

BIOEFFICACY AND PERSISTENCE OF CORAGEN 18.5 SC (CHLORANTRANILIPROLE) AGAINST EARLY SHOOT BORER, *Chilo infuscatellus* SNELLEN IN SUGARCANE AND EFFECTS ON BENEFICIAL ARTHROPODS

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ABSTRACT

Field experiments were conducted over two consecutive seasons (2016-17 and 2017-18) at four locations in Punjab, India: Jalandhar, Sangrur, Kapurthala, and Gurdaspur. The study aimed to evaluate the efficacy of different doses of Coragen 18.5 SC (chlorantraniliprole) in managing the early shoot borer (*Chilo infuscatellus* Snellen) in sugarcane. The doses tested included 75, 100, 150, and 200 mL per acre, along with a standard treatment of Dursban 20 EC (chlorpyrifos) at 2000 mL per acre, and an untreated control. Prior to insecticide application, the percentage of dead hearts in the sugarcane plants ranged from 10.84% to 12.35%. After one and two months of treatment, the incidence of early shoot borer was significantly reduced across all Coragen 18.5 SC doses, with the percentage of affected plants ranging from 0.12% to 4.86% and 0.17% to 4.64%, respectively. In contrast, the untreated control showed significantly higher infestation rates of 14.98% and 15.81% at the same intervals. The incidence in plants treated with Dursban 20 EC was 4.36% after one month and 4.25% after two months, demonstrating its efficacy, though it was slightly less effective than Coragen at the higher doses. Among the various treatments, Coragen 18.5 SC at 150 mL per acre and 200 mL per acre performed equally well in terms of early shoot borer management, crop yield, natural enemy populations, and economic returns. However, the 150 mL per acre dose was the most effective, resulting in a significantly higher sugarcane yield of 313.87 quintals per acre and a net return of Rs. 68,760.00. Additionally, no residues of chlorantraniliprole were detected in sugarcane juice or soil samples, even at the highest application rates (30 and 60 g a.i. per acre), with detection limits of 0.05 mg/kg. These findings suggest that Coragen 18.5 SC at 150 mL per acre is an effective and environmentally safe alternative to conventional insecticides for managing early shoot borer in sugarcane, offering both economic and ecological benefits.

Keywords: Field efficacy, Insecticide, Natural enemies, Sugarcane pests

Sugarcane (*Saccharum officinarum* L.) is an important cash crop in India, serving as the primary source of sugar and ethanol production. It ranks among the ten most widely cultivated crops globally. As a long-duration crop, sugarcane faces numerous biotic and abiotic stresses that significantly impact its quality, yield, and overall productivity (Kumar *et al.*, 2023). Throughout its entire growth cycle, from planting to harvest, sugarcane is susceptible to a variety of insect pests that lead to substantial losses in both crop quality and quantity. Among the different pests, the early shoot borer (*Chilo infuscatellus* Snellen) (Lepidoptera: Crambidae), is the most destructive and widely distributed pest in sugarcane-growing regions across India. This pest causes significant economic damage, particularly during the early growth stages of the crop (Li *et al.*, 2024). Early shoot borer infestations typically begin at germination, with larvae initially attacking the shoot. As the pest

progresses through its life cycle, particularly under unfavourable weather conditions such as drought and insufficient rainfall, it continues to damage the crop by boring into the millable canes. The larvae subsequently create resting sites in the internodes just below the soil surface, where they pupate (Dwivedi *et al.*, 2022). The extent of damage caused by the early shoot borer is considerable, with 26% and 65% damage to mother shoots, leading to yield losses of approximately 22% to 33%. Additionally, the pest reduces sugar recovery by 12% and decreases jaggery production by 27% (Dhaliwal and Atwal, 2004; Punithavalli, 2022). Rainfed sugarcane crop is especially vulnerable, with early shoot borer damage exceeding 70% in some cases (Rao *et al.*, 1991).

The early shoot borer primarily causes injury to young sugarcane up to eight weeks after planting. Upon hatching from eggs, the young larvae initially disperse and enter the first leaf sheath and stem, where they feed on the soft inner tissues of the sheath,

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resembling the feeding behaviour of a leaf miner for few days. Subsequently, the larvae invade the cane laterally, creating holes in the stalks just above ground level and tunnelling downward. This feeding activity results in the central shoot drying up, manifesting as the characteristic “dead heart” symptom. The presence of the pest is confirmed when the dead heart, upon being pulled, easily detaches from the central shoot and emits a foul odour. Several management strategies have been proposed to control the early shoot borer. For example, two to three rounds of light earthing-up during the early growth stages of the crop have been reported as effective (Jaipal, 2000). Additionally, trash mulching has also shown promise in managing the pest (Raja *et al.*, 1991; Visalakshi *et al.*, 2016). Various insecticides have been evaluated and recommended for controlling the early shoot borer over time, but the persistence of the pest remains a significant challenge. The indiscriminate use of pesticides has led to many issues such as resistance, pest resurgence, and pesticide residues. Thus, there is a growing need to evaluate and adopt eco-friendly pesticides that are effective at lower doses and cause relatively less adverse effects on natural enemies, such as parasitoids and predators. In this context, chlorantraniliprole (Coragen 18.5 SC) has been tested as a promising solution for the effective control of sugarcane borers and increase the yield.

Chlorantraniliprole, 3-bromo-N-[4-chloro-2-methyl-6(methylamino)carbonyl]phenyl]-1-(3-chloro-2-pyridinyl)-1H-pyrazole-5-carboxamide, is an anthranilic diamide insecticide with a novel mode of action, commonly referred to as “Ryanodine Receptor Activators.” This mechanism targets muscle contraction in insects. Chlorantraniliprole is effective against a broad spectrum of pests, including lepidopterans, coleopterans, dipterans, and hemipterans (Sharma *et al.*, 2014). The insecticidal action of chlorantraniliprole involves the activation of the Ryanodine Receptor in insects, which stimulates the release and depletion of intracellular calcium stores from the sarcoplasmic reticulum of muscle cells. This disruption impairs muscle function, leading to paralysis and, ultimately, the death of the affected insect (Cordova *et al.*, 2006). One of the key advantages of chlorantraniliprole is its high specificity toward target pests, coupled with low toxicity to mammals (both acute and chronic). It is also safe for beneficial arthropod pollinators, such as honeybees, and non-target organisms, including earthworms and soil microorganisms. Additionally, chlorantraniliprole does not exhibit cross-resistance with any existing insecticide, making it a valuable tool in pest management (Dinter *et al.*, 2008). Due to its novel mode of action and safety profile, chlorantraniliprole presents a promising option for both Insecticide Resistance Management (IRM) and Integrated Pest

Management (IPM) programs. However, the efficacy of the Coragen formulation (chlorantraniliprole 18.5 SC) has not been evaluated under Punjab conditions. Therefore, the present study was conducted to assess the efficacy of Coragen 18.5 SC for the management of early shoot borer in sugarcane, its persistence in sugarcane substrates, and its impact on beneficial insects.

MATERIALS AND METHODS

Field experiments were conducted over two consecutive years, 2016-17 and 2017-18, at four locations Jalandhar, Sangrur, Kapurthala, and Gurdaspur to evaluate the efficacy of Coragen 18.5 SC (chlorantraniliprole) against early shoot borer in sugarcane. The sugarcane variety CoJ 88 was planted using a randomized block design, with six treatments (10 x 5.4 m per plot) and four replications. All agronomic practices, including land preparation, irrigation, hoeing, and fertilization, were carried out according to the recommended practices, except for plant protection measures (Anonymous, 2016). The experiment tested four doses of chlorantraniliprole 18.5 SC, namely 75, 100, 150, and 200 g/acre. As a standard check, Dursban 20 EC (chlorpyrifos) was applied at 2000 ml/acre. An untreated control group was also included for comparison purposes.

All pesticide applications were carried out when the damage in the plots exceeded 10% dead hearts. Observations on the incidence of early shoot borer were recorded at three time points: before spraying, and one and two months after spraying. The total number of shoots and the number of dead hearts were recorded, and the percentage incidence was calculated using the following formula:

$$\text{Percentage Incidence} = (\text{Total Number of Dead Hearts} / \text{Total number of Shoots}) \times 100$$

Cane yield data were recorded plot-wise at the time of harvest, converted on an acreage basis, and subjected to further statistical analysis.

In addition to yield assessment, residue analysis of Coragen 18.5 SC (chlorantraniliprole) in both soil and juice was conducted during the study period. Chlorantraniliprole residues in sugarcane juice were estimated following the application of two dosages: 30 g active ingredient a.i./acre (150 ml/acre) and 60 g a.i./acre (300 ml/acre). At harvest, soil and juice samples were collected from each treatment, and residue analysis was performed in the Pesticide Residue Analysis Laboratory of the Department of Entomology at Punjab Agricultural University, Ludhiana. For the residue analysis, a technical grade analytical standard of chlorantraniliprole (purity 98.1%) was procured. Solvents and reagents used in the analysis,

including acetonitrile (HPLC grade), dichloromethane, water (HPLC grade), sodium chloride, sodium sulfate anhydrous, and charcoal, were sourced from the local market. The residues of chlorantraniliprole were quantified using reversed-phase high-performance liquid chromatography (HPLC) (Model DGU-2045, Shimadzu Corporation), equipped with a C₁₈ column and a photodiode array detector.

For residue analysis, cane and soil samples were collected randomly from both control and treated plots at harvest, ensuring immediate processing after sampling. Soil samples were taken from 3 to 4 locations within each treated plot using a tube auger at a depth of approximately 0-15 cm. The soil from each core was pooled, sieved to remove extraneous matter, such as stones and pebbles, and thoroughly mixed. A subsample of approximately 1 kg was then taken from each pooled sample of the treatment plot and transported to the laboratory. Once in the laboratory, the samples were air-dried, ground, and passed through a 2-mm sieve. For residue extraction, 50 g of soil was placed separately in an Erlenmeyer flask with 100 ml of acetonitrile and left to soak overnight (24 hours). Similarly, sugarcane juice was extracted and filtered through a sieve into an Erlenmeyer flask. Then, 50 ml of juice was combined with 100 ml of acetonitrile and kept overnight.

Both extracts were filtered using a separatory funnel. The filtrate in the separatory funnel was diluted with 600 ml of saturated sodium chloride solution (brine solution), and partitioning was performed by adding 75 ml of dichloromethane. This partitioning step was repeated, and the combined organic layers were filtered through a layer of anhydrous sodium sulfate, supported on pre-washed glass wool. The filtered organic phase, containing the insecticide residues, was transferred into a 500-ml beaker. The extract was then concentrated to 25 ml using a vacuum rotary evaporator at a temperature of <40°C. For the clarification of the extract, it was treated with 500 mg of activated charcoal powder for approximately 2 hours at room temperature. After this, the clear filtered extract was concentrated to near dryness. The volume was then reconstituted to approximately 20 ml using acetonitrile and concentrated further using the rotary vacuum evaporator at <40°C. Finally, the volume was reconstituted to about 5 ml using acetonitrile.

A recovery experiment was conducted at various concentrations to assess the reliability and validity of the analytical methods. Juice samples were spiked with chlorantraniliprole at concentrations of 0.05, 0.10, 0.25, and 0.50 mg/kg. These spiked samples were then processed using the aforementioned methodology to validate the effectiveness and accuracy of the analytical approach.

The HPLC analysis of the extract was performed under isocratic conditions using acetonitrile/water (80:20, v/v), with a pump flow rate set at 0.4 ml/min at a wavelength of 245 nm. An injection volume of 20 µl was used. The residues of chlorantraniliprole were quantified by comparing the peak height/peak area of the standards with those of the unknown or spiked samples, run under identical conditions. Under these operating conditions, the retention time of chlorantraniliprole was observed to be 21.26 minutes.

The mean values of all treatments were subjected to analysis of variance (ANOVA) (Fisher, 1954). The CPCS-1 software was utilized to evaluate the significance of the data, and the critical difference (CD) was calculated for comparing parameters such as the incidence of early shoot borer and cane yield, as per Gomez and Gomez (1984). Interpretations were made based on the results obtained. Additionally, the benefit-cost ratio (BCR) was calculated by dividing the benefit, measured as the increased crop value due to insecticide use, by the cost of the insecticide treatment.

RESULTS AND DISCUSSION

Efficacy of chlorantraniliprole on the incidence of early shoot borer in sugarcane

The incidence of early shoot borer was assessed by recording the pooled mean percentage of dead hearts before application, as well as one and two months post-application. The results indicated that chlorantraniliprole significantly reduced the incidence of early shoot borer compared to the untreated control across all tested doses. Before application, the percentage of dead hearts varied from 10.84% to 12.35% across the treatment plots over the two years of experimentation. After one and two months of insecticide application, the incidence was significantly reduced, with dead heart percentages ranging from 0.12% to 4.86% and 0.17% to 4.64%, respectively, in comparison to the untreated control, which recorded 14.98% and 15.81%, respectively. In contrast, the incidence of early shoot borer in plots treated with Dursban 20 EC (chlorpyrifos) was 4.36% and 4.25% one and two months after application, respectively. Among the treatments, Coragen 18.5 SC (chlorantraniliprole) at 200 ml/acre exhibited the lowest incidence of early shoot borer, followed by Coragen 18.5 SC at 150 ml/acre. However, no significant difference was found between the two doses, as both were equally effective in managing the early shoot borer incidence. These findings are consistent with those reported by Kumar *et al.* (2017). The effectiveness of Coragen 18.5 SC (chlorantraniliprole) at 150 ml/acre and 200 ml/acre persisted for up to two months in the field. Similar results were reported by Sharma *et al.* (2014), who found that chlorantraniliprole residues persisted in the soil for up

Table 1. Efficacy of Coragen 18.5 SC (chlorantraniliprole) in reducing dead hearts incidence by early shoot borer in sugarcane

Treatment	Dose (ml/acre)	2016-17				2017-18				Pooled mean	PROC*	
		Jalandhar	Sangrur	Kapurthala	Gurdaspur	Jalandhar	Sangrur	Kapurthala	Gurdaspur			
Before application (% dead hearts)												
Coragen 18.5 SC (chlorantraniliprole)	75	12.06	13.00	13.33	11.00	14.33	9.67	8.00	9.67	16.33	12.22	-
Coragen 18.5 SC (chlorantraniliprole)	100	8.69	15.00	12.00	8.00	12.00	11.00	7.00	11.00	13.00	10.84	-
Coragen 18.5 SC (chlorantraniliprole)	150	9.20	16.33	13.66	8.67	12.67	7.67	8.67	7.67	12.67	11.19	-
Coragen 18.5 SC (chlorantraniliprole)	200	7.80	16.66	16.00	10.00	9.00	10.67	10.00	10.67	13.22	11.67	-
Dursban 20 EC (chlorpyrifos)	2000	10.50	15.00	14.66	9.33	13.67	11.33	8.00	11.33	14.33	12.10	-
Control	-	12.00	17.45	15.33	8.00	12.00	10.33	8.67	10.33	15.00	12.35	-
CD (<i>p</i> ≤0.05)	-	NS	-									
One month after application (% dead hearts)												
Coragen 18.5 SC (chlorantraniliprole)	75	6.67 (14.95)	4.33 (12.00)	4.33 (12.00)	5.67 (13.73)	7.67 (16.06)	5.00 (12.87)	3.00 (9.89)	5.00 (12.87)	5.00 (12.87)	4.86 (18.04)	67.56
Coragen 18.5 SC (chlorantraniliprole)	100	2.90 (9.71)	1.25 (6.40)	1.33 (6.49)	2.89 (9.71)	4.00 (11.47)	3.67 (11.02)	2.00 (8.04)	3.67 (11.02)	4.67 (12.43)	2.84 (9.47)	81.04
Coragen 18.5 SC (chlorantraniliprole)	150	1.43 (9.71)	1.00 (5.48)	0.63 (4.33)	1.00 (5.48)	1.33 (6.59)	2.00 (8.10)	1.33 (6.59)	2.00 (8.10)	1.00 (5.68)	1.22 (5.24)	91.86
Coragen 18.5 SC (chlorantraniliprole)	200	0.00 (0.00)	0.00 (0.00)	0.30 (2.66)	0.00 (0.00)	0.33 (2.66)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.33 (2.66)	0.12 (1.21)	99.20
Dursban 20 EC (chlorpyrifos)	2000	5.58 (13.57)	3.66 (11.02)	5.60 (13.60)	3.67 (10.97)	4.00 (11.47)	3.00 (9.92)	4.33 (12.00)	3.00 (9.92)	5.00 (12.89)	4.36 (11.97)	70.89
Control	-	14.33 (13.57)	18.50 (11.02)	13.66 (13.60)	14.00 (21.95)	16.00 (23.56)	15.00 (22.74)	11.00 (19.34)	15.00 (22.74)	17.33 (24.58)	14.98 (22.70)	-
CD (<i>p</i> ≤0.05)	-	(2.40)	(1.88)	(1.91)	(2.34)	(2.28)	(1.69)	(1.83)	(1.69)	(2.73)	(6.50)	-
Two months after application (% dead hearts)												
Coragen 18.5 SC (chlorantraniliprole)	75	6.24 (14.42)	3.00 (9.89)	3.25 (10.56)	4.00 (11.47)	6.33 (14.52)	5.00 (12.87)	3.00 (9.89)	5.00 (12.87)	6.33 (14.54)	4.64 (12.95)	70.65
Coragen 18.5 SC (chlorantraniliprole)	100	1.75 (7.52)	1.20 (6.18)	1.00 (5.38)	3.00 (9.96)	3.00 (9.92)	3.67 (11.02)	2.67 (9.31)	3.67 (11.02)	3.67 (11.01)	2.49 (9.86)	84.25
Coragen 18.5 SC (chlorantraniliprole)	150	0.00 (0.00)	0.50 (3.73)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.33 (2.66)	0.00 (0.00)	2.00 (8.04)	0.39 (2.29)	97.53
Coragen 18.5 SC (chlorantraniliprole)	200	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.33 (6.47)	0.17 (0.82)	98.92
Dursban 20 EC (chlorpyrifos)	2000	5.45 (13.33)	4.00 (11.47)	4.54 (12.34)	3.33 (10.49)	4.67 (12.45)	3.00 (9.87)	3.67 (11.02)	3.00 (9.87)	5.33 (13.31)	4.25 (11.83)	73.12
Control	-	11.50 (19.34)	18.66 (25.33)	16.00 (23.46)	15.67 (23.30)	18.33 (25.33)	15.00 (22.75)	14.67 (22.48)	15.00 (22.75)	16.67 (24.08)	15.81 (23.37)	-
CD (<i>p</i> ≤0.05)	-	(1.84)	(1.56)	(2.92)	(1.46)	(1.56)	(2.07)	(2.92)	(2.07)	(2.22)	(1.90)	-

Mean of four replications, Figures in parentheses indicate arc sine transformations, *PROC = Per cent Reduction Over Control

to 49 days after application. Based on the effectiveness and persistence of the treatment, it is recommended that Coragen 18.5 SC (chlorantraniliprole) at 150 ml/acre be used for managing early shoot borer in sugarcane, in line with best practices that advocate the use of the minimum effective dose.

Cane yield

Cane yield data collected at the time of harvest indicated that the application of Coragen 18.5 SC (chlorantraniliprole) resulted in a notable increase in yield compared to the untreated control, as shown in Table 2. The pooled mean yield, averaged over two years and four locations, ranged from 280.69 to 317.72 quintals per acre across different Coragen treatments. In comparison, the standard check treatment, Dursban 20 EC (chlorpyrifos), resulted in a yield of 282.88 quintals per acre, while the untreated control yielded 248.80 quintals per acre. The highest yield of 317.72 quintals per acre, representing a 21.69% increase over the untreated control, was observed in the Coragen 18.5 SC treatment at 200 ml/acre. This result was statistically similar to that of Coragen 18.5 SC at 150 ml/acre, which yielded 313.87 quintals per acre, corresponding to a 20.73% increase over the untreated control. These findings clearly demonstrate that the application of Coragen 18.5 SC at both 150 ml/acre and 200 ml/acre not only significantly reduced the incidence of early shoot borer but also had a synergistic effect on cane yield. These results align with the findings of Jaipal *et al.* (2010), who evaluated the efficacy of rynaxypyr (Coragen) 20 SC for managing early shoot borer and top borer, and reported significant increases in cane yield.

Effect on natural enemies

The impact of various insecticidal treatments on the population of natural enemies, including spiders, *Stenobracon nicevillei*, *Fulgoraacia melanoleuca*, and *Sturmiopsis inference*, was assessed under field conditions. The population of natural enemies was comparable across all treatments of Coragen 18.5 SC (chlorantraniliprole), Dursban 20 EC (chlorpyrifos), and the untreated control (Table 3). However, the application of Dursban 20 EC resulted in a noticeable reduction in the population of natural enemies. This suggests that Dursban 20 EC may be non-selective in nature, thus adversely affecting beneficial organisms in the field. In contrast, the application of Coragen 18.5 SC did not negatively impact the population of natural enemies, indicating that this insecticide is selective and non-destructive to beneficial species. These findings align with those of Dinter *et al.* (2008), who evaluated chlorantraniliprole and found it to be less toxic to beneficial insects and predatory mites.

Residue analysis

The residue analysis of chlorantraniliprole in sugarcane juice and soil was conducted using High-Performance Liquid Chromatography (HPLC) at the time of cane harvesting. A recovery experiment was carried out at different levels to assess the reliability and validity of the analytical methods. Juice samples were spiked at 0.05, 0.10, 0.25, and 0.50 mg kg⁻¹, as presented in Table 4. The average recovery value for chlorantraniliprole varied from 89.71% to 93.40% in juice and 90.01% to 93.97% in soil. Control samples from untreated plots and reagent blanks were also processed to detect any interference from substrates or reagents. The limit of quantification (LOQ) was determined to be 0.05 mg kg⁻¹, and the limit of detection (LOD) was calculated at 0.017 mg kg⁻¹. Both the sugarcane juice and soil samples did not show any detectable residues of chlorantraniliprole when applied at 30 and 60 g a.i. acre⁻¹, at the determination level of 0.05 mg kg⁻¹ (Fig. 1). These findings suggest that chlorantraniliprole residues were below the detectable limits in the juice and soil, indicating that the pesticide is safe at both single and double doses (Table 5).

Economics

The economic analysis of Coragen 18.5 SC (chlorantraniliprole) for the management of early shoot borer in sugarcane indicated that its use at doses of 100, 150, and 200 ml/acre proved to be economically advantageous compared to the untreated control. The gross returns for these three treatments were Rs. 87,990.00, 94,161.00, and 95,316.00, respectively. In contrast, the gross return from the lowest dose of Coragen 18.5 SC (75 ml/acre) was Rs. 84,207.00, while the return from the standard check (Dursban 20 EC application) was Rs. 84,864.00, as presented in Table 6. Among all the treatments, Coragen 18.5 SC applied at 150 ml/acre and 200 ml/acre provided the highest returns for managing early shoot borer. When insecticide and labour costs were deducted, the net returns for Coragen 18.5 SC at these doses were the highest, amounting to Rs. 68,760.60 and Rs. 69,410.00, respectively. These treatments also achieved the highest benefit-cost (BC) ratio of 1.37, indicating their cost-effectiveness.

CONCLUSION

The results of the study revealed that, among the various doses of Coragen 18.5 SC (chlorantraniliprole) tested, 75, 100, 150, and 200 ml/acre, as well as the standard check, Dursban 20 EC (chlorpyrifos) at 2000 ml/acre, Coragen 18.5 SC applied at 200 ml/acre showed the lowest incidence of early shoot borer. This dose was found to be at par with Coragen 18.5 SC at 150 ml/acre in terms of pest management efficacy. The

Table 2. Sugarcane yield in different treatments

Treatment	Dose (ml/acre)	2016-17					2017-18					Pooled Mean (q/acre)	PIOC*
		Jalandhar	Sangrur	Kapurthala	Gurdaspur	Jalandhar	Sangrur	Kapurthala	Gurdaspur				
Coragen 18.5 SC (chlorantraniliprole)	75	282.80	295.90	272.51	285.43	280.46	281.98	276.80	269.67	280.69	+12.82		
Coragen 18.5 SC (chlorantraniliprole)	100	296.67	307.00	276.90	297.00	295.49	285.10	298.76	289.49	293.30	+17.89		
Coragen 18.5 SC (chlorantraniliprole)	150	321.30	318.32	291.85	312.34	318.86	320.43	326.39	301.46	313.87	+26.15		
Coragen 18.5 SC (chlorantraniliprole)	200	327.54	325.98	298.38	314.40	321.45	324.20	327.47	302.30	317.72	+27.70		
Dursban 20 EC (chlorpyrifos)	2000	281.61	290.50	272.68	291.75	284.80	281.80	283.31	276.61	282.88	+13.70		
Control	-	264.00	252.43	252.67	254.80	246.50	243.58	244.90	231.52	248.80	-		
CD ($p \leq 0.05$)	-	6.67	8.48	7.40	10.20	6.79	7.61	6.86	9.46	6.54			

Mean of four replications
*PIOC = Per cent Increase Over Control

Table 3. Effect of Coragen 18.5 SC (chlorantraniliprole) on the abundance of natural enemies on sugarcane

Treatment	Dose (ml/acre)	2016-17					2017-18					Pooled mean populations	PROC*
		Spider	Stenobracon nicevillei	Fulgoraacia melanoleuca	Sturmiopsis inference	Spider	Stenobracon nicevillei	Fulgoraacia melanoleuca	Sturmiopsis inference				
Coragen 18.5 SC (chlorantraniliprole)	75	1.08 (1.43)	0.89 (1.37)	0.55 (1.24)	0.90 (1.37)	0.56 (1.24)	0.75 (1.31)	0.81 (1.34)	0.63 (1.27)	0.77 (1.32)	7.23		
Coragen 18.5 SC (chlorantraniliprole)	100	0.83 (1.35)	0.83 (1.34)	0.67 (1.28)	0.78 (1.32)	0.94 (1.39)	0.69 (1.29)	0.56 (1.24)	0.56 (1.24)	0.73 (1.31)	12.05		
Coragen 18.5 SC (chlorantraniliprole)	150	0.58 (1.25)	0.81 (1.34)	0.47 (1.20)	0.76 (1.32)	0.88 (1.36)	0.88 (1.36)	0.75 (1.32)	0.63 (1.26)	0.72 (1.31)	13.25		
Coragen 18.5 SC (chlorantraniliprole)	200	0.86 (1.35)	0.89 (1.37)	0.55 (1.24)	0.78 (1.33)	0.75 (1.31)	0.75 (1.32)	0.50 (1.22)	0.50 (1.22)	0.70 (1.30)	15.66		
Dursban 20 EC (chlorpyrifos)	2000	0.41 (1.18)	0.54 (1.23)	0.32 (1.14)	0.41 (1.27)	0.50 (1.22)	0.50 (1.22)	0.31 (1.14)	0.25 (1.11)	0.41 (1.18)	50.66		
Control	-	0.89 (1.37)	0.94 (1.23)	0.72 (1.30)	0.95 (1.36)	1.13 (1.45)	0.75 (1.31)	0.63 (1.27)	0.63 (1.27)	0.83 (1.35)			
CD ($p \leq 0.05$)		0.14	0.76	0.89	0.10	0.13	0.14	0.78	0.73	0.42			

Mean of four replications
Figures in parenthesis indicate square root transformations
*PROC = Per cent Reduction Over Control

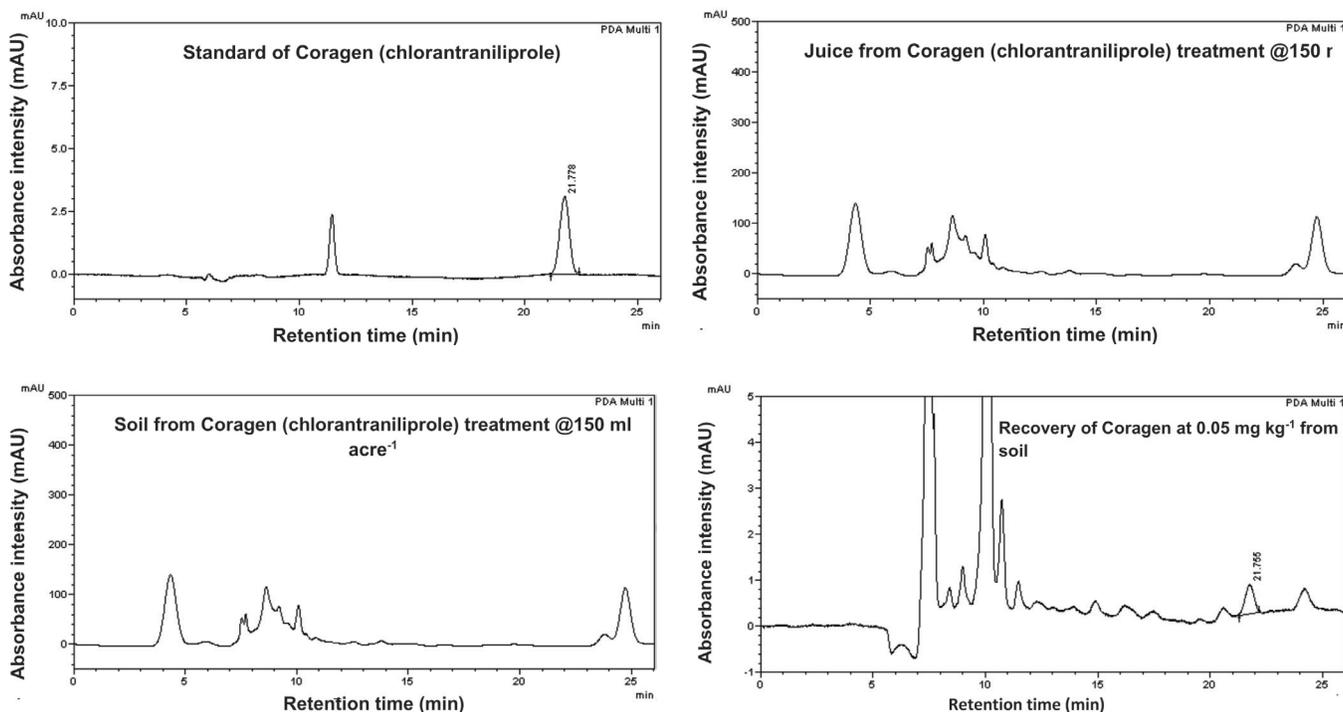


Fig. 1. Chromatogram of Coragen (chlorantraniliprole) (a) standard (b) sugarcane juice (c) sugarcane soil (d) recovery in soil

Table 4. Recovery of Coragen 18.5 SC (chlorantraniliprole) in sugarcane juice and soil

Substrate	Level of fortification (mg kg ⁻¹)	Mean recovery (%) ± SD	RSD (%)
Sugarcane juice	0.05	89.71 ± 1.77	1.98
	0.10	90.93 ± 1.04	1.14
	0.25	91.08 ± 1.19	1.31
	0.50	93.40 ± 0.98	1.05
Sugarcane soil	0.05	90.01 ± 1.96	2.18
	0.10	91.28 ± 1.73	1.90
	0.25	92.67 ± 1.30	1.40
	0.50	93.97 ± 1.40	1.49

Each value is mean ± SD of four replicated determinations; SD = Standard deviation; RSD = Relative standard deviation

Table 5. Residues of Coragen 18.5 SC (chlorantraniliprole) in sugarcane juice and soil

Residue at harvest	Coragen 18.5 SC (chlorantraniliprole) @ 30 g a.i./acre		Coragen 18.5 SC (chlorantraniliprole) @ 60 g a.i./acre	
	Replicate	Mean ± S.D.	Replicate	Mean ± S.D.
Sugarcane juice	< LOQ		< LOQ	< LOQ
	< LOQ	< LOQ	< LOQ	
	< LOQ		< LOQ	
	< LOQ		< LOQ	
Sugarcane soil	< LOQ		< LOQ	< LOQ
	< LOQ	< LOQ	< LOQ	
	< LOQ		< LOQ	
	< LOQ		< LOQ	

LOQ = Limit of Quantification 0.05 mg kg⁻¹

Table 6. Economics of Coragen 18.5 SC (chlorantraniliprole) for the control of sugarcane early shoot borer

Treatment	Dose (ml/acre)	Cost of insecticide/acre (Rs.)	Total cost (insecticide + labour)	Yield (q/acre)	Gross returns (Rs/acre)	Net returns over control (Rs/acre)	B C ratio
Coragen 18.5 SC (chlorantraniliprole)	75	975	1075	280.69	84,207.00	67,785.00	1.24
Coragen 18.5 SC (chlorantraniliprole)	100	1300	1400	293.30	87,990.00	68,110.00	1.29
Coragen 18.5 SC (chlorantraniliprole)	150	1950	2050	313.87	94,161.00	68,760.00	1.37
Coragen 18.5 SC (chlorantraniliprole)	200	2600	2700	317.72	95,316.00	69,410.00	1.37
Dursban 20 EC (chlorpyrifos)	2000	560	660	282.88	84,864.00	67,370.00	1.26
Control	-	-	-	248.80	74,640.00	66,710.00	

Price of insecticide (Rs./litre): Coragen @ 150 ml/acre = Rs 1950/-, Dursban @ 2000 ml/acre = Rs 560/- (Rs 280/- per litre)
Price of sugarcane mid maturing variety = Rs. 300/q

application of all doses of Coragen 18.5 SC did not show adverse effect on natural enemies. The plots treated with Coragen 18.5 SC at 200 ml/acre and 150 ml/acre resulted in higher cane yields and greater returns in terms of profit, with both treatments at par with each other. Following standard practices, it is recommended to use the minimum effective dose for pest control. Therefore, it can be concluded that Coragen 18.5 SC at 150 ml/acre is the best option for managing early shoot borer in sugarcane. This dosage not only provides effective pest control but also ensures the safety of natural populations and enhances cane yield, offering the maximum economic returns for cane growers.

Authors' contribution

Conceptualization of research work and designing of experiments (RK); Execution of field/lab experiments and data collection (RK, A, SS); Analysis of data and interpretation (RK, A, SS); Preparation of manuscript (RK, A, SS)

Conflicts of interest

The authors declare that they have no conflicts of interest.

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