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Evaluation of bioefficacy of Methoxyfenozide 21.8% W/W SC against early shoot borer, *Chilo infuscatellus* (Snellen), (Crambidae: Lepidoptera) on sugarcane

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Abstract

An experiment was conducted at Agriculture Research Station, Sankeshwar (Karnataka), India during Rabi 2021-2022, to assess the Methoxyfenozide 21.8% W/W SC against sugarcane early shoot borer (*Chilo infuscatellus*). Six treatments were imposed using randomized block design with four replications. Significant differences were noticed among the treatments. Methoxyfenozide 21.8% w/w SC @ 187.5 g a.i./ha (9.29% & 3.76% incidence) and Methoxyfenozide 21.8% w/w SC @ 150 g a.i./ha (9.90% & 4.15% incidence) were found to be most effective in managing the early shoot borer in the first and second spray, respectively. Fipronil 5% SC @ 100 g a.i./ha was found to be least effective in both the sprays with 12.32% and 6.66% incidence as compared to other treatments. The application of Methoxyfenozide 21.8% w/w SC @ 120, 150 and 187.5 g a.i./ha and other treatments did not show any adverse impact on the natural enemies (spiders and coccinellids) and no phytotoxicity symptoms were noticed even at the higher dose of Methoxyfenozide 21.8% W/W SC @ 300 g a.i./ha during the experiment period in sugarcane crop. Methoxyfenozide 21.8% w/w SC @ 187.5 g a.i./ha was most effective with higher cane yield with 85.74 t/ha followed by Methoxyfenozide 21.8% w/w SC @ 150 g a.i./ha (82.49 t/ha).

Keywords: *Chilo infuscatellus*, dead hearts, Methoxyfenozide, phytotoxicity, sugarcane

Introduction

Sugarcane (*Saccharum officinarum* L.) is a perennial grass from the family Poaceae, widely cultivated in tropical and subtropical regions globally. It is an important commercial crop in India and plays a pivotal role in agricultural and industrial economy of our country. Sugarcane is an important commercial crop of the world and more than 100 countries produce sugar, at present Brazil, Cuba, Mexico India and Thailand are the leading producers of sugarcane (Singhandand Gangwar, 2023) [16]. Currently 69% of the world's sugar is consumed in the country. In India, it is a crucial crop for producing white sugar and jaggery. India emerges as the world's largest producer and consumer of sugar and world's 2nd largest exporter of sugar. The country cultivated sugarcane across 5.18 M ha and with 490.53 MT production during 2022-2023. Among different states of the country, Uttar Pradesh, Maharashtra, Karnataka, Tamil Nadu and Gujarat were the top five sugarcane producing states of India (Anonymous, 2024) [1]. Sugarcane provides a consistent agroecosystem, offering both shelter and food for insects (Chaudhary, 2008) [5]. Over 1500 insect species have been reported worldwide (Box, 1953) [3], with India alone documenting around 228 pests on sugarcane (David and Nandagopal, 1986) [6]. These pests affect various phenological stages of sugarcane growth, with early shoot borer, top borer and stalk borer among the most significant (Patil and Hapase, 1981; Madan *et al.*, 1999; Singh *et al.*, 1973) [15, 13, 17].

Early shoot borers primarily damage sugarcane during its formative phase. The larvae bore into the shoots, moving downwards and upwards, destroying the apical meristem. This results in drying of the spindle and the development of a distinctive "dead heart" which emits a foul odor and can be easily pulled out. Infested shoots and tillers lead to gaps in the crop. Early shoot borers can devastate 26 to 65% of mother shoots and cause losses of 6.4%, 27.1% and 75% in primary, secondary and tertiary tillers, respectively.

This infestation results in significant economic losses, with estimates suggesting a reduction of 0.597 tonnes of sugar ha⁻¹ (Krishnamurthy Rao, 1954; Khan and Krishnamurthy Rao, 1956)^[10, 11]. Furthermore, it can cause yield losses of 22 to 33%, decrease sugar recovery by 12% and reduce jaggery production by 27% (Patil and Hapse, 1981)^[15]. Early shoot borer attacks on mother shoots and mature canes severely impact cane production, juice quality and sucrose content (Avasthy and Tiwari, 1986)^[2]. Among the different management strategies, chemical use is a key part of Integrated Pest Management (IPM) strategies. Various insecticides have been tested and suggested for controlling early shoot borers, but the issue still persists. To address this, Methoxyfenozide 21.8% SC was tested for its effectiveness in managing early shoot borers in sugarcane.

Materials and Methods

To evaluate the efficacy of Methoxyfenozide 21.8% SC an experiment was laid out in Randomized Complete Block Design (RCBD) with six treatments (Table 1), including an untreated control and replicated four times at ARS, Sankeshwar (Latitude: 16.14N, Longitude: 74.30E and altitude: 698 m) (UAS, Dharwad) in *Rabi* during 2021-22 in sugarcane. The experiment was conducted on commercial sugarcane variety, Co 86032. Plot area was 50 m² (10 × 5 m) and spacing of 50×50 cm was followed. The objective was to assess the effectiveness of Methoxyfenozide 21.8% SC against early shoot borer, as well as its impact on plants (phytotoxicity) and natural enemies. The crop was regularly monitored for the appearance of dead hearts in the experimental field. On dead hearts appearance, the observations were recorded on dead hearts and application of treatments was made and repeat application was also done after 30 days. The observations on post treatment application were recorded at 7, 15 and 30 days after each spray. The percent dead hearts of early shoot borer was calculated by using the following formula (Lalit Kumar Verma and Arun Solanki),

Percent dead hearts = Number of dead hearts/Total number of tillers × 100

Percent dead hearts was calculated and subjected to statistical analysis after angular transformation. The percent reduction in dead hearts over the time was also calculated over control. The observations on spiders and coccinellids were recorded before first spray and at 3 and 7 days after each spray. The mean data recorded during the study were analyzed statistically after subjecting to square root transformation.

The observations for phytotoxicity symptoms on sugarcane crop were observed for the symptoms like Leaf injury on tips/ surface, Wilting, Vein Clearing, Necrosis, Epinasty and Hyponasty using the 0-1 rating scale as given in Table 2. Sugarcane yield was recorded plot wise and expressed in terms of t/ha. The data were subjected to statistical analysis.

Results and Discussion

Efficacy of different treatments on early shoot borer

The data presented in Table 3 for first spray showed that there was no significant difference in percent dead hearts before spray, so the early shoot borer incidence was uniform in all the experimental plots. The percent dead hearts recorded at 7, 15 and 30 days after spray revealed that all

the treatments were significantly effective to check the early shoot borer incidence as compared to untreated control. The mean percent dead hearts in different treatments varied from 9.29 to 22.98% and 3.76 to 25.40% in first and second spray, respectively. Amongst the treatments Methoxyfenozide 21.8% w/w SC @ 187.5 g a.i./ha (9.29%) was most effective in managing the early shoot borer followed by Methoxyfenozide 21.8% w/w SC @ 150 g a.i./ha (9.90%), Flubendiamide 20% WG @ 75 g a.i./ha (11.02%), Methoxyfenozide 21.8% w/w SC @ 120 g a.i./ha (11.45%) and Fipronil 5% SC @ 100 g a.i./ha (12.35%) were next in order of effectiveness after first spray. Methoxyfenozide 21.8% w/w SC @ 187.5 g a.i./ha (3.76%) was found to be most effective in managing the early shoot borer followed by Methoxyfenozide 21.8% w/w SC @ 150 g a.i./ha (4.15%), Methoxyfenozide 21.8% w/w SC @ 120 g a.i./ha (5.69%), Flubendiamide 20% WG @ 75 g a.i./ha (5.76%) and Fipronil 5% SC @ 100 g a.i./ha (6.66%) after second spray (Table 4). The dead hearts due to early shoot borer incidence during early crop growth and timely application of treatments resulted in sprouting of more healthy tillers. The percent reduction in percent dead hearts over control also showed that Methoxyfenozide 21.8% w/w SC @ 187.5 g a.i./ha and Methoxyfenozide 21.8% w/w SC @ 150 g a.i./ha effectively controlled early shoot borer incidence in both the sprays during the experimental period. Based on the results of the study, it may be stated that the treatments Methoxyfenozide 21.8% w/w SC @ 150 g a.i./ha was equally effective to Methoxyfenozide 21.8% w/w SC @ 187.5 g a.i./ha. Hence the application of Methoxyfenozide 21.8% w/w SC @ 150 g a.i./ha was optimal for effective control of early shoot borer incidence in sugarcane crop.

Impact of treatments on natural enemies

The population of natural enemies (Spiders and coccinellids) recorded before first spray and at 3 and 7 days after each spray has been presented in Table 5. The application of Methoxyfenozide 21.8% w/w SC @ 120, 150 and 187.5 g a.i./ha and other treatments did not show any adverse impact on the natural enemies (spiders and coccinellids) in sugarcane crop after each application of treatments, since the difference in population was not significant at each observation time.

Yield at harvest

The sugarcane yield recorded at harvest has been presented in Table 6. It was observed that Methoxyfenozide 21.8% w/w SC @ 187.5 g a.i./ha was most effective with higher cane yield (85.74 t/ha) followed by Methoxyfenozide 21.8% w/w SC @ 150 g a.i./ha (82.49 t/ha). The next best treatments were Methoxyfenozide 21.8% w/w SC @ 120 g a.i./ha (79.16 t/ha), Flubendiamide 20% WG @ 75 g a.i./ha (77.83 t/ha) and Fipronil 5% SC @ 100 g a.i./ha (73.85 t/ha). Comparatively yield in control was lowest as 63.26 t/ha.

Phytotoxicity evaluation

Methoxyfenozide 21.8% w/w SC applied @ 120, 150 and 187.5 g a.i./ha and even at the higher dose of 300 g a.i./ha did not show any phytotoxicity symptoms on the sugarcane crop in terms of Leaf injury on tips/ surface, Wilting, Vein clearing, Necrosis, Epinasty and Hyponasty at each observation time (Table 7).

There is a lack of reviews on the management of early shoot borer using Methoxyfenozide 21.8% W/W SC. However, some reports suggest that Methoxyfenozide is highly selective for lepidopteran pests and does not harm other orders of arthropods or natural enemies (Dhadialla *et al.*, 1998; Smagghe and Degheele, 1998) [7, 18]. Additionally, there is evidence that Methoxyfenozide, as an ecdyson receptor agonist, significantly reduces the population of spotted bollworms and boll infestation in cotton. This effect may be attributed to its impact on insect cells, similar to other insecticides reported to affect cells in various insects (Iqbal *et al.*, 2002; Zibae *et al.*, 2012) [8, 30]. Studies by Pavviya and Muthukrishnan have shown a significant decrease in the incidence of *Aproaerema modicella* in methoxyfenozide treated plots, resulting in higher pod yields

of groundnut. Methoxyfenozide, a second-generation moulting accelerating compound, operates similarly to tebufenozide in its mode of action (Carlson *et al.*, 2001) [4]. It is five to ten times more potent than tebufenozide (Ishaaya *et al.*, 1995) [9] due to its superior binding with lepidopteran receptors and longer residual efficacy. Methoxyfenozide exhibits a lower ability to bind with receptors in non-lepidopteran species, making it a highly selective insecticide. It effectively controls lepidopteran larvae, with a stronger impact on bollworms and diamondback moths. Larvae die of dehydration and starvation. Methoxyfenozide is considered highly selective for lepidopteran pest with no harm to other orders of arthropods and natural enemies make them fit well into IPM and IRM programs (Dhadialla *et al.*, 1998; Smagghe and Degheele, 1998) [7, 18].

Table 1: Treatment details of insecticides used in the management of early shoot borer in sugarcane

SL. No.	Treatment details	Dose/ha	
		g a.i./ha	Formulation dose(ml/ha)
T ₁	Methoxyfenozide 21.8% w/w SC (Tagros)	120	500
T ₂	Methoxyfenozide 21.8% w/w SC (Tagros)	150	625
T ₃	Methoxyfenozide 21.8% w/w SC (Tagros)	187.5	781
T ₄	Fipronil 5% SC	100	2000
T ₅	Flubendiamide 20% WG	75	375
T ₆	Untreated Control	-	-
T ₇	Methoxyfenozide 21.8% w/w SC (Tagros), (For phytotoxicity evaluation only)	300	1250

Note: Methoxyfenozide 21.8% w/w SC is equivalent to Methoxyfenozide 24% w/v SC

Table 2: Phytotoxicity rating scale

Phytotoxicity Rating scale			
Crop Injury	Rating	Crop Injury	Rating
0%	0	51-60%	6
1-10%	1	61-70%	7
11-20%	2	71-80%	8
21-30%	3	81-90%	9
31-40%	4	91-100%	10
41-50%	5		

Table 3: Efficacy of Methoxyfenozide 21.8% w/w SC against early shoot borer (% dead hearts) during 2022-23 (First Spray)

SL. No.	Treatments	Dose (g a.i./ha)	Percent dead hearts by early shoot borer					Percent reduction over control			
			DBS	7 DAS	15 DAS	30 DAS	Mean	7 DAS	15 DAS	30 DAS	Mean
1	Methoxyfenozide 21.8% w/w SC (Tagros Sample)	120	14.34 (22.17)	13.17 (21.25)	11.34 (19.64)	9.84 (18.26)	11.45	31.70	49.26	63.97	48.31
2	Methoxyfenozide 21.8% w/w SC (Tagros Sample)	150	13.95 (21.92)	11.88 (20.06)	9.85 (18.23)	7.99 (16.35)	9.90	38.40	55.93	70.75	55.02
3	Methoxyfenozide 21.8% w/w SC (Tagros Sample)	187.5	14.82 (22.35)	11.20 (19.46)	9.49 (17.91)	7.20 (15.53)	9.29	41.91	57.53	73.64	57.69
4	Fipronil 5% SC	100	14.85 (22.56)	13.72 (21.72)	12.40 (20.61)	10.93 (19.27)	12.35	28.84	44.48	59.98	44.43
5	Flubendiamide 20% WG	75	15.17 (22.70)	12.66 (20.72)	10.89 (19.23)	9.53 (17.88)	11.02	34.38	51.26	65.09	50.24
6	Untreated check	--	14.57 (22.33)	19.29 (26.02)	22.34 (28.14)	27.31 (31.47)	22.98	-	-	-	-
	S.E.m±		1.77	1.11	0.93	0.92	-	-	-	-	-
	C.D. (0.05)		NS	3.33	2.81	2.76	-	-	-	-	-
	C.V.%		15.86	10.26	9.03	9.26	-	-	-	-	-

Note: Figures in the parentheses are angular transformed values, DBS-Day before spray, DAS-Day after spray and NS-Non-significant

Table 4: Efficacy of Methoxyfenozide 21.8% w/w SC against early shoot borer (% dead hearts) during 2022-23 (Second Spray)

SL. No.	Treatments	Dose (g a.i./ha)	Percent dead hearts by early shoot borer					Percent reduction over control			
			DBS	7 DAS	15 DAS	30 DAS	Mean	7 DAS	15 DAS	30 DAS	Mean
1	Methoxyfenozide 21.8% w/w SC (Tagros Sample)	120	9.84(18.26)	7.63(16.02)	5.72(13.81)	3.73(11.03)	5.69	74.35	77.36	82.40	78.03
2	Methoxyfenozide 21.8% w/w SC (Tagros Sample)	150	7.99(16.35)	5.81(13.92)	3.95(11.41)	2.71(9.30)	4.15	80.46	84.37	87.21	84.01
3	Methoxyfenozide 21.8% w/w SC (Tagros Sample)	187.5	7.20(15.53)	5.14(12.95)	3.69(10.98)	2.45(8.91)	3.76	82.72	85.39	88.42	85.51
4	Fipronil 5% SC	100	10.93(19.27)	8.81(17.25)	6.94(15.21)	4.23(11.79)	6.66	70.40	72.52	80.04	74.32
5	Flubendiamide 20% WG	75	9.53(17.88)	7.90(16.32)	5.88(13.99)	3.50(10.50)	5.76	73.45	76.75	83.47	77.89
6	Untreated check	--	27.31(31.47)	29.75(33.04)	25.27(30.15)	21.18(27.32)	25.40	-	-	-	-
	S.E.m±		0.92	0.74	0.82	1.15	-	-	-	-	-
	C.D. (0.05)		2.76	2.22	2.47	3.46	-	-	-	-	-
	C.V.%		9.26	8.08	10.31	17.47	-	-	-	-	-

Note: Figures in the parentheses are angular transformed values, DBS-Day before spray and DAS-Day after spray

Table 5: Effect of Methoxyfenozide 21.8% w/w SC treatment on natural enemies in sugarcane crop during 2022-23

Sl. No.	Treatments	Dose (g a.i./ha)	Population of spiders/5 plants					Population of coccinellids/5 plants				
			DBS	3 DAFS	7 DAFS	3 DASS	7 DASS	DBS	3 DAFS	7 DAFS	3 DASS	7 DASS
1	Methoxyfenozide 21.8% w/w SC (Tagros Sample)	120	4.66 (2.27)	4.45 (2.22)	4.36 (2.20)	3.95 (2.10)	3.30 (1.94)	4.12 (2.15)	3.47 (1.99)	3.62 (2.03)	3.10 (1.89)	2.02 (1.58)
2	Methoxyfenozide 21.8% w/w SC (Tagros Sample)	150	4.82 (2.31)	4.47 (2.23)	4.45 (2.23)	4.26 (2.18)	3.12 (1.90)	4.22 (2.17)	3.41 (1.98)	3.49 (2.00)	2.84 (1.82)	1.93 (1.56)
3	Methoxyfenozide 21.8% w/w SC (Tagros Sample)	187.5	5.09 (2.36)	4.57 (2.25)	4.47 (2.23)	4.20 (2.17)	2.89 (1.84)	3.85 (2.09)	3.20 (1.92)	3.32 (1.95)	2.76 (1.80)	1.82 (1.52)
4	Fipronil 5% SC	100	4.68 (2.27)	4.48 (2.23)	4.48 (2.23)	4.34 (2.20)	3.34 (1.95)	4.19 (2.17)	3.56 (2.01)	3.64 (2.03)	3.03 (1.87)	1.96 (1.56)
5	Flubendiamide 20% WG	75	4.75 (2.29)	4.39 (2.21)	4.27 (2.18)	4.10 (2.14)	3.49 (1.99)	3.94 (2.11)	3.30 (1.95)	3.42 (1.98)	2.67 (1.78)	1.90 (1.54)
6	Untreated check	--	4.59 (2.26)	4.61 (2.26)	4.52 (2.24)	4.18 (2.16)	3.29 (1.93)	4.16 (2.16)	3.64 (2.03)	3.75 (2.065)	3.29 (1.95)	2.34 (1.68)
	S.Em±		0.03	0.04	0.02	0.04	0.04	0.03	0.03	0.02	0.03	0.04
	C.D. (0.05)		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	C.V.%		13.74	14.92	11.87	14.88	15.12	12.93	13.44	12.58	13.99	16.72

Note: Figures in the parentheses are square root transformed values, NS-Non-Significant, DBS-Day before spray, DAFS-Day After First Spray and DASS-Day After Second Spray

Table 6: Effect of Methoxyfenozide 21.8% w/wSC treatment on sugarcane yield during 2022-23

Sl. No.	Treatments	Dose (g a.i./ha)	Cane yield (t/ha)	Percent increase over control
1	Methoxyfenozide 21.8% w/w SC (Tagros Sample)	120	79.16	25.13
2	Methoxyfenozide 21.8% w/w SC (Tagros Sample)	150	82.49	30.39
3	Methoxyfenozide 21.8% w/w SC (Tagros Sample)	187.5	85.74	35.53
4	Fipronil 5% SC	100	73.85	16.74
5	Flubendiamide 20% WG	75	77.83	23.02
6	Untreated check	--	63.26	-
	S.Em±		0.66	
	C.D. (0.05)		2.44	
	C.V.%		12.10	

Table 7: Phytotoxicity evaluation of Methoxyfenozide 21.8% w/w SC on sugarcane crop during 2022-23

Sl. No.	Treatments	Dose (g a.i./ha)	Phytotoxicity symptoms observed* (Mean data recorded at 1, 3, 7, 10 and 15 days after each spray)					
			Leaf injury on tips/ surface	Wilting	Vein clearing	Necrosis	Epinasty	Hyponasty
1	Methoxyfenozide 21.8% w/w SC (Tagros Sample)	120	0	0	0	0	0	0
2	Methoxyfenozide 21.8% w/wSC (Tagros Sample)	150	0	0	0	0	0	0
3	Methoxyfenozide 21.8% w/w SC (Tagros Sample)	187.5	0	0	0	0	0	0
4	Fipronil 5% SC	100	0	0	0	0	0	0
5	Flubendiamide 20% WG	75	0	0	0	0	0	0
6	Untreated check	--	0	0	0	0	0	0
7	Methoxyfenozide 21.8% w/wSC (Tagros Sample)	300	0	0	0	0	0	0

*Based on 0-10 scale where: 0 = 0%, 1 = 1-10%, 2 = 11-20%, 3 = 21-30%, 4 = 31-40%, 5 = 41-50%, 6 = 51-60%, 7 = 61-70%, 8 = 71-80%, 9 = 81-90%, 10 = 91-10

Conclusion

Studies on bio-efficacy of Methoxyfenozide 21.8% w/w SC on commercial sugarcane variety Co 86032 revealed that the Methoxyfenozide 21.8% w/w SC @ 187.5 g a.i./ha recorded lowest incidence and highest percent reduction over control of sugarcane early shoot borer which was followed by Methoxyfenozide 21.8% w/w SC @ 150 g a.i./ha in both first and second sprays. Methoxyfenozide 21.8% w/w SC @ 187.5 g a.i./ha was also found to best effective treatment in getting highest yield (85.74 t/ha). None of the tested treatments shown any impact on natural enemies and no phytotoxicity symptoms were noticed even at the higher dose of Methoxyfenozide 21.8% W/W SC @ 300 g a.i./ha during the experiment period in sugarcane crop.

Conflict of Interest

The authors have no conflicts of interest to declare that they have seen and agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

Acknowledgement

Authors' contributions

Data Availability Statement

Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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