,* em fevereiro e março de 2017. Em maio de 2017, avaliaram-se a altura das plantas, o diâmetro do coleto e o número de perfilhos. Em outubro de 2017, avaliaram-se a massa de colmos, o número de orifícios de saída da broca, o número e a porcentagem de internódios danificados. Clorantraniliprole aplicado no sulco de plantio não reduziu o dano causado por *D. saccharalis*. A pulverização de clorantraniliprole reduziu o dano da broca em 52%. A aplicação de clorantraniliprole não afetou o desenvolvimento inicial da cultura ou a produção de cana-de-açúcar. Uma pulverização de clorantraniliprole em cana-de-açúcar não foi suficiente para evitar o dano de *D. saccharalis,* e outras medidas adicionais de controle devem ser usadas.

Palavras-chave adicionais: diamida; *Diatraea saccharalis*; inseticida; sistêmico.

Introduction

Brazil is the world's largest sugarcane producer with production of around 615 million tons in an area of 8.6 million hectares (CONAB, 2018). The sugarcane borer *Diatraea saccharalis* Fabricius (Lepidoptera: Crambidae) is one of the most important pest of this crop in Brazil (Dinardo-Miranda et al., 2012). This insect causes the death of the apical bud in new plants, and in mature plants causes holes and galleries in the stalk opening entrances to decomposing fungi. The losses in sugar and ethanol production are proportional to the internodes damaged. For each 1% of damaged internode, a reduction of 1.5%, 0.49%, and 0.28% in the mass of stalks, sugar, and ethanol is expected (Arrigoni, 2002). Also, new varieties have been shown to be more susceptible to the sugarcane borer, with greater damage under the same infestation (Dinardo-Miranda et al., 2012).

In sugarcane, despite the long history of biological control, there has been an increase in the use of insecticides to control the sugarcane borer. The insecticide chlorantraniliprole presents a mode of systemic action and it is effective in the control of *D. saccharalis* larvae in rice when the seeds are treated (Sidhu et al., 2014). The biological control with *Cotesia flavipes* (Cameron) (Hymenoptera: Braconidae) is still the main tactic to control the sugarcane borer in Brazil; thus, the selectivity of any insecticide to this parasitoid is desirable. The chlorantraniliprole insecticide does not cause mortality of *C. flavipes*, however, deleterious effects on the offspring were reported (Matioli, 2018). *Trichogramma galloi* Zucchi (Hymenoptera: Trichogrammatidae) is another biological agent to control the sugarcane borer, but chlorantraniliprole presents moderate selectivity to this parasitoid by reducing its parasitism on *D. saccharalis* eggs and the emergence of parasitoids from treated eggs (Antigo et al., 2013; Oliveira et al., 2013).

The diamide insecticides act on the ryanodine receptors of insects and have been shown to be highly effective in the control of different Lepidoptera species (Lahm et al., 2009). Chlorantraniliprole proved to be efficient in the control of *Eoreuma loftini* (Dyar) (Lepidoptera: Crambidae) and *D. saccharalis* in sugarcane in the United States (Wilson et al., 2017). In sorghum, it reduced the damage of *D. saccharalis* larvae in Brazil (Vilela et al., 2017), and in peppers, the application of chlorantraniliprole in drip irrigation controlled *Ostrinia nubilalis* (Hübner) (Lepidoptera: Crambidae) (Ghidiu et al., 2009). The systemic action of chlorantraniliprole allows the insecticide reaches vegetative structures of soybean that develop after the insecticide spray protecting these tissues (Adams et al., 2016). However, in sugarcane, despite the recommendation of chlorantraniliprole for furrow application at planting, as far as we know, there are no published studies that validate the efficacy of this method. In this study, the effectiveness of chlorantraniliprole applied in the sugarcane planting furrow and in foliar spray on sugarcane borer damage and sugarcane biomass production was assessed.

Materials and methods

The experiment was carried out in a sugarcane experimental area located at the Instituto Federal do Triângulo Mineiro, Uberaba, Brazil. The area consisted of 30 rows spaced 1.5 m and 40 m long and was planted with the SP80-3280 sugarcane variety on November 9th, 2016. The soil in the area was harrowed three times (two heavy harrowing and one leveler harrowing) prior to the furrow opening (0.3 m depth). Fertilization was performed at planting and topdressing. Pre-emergence herbicides, amicarbazone, clomazone and diuron + sulfometuron-methyl were also applied. Insecticide fipronil (250 g ha^{-1} of Regent® 800WG) was applied in the planting furrow to control termites and soil beetles (*Sphenophorus* levis and *Migdolus fryanus*) in all plots.

The experiment was set as a randomized block design with four treatments and five replicates (plots). The experimental plot had six lines spaced 10 m long spaced 1.5 m (90 m^2) and useful area of four lines 8 m long by 1.5 m (48 m^2). The treatments were: control (no chlorantraniliprole application), foliar application of chlorantraniliprole 21 g ha^{-1} (Altacor® 350 WG, Du Pont do Brasil S.A., Barueri, SP, Brazil), chlorantraniliprole 105 g ha^{-1} applied in the planting furrow and chlorantraniliprole furrow (105 g ha^{-1}) + foliar (21 g ha^{-1}) .

A backpack sprayer (CO_2 pressurized) with two nozzles was used to apply the insecticide solution using a volume corresponding 200 L ha^{-1}. In the planting furrow treatments, the insecticide was applied after the distribution of the sugarcane stalks ("seedlings"), and before their burying. In the foliar treatments, one application was done on March 14th, 2017. Two infestations with *D. saccharalis* eggs (Biocontrol®, Sertãozinho, SP, Brazil) were done in all plots, on February 13th and on March 30th, 2017. The paper sheets containing *D. saccharalis* eggs were cut into small portions with approximately 100 eggs each and fixed on sugarcane leaves close to their sheaths. Each plot was infested with about 1600 eggs.

The experiment was evaluated in May and in October 2017. In May 2017, the plots were evaluated for the number of tillers in a 3 m line, plant height from the soil base to the new leaf sheet (ruler), and stalk diameter at the base of the stalks (digital caliper). In October 2017, the mass of stalks (biomass production) and sugarcane borer damage were evaluated in the stalks in a 3 m planting line in each plot. The stalks in a 3 m planting line in each plot were cut at the base, drawn from the experimental area, the leaves were removed and the stalks were tied to be weighed with the aid of a balance. For the evaluation of sugarcane borer damage, the same stalks were cut in a transverse direction and its inner part was evaluated for the presence of sugarcane borer and its damage. The number of internodes and damaged internodes in each stalk was determined. The percentage of plot infestation was obtained by calculating the ratio between internodes damaged by *D. saccharalis* or the presence of associated fungi and the total number of internodes.

The data obtained were submitted to analysis of variance (*F* test) and the Scott-Knott test. The variable number of stalk holes was analyzed by generalized linear models, deviance with Poisson distribution and Tukey's test. It was used the software R (R Core Team, 2018) with 95% confidence intervals.

Results and discussion

There was a block effect for the variables plant height, stalk diameter, tiller number, mass of stalks, number of damaged internodes, and percentage of damaged internodes ($P<0.05$), which justifies the experimental design (Table 1).

Table 1 - Analysis of variances of the variables: plant height, stalk diameter, number of tillers 150 days after sprouting; mass of stalks, number of stalk holes, number of internodes damaged, and percentage of internodes damaged after a year of the sprouting under the effect of the insecticide chlorantraniliprole in the sugarcane planting furrow (105 g ha^{-1}), furrow + foliar (105 + 21 g ha^{-1}), and foliar spray (21 g ha^{-1}), Uberaba, Brazil.

Variable	SV	Df	SM	*F*	*P*-valor
Plant height	treatments	3	2.7153	1.8038	0.2001
	blocks	4	4.9750	3.3049	0.0481
	error	12	1.5053		
Stalk diameter	treatments	3	12.2227	1.0437	0.4086
	blocks	4	76.2093	6.5077	0.0050
	error	12	11.7106		
Number of tillers	treatments	3	14.8500	0.9153	0.4627
	blocks	4	112.6250	6.9414	0.0039
	error	12	16.2250		
Mass of stalks	treatments	3	14.4635	1.0838	0.3931
	blocks	4	61.4214	4.6024	0.0175
	error	12	13.3454		
Number of stalk holes	treatments	3	40.4500	2.5833	0.1019
	blocks	4	31.8250	2.0325	0.1536
	error	12	15.6583		
Number of internodes damaged	treatments	3	27.5167	4.1957	0.0302
	blocks	4	45.4250	6.9263	0.0040
	error	12	6.5583		
Internodes damaged (%)	treatments	3	1.0950	3.9477	0.0359
	blocks	4	1.2995	4.6801	0.0165
	error	12	0.2772		

SV: source of variation; df: degrees of freedom; SM: square mean; *F*: F test.; *P*-value: probability value.

At 150 days after sugarcane sprouting, no significant difference was observed to plant height, stalk diameter, and number of tillers (Tables 1 and 2). These results indicate that chlorantraniliprole applied in the planting furrow or foliar did not influence the early sugarcane development. In October 2017, one year after planting, no significant difference was observed to mass of stalks (Tables 1, and 2).

Table 2 - Plant height, stalk diameter, number of tillers after 150 days of sprouting and the mass of stalks after one year of sugarcane planting applied with chlorantraniliprole in the planting furrow (105 g ha^{-1}), furrow + foliar (105 + 21 g ha^{-1}), and foliar spray (21 g ha^{-1}). Uberaba, Brazil.

Treatment	Plant height (cm)	Stalk diameter (mm)	Number of tillers (3m)	Mass of stalks (kg 3m^{-1})
Control	42,2 (±1,3)[1]	17,3 (±0,5)	39,8 (±3,8)	25,2 (±1,8)
Chlorantraniliprole foliar	42,1 (±3,0)	17,2 (±0,8)	39,2 (±2,1)	30,0 (±1,7)
Chlorantraniliprole furrow + foliar	41,7 (±2,7)	16,5 (±0,8)	36,2 (±3,1)	26,1 (±3,7)
Chlorantraniliprole furrow	38,9 (±2,1)	15,7 (±0,5)	39,8 (±2,0)	27,9 (±0,8)
CV (%)[2]	8,3	7,4	10,4	13,5

[1]Mean ± standard error, [2]coefficient of variation.

The chlorantraniliprole foliar treatments presented lower means of holes made by sugarcane borer in comparison to control treatment and chlorantraniliprole applied in the furrow (deviance treatments = 18.108; P = 0.0004). Regarding the damage caused by the sugarcane borer, the lowest means were also verified in the treatments including chlorantraniliprole foliar applications (Table 3). This result indicates that chlorantraniliprole insecticide may be recommended to control sugarcane borer by the foliar application in sugarcane, as it has also been observed to diamides (chlorantraniliprole and flubendiamide) and insect growth regulators (novaluron and tebufenozide) (Wilson et al., 2017).

The percentage of damaged internodes was similar between the control and the chlorantraniliprole applied in-furrow treatments (around 1.5%) (Table 3); however, this damage was below 1% in the chlorantraniliprole foliar treatments. The damaged internodes and percentage of damaged internodes in the treatments including chlorantraniliprole applied via foliar were 51 and 53% lower than in the control treatment, respectively.

The insecticide tebufenozide applied every 15 days for 150 days reduced the damaged internodes from 2.8% (control treatment) to 0.4% (treated plots) (Wilson et al., 2018). These same authors also observed a negative correlation between the damaged internodes and stalk production. This was in disagreement with what was found in this study, where the reduction of damaged stalks with a foliar application of chlorantraniliprole generated no gain in the stalk production. Positive results were obtained in *D. saccharalis* control in sorghum crop by Vilela et al. (2017) with three foliar applications at 20, 37, and 42 days after sowing, with the same dose used in this study (21 g ha^{-1} of chlorantraniliprole). These authors also observed greater damage reductions, from 4.16% in the control treatment to 0.53% of damaged internodes in the chlorantraniliprole treatment.

Table 3 - Number of stalk holes made by the sugarcane borer and number and percentage of damaged internodes after one year of sugarcane planting applied with chlorantraniliprole in the planting furrow (105 g ha^{-1}), furrow + foliar (105 + 21 g ha^{-1}), and foliar spray (21 g ha^{-1}). Uberaba, Brazil.

Treatment	Number of stalk holes (3m)	Number of damaged internodes (3m)	Percentage of damaged internodes
Control	9,6 (±0,7)[1] a[2]	8,4 (±1,2) a[3]	1,62 (±0,2) a[3]
Chlorantraniliprole foliar	4,2 (±2,0) b	4,8 (±2,2) b	0,90 (±0,4) b
Chlorantraniliprole furrow + foliar	4,6 (±2,0) b	3,4 (±1,6) b	0,62 (±0,3) b
Chlorantraniliprole furrow	9,0 (±2,7) a	7,6 (±2,0) a	1,46 (±0,4) a
CV (%)[4]	57,8	42,3	45,8

[1]Mean ± standard error; [2]Means with the same letter in a column are not different by Tukey test (P<0.05); [3]Means with the same letter in a column are not different by Scott-Knott test (P<0.05); [4]Coefficient of variation.

In this study, the application of chlorantraniliprole on sugarcane stalks in the planting furrow has not reduced the damage caused by the sugarcane borer. Despite the artificial infestations of *D. saccharalis* it is likely that also natural infestations have occurred. The assessment of the damage was done after one year of the sugarcane planting and it is not expected that the treatments prevent the damage throughout the period. Despite being a systemic insecticide effective for control of *D. saccharalis* via seed treatment in rice (Sidhu et al., 2014) or via drip irrigation for control of *O. nubilalis* in peppers (Ghidiu et al., 2009), the application of chlorantraniliprole in sugarcane stalks could have had limited absorption or insufficient concentration when there were roots and shoots able to absorb and translocate this chemical into plant. Chlorantraniliprole sprayed on soybean moved to vegetative plant structures, but not to the reproductive structures (Adams et al., 2016). However, in seed treatment, it caused from 40 to 80% mortality of *D. saccharalis* in rice plants after 2 months of its application (Sidhu et al., 2014). Other experiments should be performed with higher doses or drench application in the soil after the sugarcane sprouting. The operating gain from the application of this diamide insecticide together with other soil insecticide and nematicide is not justified if there is no efficacy of this method to control initial infestations of *D. saccharalis*.

Despite chlorantraniliprole is not entirely selective to *C. flavipes* (Matioli, 2018) or *T. galloi* (Antigo et al., 2013; Oliveira et al., 2013) parasitoids, it seems to be an appropriate insecticide to the integrated management of *D. saccharalis*. In addition to the selectivity criteria to choose a control tactic, it must be considered the insecticide cost and effectiveness. In Brazil, one aerial (foliar) application of chlorantraniliprole insecticide has a cost of about 3-fold higher than one *C. flavipes* release (Ferreira, 2013). Otherwise, the intensive chemical control (biweekly application) was more efficient than the biological control with *Trichogramma* spp. in Indonesia (Goebel et al., 2014). Thus, these two tactics can be complementary and taken at different periods in sugarcane crops in Brazil; the chemical control at the beginning of the sugarcane crop development and biological control during its further development.

Conclusions

The chlorantraniliprole insecticide at 105 g ha^{-1} applied in the planting furrow has not reduced the damage of *D. saccharalis* in sugarcane. However, foliar chlorantraniliprole spray (21 g ha^{-1}) at 120 days after sugarcane sprouting reduced the damage of the sugarcane borer in about 52%. This insecticide did not affect the initial development of sugarcane crop or the production of sugarcane stalks.

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