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Comparative Efficacy of Insecticides against Fall Armyworm (*Spodoptera frugiperda)* in Baby Corn

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Authors' contributions

This work was carried out in collaboration among all authors. Author BM conducted the experiment and wrote the manuscript. Author GS designed the research and corrected the draft. Authors KVS, MVNK and ST corrected and proof reading of the article. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The fall armyworm (*Spodoptera frugiperda*) is a major pest threatening baby corn production, significantly impacting yield and profitability. This study aimed to evaluate the efficacy of various insecticides and their combinations in managing fall armyworm populations while ensuring sustainable crop production.
Study Design: Randomized Block Design (RBD).
Place and Duration of Study: Maize Research Centre, Agricultural Research Institute, Rajendranagar, Hyderabad, during the rabi season of 2022–2023.
Methodology: Field experiments were conducted to assess the impact of seed treatments, foliar sprays, and their combinations on pest control, crop performance, and natural enemy conservation. The experiment followed a Randomized Block Design with three replications and eight treatments, T_1 (tetraniliprole 480 FS and cyantraniliprole 10.26% OD spray, T_2 (cyantraniliprole 19.8% + thiamethoxam 19.8% FS and spinetoram spray), T_3 (cyantraniliprole 600 FS and chlorantraniliprole 9.3% + lambda-Cyhalothrin 4.6% ZC spray), T_4 (chlorantraniliprole 18.5% SC), T_5 (emamectin Benzoate 5% SG), T_6 (flubendiamide 480 SC), T_7 (dimethoate 30 EC) and T_8 (untreated control). Insecticides were applied twice at a 14-day interval. Observations on leaf injury rating (LIR) and percent infestation were recorded using the standard 1–9 scale given by modified Davis and Williams. Pre-treatment observations were taken one day before spraying, and post-treatment observations were recorded at 7 and 14 days after each application. Parameters such as percent reduction over control, dehusked cob yield, green fodder yield, and cost-benefit ratio were calculated to evaluate treatment efficacy.
Results: Results indicated that seed treatments followed by foliar sprays provided superior control of fall armyworm, with T_2 (cyantraniliprole 19.8% + thiamethoxam 19.8% FS and spinetoram spray) demonstrating the lowest leaf injury ratings and highest yield benefits. T_3 (cyantraniliprole 600 FS and chlorantraniliprole 9.3% + lambda cyhalothrin 4.6% ZC spray) exhibited comparable performance, followed by T1, T4, T5, T6 and T7. The study underscores the importance of integrating effective pest management strategies to enhance baby corn productivity and profitability.
Conclusion: The study highlights the effectiveness of integrating seed treatments with foliar sprays for managing *S. frugiperda* in baby corn. T_3 and T_2 emerged as the most effective treatments, both in terms of pest control and economic viability, underscoring their potential for sustainable pest management and enhanced crop productivity.

Keywords: Almora; baby corn; fall armyworm; insecticide; leaf injury rating; per cent infestation.

1. INTRODUCTION

Baby corn (*Zea mays* L.), an economically significant crop, has gained prominence as a nutritious and versatile vegetable consumed globally. Its tender, immature cobs are a rich source of vitamins, minerals, and dietary fiber, making it a key ingredient in various culinary dishes (Dar et al., 2017). Additionally, baby corn is a short-duration crop with immense potential for both domestic markets and export, thus serving as a vital income source for farmers (Singh et al., 2019). However, its successful cultivation faces numerous challenges, with pest infestations being a major concern. Among the pests threatening baby corn production, the fall armyworm (*Spodoptera frugiperda*) has emerged as a formidable adversary (Kumar et al., 2024). Originating in the Americas, this polyphagous pest has rapidly spread to Asia and Africa, causing extensive damage to maize and related crops (Devi et al., 2024). The pest's voracious feeding behavior, high reproductive rate, and ability to develop resistance to control measures make it a significant threat to food and nutritional security (Navik et al., 2023). Infestation by fall armyworm in baby corn can lead to substantial yield losses, reducing the crop's marketable value and affecting farmers' livelihoods. Insecticides remain one of the most effective tools in managing fall armyworm infestations (Deshmukh et al., 2020). The judicious use of insecticides not only mitigates crop damage but also ensures economic viability for farmers. However, the choice of insecticide, its efficacy, and the timing of application are critical for effective pest management. Evaluating the performance of different insecticides under field conditions is essential to develop sustainable and integrated pest management (IPM) strategies (Rashwin & Sanjeeth, 2023). Such studies not only help identify the most effective options but also minimize the environmental footprint and delay the onset of resistance in pest populations. This current study focuses on assessing the efficacy of various insecticides against fall armyworm in baby corn, with the objective of optimizing pest management practices and safeguarding the productivity and profitability of this vital crop.

2. MATERIAL AND METHODS

A field experiment was conducted during the *Rabi* 2022-2023 at the Maize Research Centre, Agricultural Research Institute, Rajendranagar, Hyderabad, to evaluate the effectiveness of different insecticides in managing *Spodoptera frugiperda* in maize. The baby corn hybrid 'Almora' which was produced by public sector was used, with each plot measuring 3 m × 3.6 m. The crop was sown with a row spacing of 45 cm and plant spacing of 20 cm, under protective irrigation, following a randomized block design (RBD) with eight treatments and three replications. Insecticides used were T_1 (tetraniliprole 480 FS and cyantraniliprole 10.26% OD spray, T_2 (cyantraniliprole 19.8% + thiamethoxam 19.8% FS and spinetoram spray), T3 (cyantraniliprole 600 FS and chlorantraniliprole 9.3% + lambda-Cyhalothrin 4.6% ZC spray), T_4 (chlorantraniliprole 18.5% SC), T_5 (emamectin Benzoate 5% SG), T_6 (flubendiamide 480 SC), T_7 (dimethoate 30 EC) including untreated control. Foliar sprays were applied twice at a 14-day interval. Observations on leaf injury rating (LIR) were recorded using the standard 1–9 scale (Davis et al., 1992), along with percent infestation data. Pre-treatment observations were taken one day before spraying, while post-treatment observations were recorded at 7 and 14 days after each application. The LIR data were square-root transformed ($\sqrt{X + 0.5}$), and percent infestation data were arcsine transformed (Gomez & Gomez, 1984). Additionally, percent reduction in infestation over the untreated control (mean of percent reduction over control at 14 days after first spray and 14 days after second spray), dehusked cob yield, green fodder yield and cost-benefit ratio were calculated to assess treatment efficacy and data was subjected to analysis of variance (ANOVA) in a randomized complete block design using SAS version 9.3. Duncan Multiple Range Test (DMRT) was applied for comparing the treatments.

3. RESULTS AND DISCUSSION

3.1 Efficacy of Insecticides

All treatments performed significantly ($p<0.05$) better than the untreated control, with seed treatment followed by foliar spray proving more effective than other methods. At one day before spraying, ($p<0.001$) treatments showed significant differences in leaf injury rating (LIR). The lowest LIR (2.65) was recorded in T_2 (cyantraniliprole 19.8% + thiamethoxam 19.8% FS and spinetoram spray), which was on par with T_3 (cyantraniliprole 600 FS and chlorantraniliprole 9.3% + lambda-cyhalothrin 4.6% ZC spray) at 2.95. This was followed by T_1 (tetraniliprole 480 FS and cyantraniliprole 10.26% OD) at 3.80. Other treatments (T_4, T_5, T_6, and T_7) were not significantly different and were on par with the untreated control. These differences were attributed to the efficacy of seed treatments prior to foliar sprays. After the first spray, leaf injury ratings (LIR) decreased at 7 days ($p<0.001$) after spraying (DAS) but increased again by 14 DAS ($p=0.001$). Following the second spray, LIR consistently decreased at both 7 ($p<0.001$) and 14 DAS ($p<0.001$). Across all observations, T_2 (cyantraniliprole 19.8% + thiamethoxam 19.8% FS and spinetoram spray) consistently recorded the lowest LIR at 7 and 14 DAS, demonstrating its superior effectiveness against *S. frugiperda*. It achieved the highest percentage reduction over the control (59.16%) and was statistically on par with T_3 (cyantraniliprole 600 FS and chlorantraniliprole 9.3% + lambda-cyhalothrin 4.6% ZC spray), which showed a 51.79% reduction. T_1 (tetraniliprole ST 480 FS and cyantraniliprole 10.26% OD) followed with a 41.18% reduction, comparable to T_4 (chlorantraniliprole 18.5% SC) with a 33.88% reduction. Conversely, the control treatment (T_8) displayed the highest LIR, indicating severe damage from *S. frugiperda*. The percent infestation followed a similar trend. T_2 consistently exhibited the lowest infestation levels across all observations, comparable to T_3. These were followed by T_1, which was on par with T_4. The untreated control (T_8) recorded the highest infestation percentages, underscoring the importance of effective pest management strategies to mitigate the damage caused by *S. frugiperda*. The superior performance of T_2 (cyantraniliprole 19.8% + thiamethoxam 19.8% FS and spinetoram spray) can be attributed to its

Table 1. Management of fall armyworm in maize (baby corn) during *rabi* 2022-2023

	Chemical Name	Dosage/ha		Leaf injury rating					Per cent infestation					Overall Mean Per cent reduction over control	Dehusked cob yield (Kg ha^{-1})	Green fodder yield (Kg ha^{-1})	CB ratio
				1 DBS	DAS (1st spray)		DAS (2nd spray)		1 DBS	DAS (1st spray)		DAS (2nd spray)					
		a.i. (g)	g or ml		7	14	7	14		7	14	7	14				
T_1	(i) Tetraniliprole ST 480 FS (ii) Cyantraniliprole 10.26% OD	3.6 g/kg seed 71.8	 700	3.80 (2.19)^{b}	2.20 (1.79)^{ab}	5.00 (2.45)^{bc}	2.83 (1.96)^{bc}	2.05 (1.75)^{b}	74.50 (59.87)^{b}	48.50 (44.12)^{c}	68.33 (55.74)^{abc}	42.76 (40.81)^{b}	40.25 (39.34)^{b}	41.18	2050 (45.27)^{a}	25650 (160.05)^{a}	1:1.10
T_2	(i) Cyantraniliprole 19.8% +Thiamethoxam 19.8 % FS (ii)Spinetoram 11.7% SC	6 ml/kg seed 30	 256.4	2.65 (1.91)^{a}	1.35 (1.53)^{a}	3.43 (2.11)^{a}	1.40 (1.55)^{a}	1.00 (1.41)^{a}	58.50 (49.88)^{a}	22.35 (28.18)^{a}	55.35 (48.07)^{a}	22.75 (28.48)^{a}	19.85 (26.44)^{a}	59.16	2120 (46.04)^{a}	26220 (161.92)^{a}	1:1.19
T_3	(i) Cyantraniliprole 600 FS (ii) Chlorantraniliprole 9.3%+ lambda cyhalothrin 4.6% ZC	2.4 ml/kg seed 35	 251.82	2.95 (1.99)^{ab}	1.60 (1.61)^{a}	4.40 (2.32)^{ab}	1.90 (1.70)^{ab}	1.35 (1.53)^{a}	65.65 (54.18)^{ab}	32.76 (34.90)^{b}	61.50 (51.63)^{ab}	31.25 (33.95)^{a}	27.36 (31.52)^{a}	51.79	2185 (46.72)^{a}	26880 (163.79)^{a}	1:1.28
T_4	Chlorantraniliprole 18.5% SC	40	216.21	5.25 (2.50)^{c}	2.55 (1.88)^{bc}	5.37 (2.52)^{bc}	2.90 (1.97)^{bc}	2.68 (1.92)^{b}	86.60 (69.22)^{c}	53.35 (46.90)^{c}	74.65 (59.82)^{bcd}	49.52 (44.70)^{b}	47.45 (43.52)^{b}	33.88	1850 (43.01)^{ab}	25100 (158.26)^{a}	1:0.95
T_5	Emamectin benzoate 5 % SG	10	200	5.28 (2.50)^{c}	3.28 (2.07)^{cd}	5.83 (2.61)^{cd}	3.97 (2.23)^{cd}	3.65 (2.16)^{c}	86.95 (68.83)^{c}	63.45 (52.84)^{d}	80.50 (64.21)^{cde}	65.65 (54.20)^{c}	63.52 (53.00)^{c}	22.11	1615 (40.18)^{bc}	23850 (154.31)^{ab}	1:0.75
T_6	Flubendamide 480 SC (39.35 w/w)	59	150	5.30 (2.51)^{c}	3.87 (2.21)^{de}	6.30 (2.70)^{cd}	4.23 (2.29)^{cd}	3.95 (2.23)^{cd}	87.20 (69.06)^{c}	72.52 (58.47)^{e}	82.50 (65.32)^{de}	69.55 (56.48)^{c}	67.46 (55.24)^{c}	18.92	1585 (39.81)^{bc}	23620 (153.66)^{ab}	1:0.70
T_7	Dimethoate 30 EC	300	1000	5.32 (2.51)^{c}	4.47 (2.33)^{e}	6.80 (2.79)^{d}	5.18 (2.46)^{d}	4.78 (2.40)^{d}	87.80 (69.75)^{c}	80.55 (63.81)^{f}	87.80 (69.83)^{ef}	79.55 (63.20)^{d}	77.68 (61.78)^{d}	10.56	1325 (36.36)^{c}	23125 (152.06)^{ab}	1:0.48
T_8	Control	-		5.35 (2.51)^{c}	6.90 (2.80)^{f}	7.20 (2.85)^{d}	7.95 (2.98)^{e}	7.80 (2.96)^{e}	87.80 (69.68)^{c}	90.25 (72.19)^{g}	91.52 (74.91)^{f}	94.00 (76.83)^{e}	93.65 (76.82)^{e}	0	820 (28.08)^{d}	20350 (142.51)^{b}	-
	SE(m)			0.07	0.08	0.08	0.10	0.07	2.34	1.76	2.84	2.13	1.86	-	1.54	3.99	-
	CD 5%			0.21	0.24	0.25	0.31	0.21	7.15	5.38	8.70	6.52	5.69	-	4.62	11.96	-
	p (0.05)			<0.001*	<0.001*	0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	-	<0.001*	0.026*	-
	CV%			6.23	6.75	6.07	8.30	5.76	6.34	6.07	8.04	7.40	6.64	-	6.48	4.38	-

*DBS- Days before spraying; DAS- Days after spraying; Figures in parantheses are square root transformed values; Treatments denoted with same alphabets within a column are not significant at 5 % level CB- cost benefit; *Significant at 5 % level of significance* dual-action mechanism targeting larvae of *S. frugiperda*. Cyantraniliprole, a diamide insecticide, disrupts calcium ion balance in muscles, causing paralysis, while thiamethoxam enhances systemic activity. These findings are consistent with prior research highlighting the efficacy of specific insecticides in managing fall armyworm (*Spodoptera frugiperda*), particularly in maize. For instance, the observed effectiveness of T_2 (cyantraniliprole 19.8% + thiamethoxam 19.8% FS and spinetoram spray) aligns closely with (Chinwada et al., 2023), who reported significantly reduced plant damage within the first 3–5 weeks of crop growth when seeds were treated with cyantraniliprole 19.8% + thiamethoxam 19.8% FS. This suggests that the systemic protection provided by these compounds during the critical early growth stages is a consistent and reliable strategy for fall armyworm management. Similarly, the superior performance of T_3 (cyantraniliprole 600 FS and chlorantraniliprole 9.3% + lambda-cyhalothrin 4.6% ZC spray) supports the findings of (Suganthi et al., 2022), which identified chlorantraniliprole 625 FS @ 6 ml kg^{-1} as the most effective seed treatment for protecting maize against fall armyworm. The comparable efficacy of treatments involving cyantraniliprole and tetraniliprole observed in this study further corroborates their findings, reinforcing the value of these insecticides in integrated pest management (IPM) programs. Furthermore, the effectiveness of spinetoram in the T_2 treatment as observed in this study echoes the results of (Supriya, 2022), who reported that spinetoram achieved a remarkable population reduction of 97.61% against *S. frugiperda*. This highlights its potential as a key component in fall armyworm management, particularly when used in combination with other effective insecticides. (Roy et al., 2021) reported that, T_3 (constituted with Barazide®, Delegate®, and Ampligo®) showed high efficacy with a signifcantly higher yield, whereas T_7 (Proclaim Fit®, Ampligo®, and Delegate®) and T_6 (Fimecta®, Ampligo®, and Spintor®) exhibited a high cumulative efficacy .These findings not only align with previous studies but also provide additional evidence supporting the integration of systemic seed treatments and selective foliar sprays into maize IPM strategies. The observed reduction in leaf injury and pest infestation levels across multiple treatments emphasizes the importance of selecting insecticides that balance efficacy against pests and safety for natural enemies, contributing to sustainable pest management practices.

3.2 Economic Viability

T_3 (cyantraniliprole 600 FS and chlorantraniliprole 9.3% + lambda cyhalothrin 4.6% ZC spray) resulted in the highest dehusked cob yield (2,185 kg/ha) and green fodder yield (26,880 kg/ha), with a cost-benefit ratio of 1:1.28, indicating its cost-effectiveness for large-scale applications. This was on par with T_2 (cyantraniliprole 19.8% + thiamethoxam 19.8% FS and spinetoram spray), which recorded a dehusked cob yield of 2,120 kg/ha and green fodder yield of 26,220 kg/ha, along with a cost-benefit ratio of 1:1.19. Thus, T_3 emerged as the most economically viable treatment, followed by T_2. The lowest yield and cost-benefit ratio were recorded in the untreated control (T_8). These results are supported by (Ahir et al., 2021), who reported that chlorantraniliprole was highly effective against fall armyworm (*Spodoptera frugiperda*) in maize, yielding the highest grain output. Emamectin benzoate showed similar effectiveness to chlorantraniliprole and had the highest Incremental Benefit-Cost Ratio (ICBR). Chlorantraniliprole recorded a higher grain yield of 6,650 kg/ha, comparable to emamectin benzoate (6,517 kg/ha) and spinetoram (6,467 kg/ha). The untreated control recorded the lowest yield (3,246 kg/ha) (Deshmukh et al., 2020). These results underscore the importance of integrating seed treatments with foliar sprays for effective management of *S. frugiperda* and minimizing crop losses. While T_1, T_2, T_3, T_4, T_6 and T_5 treatments were shown to be less harmful to beneficial organisms like coccinellids and spiders compared to broad-spectrum insecticides, their compatibility with other non-target arthropods and pollinators warrants further investigation. Sub-lethal effects, such as altered behavior or reproduction, could still occur. Both tetraniliprole and cyantraniliprole are relatively selective against pests, causing minimal harm to beneficial arthropods like coccinellids and spiders. Cyantraniliprole and spinetoram are relatively safe for natural enemies, but thiamethoxam (a neonicotinoid) is highly toxic to pollinators, such as bees, particularly during flowering stages. Runoff from chlorantraniliprole and lambda-cyhalothrin applications can pose risks to aquatic ecosystems. Chlorantraniliprole is considered less toxic to fish, birds, mammals and aquatic invertebrates, but lambda-cyhalothrin has been shown to be highly toxic to aquatic organisms. Emamectin benzoate has a selective action against target pests but may harm non-target lepidopteran larvae and parasitoids at higher doses. Flubendiamide is highly selective for lepidopteran pests, with minimal effects on predatory and parasitic arthropod. Dimethoate is a broad-spectrum organophosphate, highly toxic to a wide range of non-target organisms, including pollinators, predators, and parasitoids, It is also harmful to soil invertebrates and microbial communities and high toxicity to aquatic organisms and moderate persistence in the environment, raising concerns about runoff and groundwater contamination.

4. CONCLUSION

The study demonstrates that integrating seed treatments with foliar sprays is an effective strategy for managing *S. frugiperda* in baby corn. T_3 (cyantraniliprole 600 FS and chlorantraniliprole 9.3% + lambda cyhalothrin 4.6% ZC spray) and T_2 (cyantraniliprole 19.8% + thiamethoxam 19.8% FS and spinetoram spray) emerged as the most efficient treatments, providing superior pest control, higher yields, and better economic returns. These treatments show promise for sustainable pest management and enhanced productivity, though further research across diverse environments is needed to confirm their broader applicability.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTEREST

Authors have declared that no competing interests exist.

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