

International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; 8(9): 641-648
www.biochemjournal.com
Received: 01-06-2024
Accepted: 08-07-2024

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Field evaluation of insecticides against the fall armyworm, *Spodoptera frugiperda* in maize

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DOI: <https://doi.org/10.33545/26174693.2024.v8.i9i.2240>

Abstract

Fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae), is a serious invasive insect pest affecting global maize production. The use of chemical control extensively results in repeated control failure posing a need for continuous evaluation of the insecticides recommended for control of fall armyworm at the field level. A field trial was conducted in the winter season (November-February) of 2023-24 with an objective to evaluate six different insecticides namely Emamectin benzoate, Spinosad, Chlorantraniliprole, Spinetoram, Indoxacarb, Imidacloprid. Among the different treatments evaluated Spinetoram showed the most effective control with the highest percent reduction over control in larval population reduction (71.61%; 86.30%) and leaf damage reduction (45.25%; 64.70%) after two rounds of treatment application respectively. Emamectin benzoate and Chlorantraniliprole followed as the next best treatments in controlling the fall armyworm in maize. The above three treatments confirmed the efficacy in controlling with the highest grain yield (2213.33, 2360, 2480 kg/ha) and lowest cob damage (15.28%, 13.06%, 10.28%) respectively. The imidacloprid was a poor performer of all six treatments evaluated in terms of fall armyworm damage and grain yield.

Keywords: Population reduction, leaf damage, spinetoram, emamectin benzoate, Chlorantraniliprole

Introduction

The fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith), represents a significant invasive insect pest, posing a serious threat to global food security, particularly in maize production. Originally native to the Neotropical regions of the Americas, FAW was first detected in West Africa in 2016, and has since rapidly spread across sub-Saharan Africa and various countries worldwide (Prasanna *et al.*, 2021; CABI, 2022) [10, 5]. In India, the pest was first reported in Karnataka in 2018, leading to considerable maize yield losses, and within a year, it had disseminated to major maize-growing regions (Sharanabasappa *et al.*, 2018; Shylesha *et al.*, 2018; Suby *et al.*, 2020) [11, 12, 14]. This highly polyphagous insect is capable of infesting over 350 host plant species and completing up to 12 generations per year in tropical climates (Busato *et al.*, 2005) [4]. The larval stages feed on various parts of the plant, leading to substantial yield reductions. FAW infestations in maize have been reported to result in yield losses ranging from 50% to 80%, causing economic losses amounting to millions of dollars (Adhikari *et al.*, 2020) [1]. In Africa, in the absence of effective management strategies, FAW is responsible for annual maize yield reductions of between 8.3 to 20.6 million tonnes, translating to economic losses estimated at \$2.5 to \$6.2 million (Mendesil *et al.*, 2023) [9].

In India, maize production saw a 3.2% decline in 2017, with a total output of 27.8 million tonnes, largely due to infestations by insect pests, including FAW (Manupriya, 2019) [8]. Preliminary studies have estimated FAW-induced yield losses in India to be between 33% and 36% (Jagdish *et al.*, 2019) [7]. Currently, FAW is established in over 42 countries, with an estimated annual economic impact of \$13 billion globally (Stokstad, 2017). In Indian conditions, the FAW control is primarily focused on synthetic insecticides which evolved as effective control options. The overuse and misuse of these synthetic insecticides result in rapid resistance development and control failure. According to the Arthropods Pesticide Resistance Database, there are 42 active ingredients and 182 resistance cases were reported for FAW worldwide (Gutierrez-Moreno *et al.*, 2020) [6]. Despite the cost-intensiveness of chemical usage, documented instances of resistance, and the adoptive practices of Integrated Pest Management (IPM) strategies, chemical control continues to represent a viable and

efficacious management approach for mitigating fall armyworm infestations, particularly within the context of small-scale and economically marginalized farming communities worldwide. It has been around five years since the pest's initial appearance in India, there exists a variation in the effectiveness of various synthetic insecticides in the field level. In this context, the continuous evaluation of major insecticide's efficacy against the FAW at the field level plays a crucial role in the recommendation of management actions.

Materials and Methods

Experimental design

The study was conducted during the winter season (November 2023 – February 2023) at Research farm (21° 14' 55.8312" N latitude and 81° 38' 24.324" E longitude), ICAR – National Institute of Biotic Stress Management, Raipur, Chhattisgarh, India. The maize hybrid JKMH - 4222 was sown at a spacing of 60×20 cm in a 5 m row length with a plot size of 60 m² for each module. The experiments were laid out in randomized block design with three replications. Six different treatments were evaluated and compared the effectiveness along with a control treatment. Recommended package and practices were followed to raise the maize crop except for insecticidal treatment and a good crop stand was maintained. Insecticide treatments were applied twice in the crop period except for the control plot, initially at knee height stage followed by 15 days to the first spray. Spraying was carried during calm and warm evening conditions using a high-volume knapsack sprayer equipped with a hollow cone nozzle. Application rates were set at 400 L per hectare for the first spray and 500 L per hectare for the second. During the first spray, insecticides were distributed on both leaves and whorls, while the second application targeted only the whorls by adjusting the hollow cone nozzle.

Data collection

Visual assessments of live larvae and damaged leaves (%) were recorded from 10 plants per treatment plot excluding border rows, one day before treatment and at 1, 3, 5, 7, 10, and 14 days after the application of treatments. The final observation data of initial spraying was considered as pre-treatment observation for the second round of application. Cob damage (%) was taken once at 90 days of crop growth as the number of damaged cobs to the total number of cobs in each treatment plot. Marketable grain yield was measured for each treatment and expressed in kilograms per hectare.

Statistical analysis

All the observations recorded were subjected to appropriate statistical transformations with subsequent ANOVA analysis. Tukey's test was employed for the mean separation with a significance level set at $p \leq 0.01$. IBM SPSS 2.0 statistical software is used for data analysis.

Results

Population reduction

Foliar application of different insecticides substantially decreased the FAW incidence on maize evident as a reduction of larval population in standing crop recorded after the initial treatment application in comparison to pre-treatment observation (4.17 to 7.50).

All the treatments applied showed similar control of larval population 1 day after treatment (1 DAT) ranging from 1.50

- 2.50 mean larvae per plant ($F = 10.37$; $df = 6, 12$; $p < 0.01\%$) and statistically at par with each other. Spinosad, Spinetoram and Indoxacarb treatments resulted in an overall mean larval population of FAW 1.50 larvae per plant that were significantly low compared to 6.50 larvae per plant in control, followed by Emamectin benzoate (1.83) and Chlorantraniliprole (2.17). Despite all the treatments being superior over the control plot, the lowest level of control was reported in imidacloprid (2.50). The mean larval population in each treatment ranged from 1.17 to 2.5 larvae ($F = 8.49$; $df = 6, 12$; $p < 0.01\%$), with 6.17 larvae in the untreated control plot at 3 DAT. All the treatments are significantly at par in controlling the larval population. The lowest level of the larval population (1.17) was recorded in Emamectin benzoate, Spinosad, Spinetoram and Indoxacarb. Similarly. It is followed by Chlorantraniliprole (1.50) and the highest larval population in imidacloprid (2.50) was reported. At 5 DAT, the mean larval population of FAW ranged from 1.17 larvae per plant to the 5.83 larvae per plant. The significant lowest level of the larval population of 1.17 larvae per plant ($F = 7.52$; $df = 6, 12$; $p < 0.01\%$) was reported in both the treatments Emamectin benzoate and Indoxacarb. Spinosad, Spinetoram and Chlorantraniliprole reported a mean larval population of 1.50 larvae per plant. Imidacloprid (3.5) differed significantly among the treatments in controlling the larval population. At 7 DAT, Spinetoram treated plots have shown the lowest larval population of 1.5 larvae per plant ($F = 5.78$; $df = 6, 12$; $p < 0.01\%$) among all the treatments. Chlorantraniliprole and Emamectin benzoate was statistically at par with each other recording 1.83 larvae per plant. Following the above treatments, Spinosad, Indoxacarb and Imidacloprid were effective respectively, with larval population ranging from 1.83 to 3.83 larvae per plant. At 10 DAT, the highest larval population was reported in Imidacloprid (3.83 larvae per plant) among the treatments and 6.50 larvae per plant in the untreated control. Significant reduction over control was reported in the remaining five treatments which are statistically at par, ranging from 1.83 to 3.17 larvae per plant ($F = 3.66$; $df = 6, 12$; $p < 0.01$). At 14 DAT, the significant lowest larval population recorded in Chlorantraniliprole (1.50 larvae per plant) which is on par with Emamectin benzoate and Spinetoram ($F = 6.55$; $df = 6, 12$; $p < 0.01$). The highest larval population was recorded in the untreated control (6.06). Among the treatments, Imidacloprid was the least effective with 3.33 larvae per plant (Table No. 2).

The final mean larval population of FAW obtained by pooling over the different periods has revealed that all the treatments applied are significantly superior to the untreated check. A similar and significantly lowest larval population of 1.72 larvae per plant was reported in Spinetoram and Emamectin benzoate treatments ($F = 40.89$; $df = 6, 30$; $p < 0.01\%$) with a 71.61% of population reduction over control, proved as effective treatments among all. The Chlorantraniliprole (1.78), Indoxacarb (2.11) and Spinosad (2.22) has followed the superiority respectively. The Imidacloprid was found least effective (3.33) with a 45.04% reduction over control. The highest larval population of 6.60 larvae per plant was reported in control (Fig No. 1)

The larval population of FAW after the day of a second round of treatment application resulted in a significant reduction over the untreated check in all the respective treatments. The significant lowest population reduction of 0.5 larvae per plant was reported similarly in Emamectin

benzoate, Chlorantraniliprole and Spinetoram ($F = 12.06$; $df = 6, 12$; $p < 0.01\%$). The reduction of the larval population (0.83) in Spinosad, Indoxacarb and Imidacloprid was at par with each other. The larval population of FAW in the control plot was 6.5 larvae per plant, which is significantly different from all the insecticide treatments. At 3 DAT, the significantly lowest larval population was reported in Spinetoram (0.5) and a uniform larval population of 0.83 larvae per plant was reported in Chlorantraniliprole, Emamectin benzoate, Spinosad and Spinetoram treated plots. The population in Indoxacarb and Imidacloprid was 1.83 larvae per plant, which are less effective compared to remaining treatments ($F = 8.25$; $df = 6, 12$; $p < 0.01\%$). At 5 DAT, the treatments Chlorantraniliprole, Emamectin benzoate, Spinosad and Spinetoram reported an unvarying population of FAW larvae (0.83) and are statistically on par with each other ($F = 11.43$; $df = 6, 12$; $p < 0.01\%$). The least effective is Imidacloprid (3.5) though the Indoxacarb (2.16) is at par with it. Control plot with highest larval population of 6.16 larvae per plant. At 7 DAT, a significant and similar lowest population of FAW (0.83) was recorded in Spinetoram, Emamectin benzoate and Chlorantraniliprole ($F = 10.06$; $df = 6, 12$; $p < 0.01\%$). The Spinosad (1.83) and Indoxacarb (2.16) are on par with each other showing average effectiveness in controlling larval population. The least effective treatments are Imidacloprid (2.83) and Indoxacarb (2.16) in comparison to the control plot (6.16). In accordance with the previous observation significantly lowest larval population was reported in Spinetoram (1.1) and both the treatments Emamectin benzoate (1.5) and Chlorantraniliprole (1.17) followed the Spinetoram in effectiveness respectively ($F = 8.59$; $df = 6, 12$; $p < 0.01\%$). The highest larval population was reported in Imidacloprid (3.83) and Indoxacarb (2.5) which are on par with each other. The last observation on the larval population of FAW taken 14 DAT has shown a significant minimum larval population in Spinetoram treatments and Chlorantraniliprole (1.17). Emamectin benzoate (2.17) and Spinosad (2.17) recorded similar larval count continuing the previous observation trends. An intermediate level of larval population (2.83) was reported in Indoxacarb which is on par with the highest larval population recorded treatment Imidacloprid (3.5). The larval population count in the control plot was 5.17 larvae per plant ($F = 6.34$; $df = 6, 12$; $p < 0.01\%$) (Table No. 2).

The mean FAW larval population from different taken dates of observation on different dates of observations after the application of treatment revealed that all the treatments are superior to untreated check plot (6.06) in controlling the larval load of FAW in maize, recording the best treatment among them as Spinetoram with a significantly lowest larval population (0.83) and 86.30% population reduction over control ($F = 12.18$; $df = 6, 30$; $p < 0.01\%$). However, the Chlorantraniliprole (0.89) is almost similar to above treatment with 80.68% reduction over control and statistically at par. The next best treatment is Emamectin benzoate with a mean larval population of 1.11 larvae per plant having an 81.63% reduction over control. A mediocre level of control was achieved in Spinosad (1.44) with 76.23% reduction followed by Indoxacarb (2.22) showing 63.36% reduction over control. The minimum effectiveness was noticed in the case of Imidacloprid (2.89) with a 53.30% population reduction over control (Fig No. 1).

Leaf damage

The pre-treatment leaf damage in maize taken a day before the application of respective treatments has shown the leaf damage ranging from 38.71% to 41.99% without any significant difference between the treatment plots. Similar to the pre-treatment count the leaf damage recorded from all the treatment plots 1DAT showed no significant difference between the treatments ranging from 39.36% to 41.41%.

At 3 DAT, the leaf damage percentage was reported significantly lowest in Spinosad (27.53%) and both treatments Chlorantraniliprole (29.28%), Spinetoram (31.07%) are on par with Spinosad ($F = 14.00$; $df = 6, 12$; $p < 0.01$). An average reduction in leaf damage was recorded in Emamectin benzoate (38.59%), Indoxacarb (33.96%) and Imidacloprid (33.91%) which are on par with each other. The highest percentage of leaf damage was recorded in the control plot (44.43%). At 5 DAT, there was a significant lowest leaf damage reported in Chlorantraniliprole (24.15%) and Spinetoram (24.48%) treated plots which are almost invariable. And the next-best minimum leaf damage was reported in Spinosad (27.93%) and Indoxacarb (34.28%) respectively ($F = 4.30$; $df = 6, 12$; $p < 0.01$). The highest leaf damage among the treatments was recorded in Imidacloprid (38.20%), however, it is on par with the Emamectin benzoate (36.2%). At 7 DAT the Spinetoram continued to record the lowest leaf damage (20.22%) among the treatments applied ($F = 9.53$; $df = 6, 12$; $p < 0.01$) and the treatments Emamectin benzoate (24.68%), Chlorantraniliprole (24.27%), Spinosad (25.98%) are on par with it. The highest damage among the treatments applied was recorded in Imidacloprid (36.18%) which was again at par with Indoxacarb (27.90%). A similar trend of leaf damage was observed in 10 DAT, where all four treatments Spinetoram (17.97%), Chlorantraniliprole (19.81%), Emamectin benzoate (19.78%) and Spinosad (22.17%) were on par with each other, again the Spinetoram with lowest leaf damage ($F = 32.92$; $df = 6, 12$; $p < 0.01$). Imidacloprid (42.14%) reported the highest leaf damage when compared to all treatments applied. A slight peek in leaf damage of maize was reported in observations taken at 14 DAT in comparison to the previous observation, even so, the Spinetoram (20.31%) continued to be an effective treatment and Chlorantraniliprole (20.64%) is next best treatment being on par with it ($F = 6.95$; $df = 6, 12$; $p < 0.01$). The Spinosad (25.64%), Emamectin benzoate (22.31%) and Indoxacarb (30.96%) recorded average leaf damage. In continuation with previous observations Imidacloprid (32.1%) proved to be less effective with the highest leaf damage among the treatments applied (Table No. 3).

The mean data of leaf damage in maize crop due to fall armyworm in all the treatment plots was effectively less when compared with untreated check plot. The significantly highest control of leaf damage was reported in the treatment plot Spinetoram with a damage percentage of 25.71% and 45.25% reduction over control ($F = 10.65$; $df = 6, 41$; $p < 0.01$). However, the remaining effective treatment Chlorantraniliprole (26.38%), Spinosad (28.10%), Emamectin benzoate (30.49%) are equally effective with Spinetoram and are statistically on par with it. A mediocre effectiveness in reducing leaf damage was reported with respect to Indoxacarb (31.31%) and Imidacloprid (36.98%) continued to be least effective among the treatments. The peek leaf damage of 46.96% was recorded in the untreated check plot (Fig No. 2).

A day after the treatment application for the second time, the leaf damage in all the treatment plots was constantly low in comparison to the control plot. The significantly lowest level of leaf damage was reported in the plot treated with Spinetoram (20.40%) in line with previous spraying ($F = 29.78$; $df = 6, 12$; $p < 0.01$), and the treatments Chlorantraniliprole (21.40%), Spinosad (21.21%), Emamectin benzoate (22.7%) and Indoxacarb (24.79%) reported to be equally effective with it. A constant increase in leaf damage (52.08%) was observed in the control plot. At 3 DAT, the lowest level of leaf damage 16.79% was reported in plots treated with Emamectin benzoate and more or less similar levels of control were achieved in treatments Chlorantraniliprole (19.40%), Spinosad (24.71%), Spinetoram (17.50%) and Indoxacarb (22.93%) which are on par with each other. Imidacloprid (35.21%) was the highest leaf damage reported treatment among all ($F = 13.54$; $df = 6, 12$; $p < 0.01$). At 5 DAT, a continuation of previous observation trends was reported with the lowest leaf damage in Emamectin benzoate (14.98%) and, both treatments Chlorantraniliprole (18.44%) and Spinetoram (16.75%) are on par with each other showing almost similar levels of damage ($F = 6.68$; $df = 6, 12$; $p < 0.01$). Average damage is observed in Spinosad (26.21%) and Indoxacarb (26.79%) which are on par with each other. The comparative highest leaf damage was reported in plot treated with Imidacloprid (31.02%). At 7 DAT, the significantly lowest leaf damage was continued in Emamectin benzoate (11.64%) when compared to all the treatments applied ($F = 4.41$; $df = 6, 12$; $p < 0.01$). A similar level of damage was reported in the case of Spinosad (20.54%), Chlorantraniliprole (18.69%), Spinetoram (17.97%) and Indoxacarb (20.37%) that are on par with each other. However, the treatment Imidacloprid (26.95%) showed lesser leaf damage than control, it is statistically on par with control (45.18%) plot leaf damage. At, 10 DAT, the Emamectin benzoate (10.08%) has shown the significant lowest level of leaf damage with which the treatment Spinetoram (14.47%) was at par with almost similar levels of damage ($F = 13.09$; $df = 6, 12$; $p < 0.01$). Treatments Spinosad (19.87%), Chlorantraniliprole (20.50%) and Indoxacarb (25.61%) on par with each other yet the damage reported in Indoxacarb was comparatively quite high. With 35.95% leaf damage Imidacloprid has been the least effective among the treatments applied. 14 DAT data on leaf damage slightly differed from previous observations taken, with the lowest leaf damage reported in Spinetoram (14.47%) and along with that Emamectin benzoate (19.06%), Chlorantraniliprole (18.29%) and Spinosad (20.41%) shown similar levels of damage which are on par with each other ($F = 5.78$; $df = 6, 12$; $p < 0.01$). The average level of leaf damage was recorded in Indoxacarb (23.39%) and the highest damage among the treatments was in Imidacloprid (36.16%) which is on par with control plot (46.69%) (Table No. 4).

The mean data of leaf damage in maize influenced by different insecticidal treatments after the second application exhibited a moderate deviation from the result obtained

from the first round of treatment application. The effective treatment in controlling the leaf damage in maize due to FAW larvae was Emamectin benzoate (15.89%) with a 66.91% reduction over control ($F = 85.53$; $df = 6, 30$; $p < 0.01$). The Spinetoram (16.95%) with a 64.70% reduction over control stands as the next best treatment with which the Chlorantraniliprole (19.45%) was at par statistically. A mediocre range of effectiveness with 22.16% and 23.98% leaf damage was reported in Spinosad and Indoxacarb treated plots respectively. A constant peak of leaf damage was continued in the Imidacloprid (32.97%) with a damage reduction of 31.34%. Control plot leaf damage was significantly high reporting 48.02% (Fig No. 2).

Cob damage and Yield

All the insecticidal treatments significantly reduced cob damage when compared to the control ($F = 30.23$; $df = 6, 12$; $p < 0.0001$). The extent of cob damage varied across the treatments, ranging from the lowest 10.28% in the case of Spinetoram and 36.95% in the control plot. Among the insecticides, Imidacloprid was the least effective with a damage percentage of 22.78% (Table No. 5).

Furthermore, the assessment of yield (kg/ha) revealed that the highest yield of 2480 kg/ha was obtained from plots treated with Spinetoram, exhibiting a significant superiority over all other treatments ($F = 15.67$; $df = 6, 12$; $p < 0.0001$). Comparable yields were also observed for Emamectin benzoate (2213.33 kg/ha) and Chlorantraniliprole (2360 kg/ha). Additionally, the yields from Spinosad (2133.33 kg/ha) and Indoxacarb (2186.67 kg/ha) were found to be statistically similar (Table No. 5).

Discussion

The field trial aimed to assess the efficacy of various insecticides against the fall armyworm in maize. The results of the trial demonstrated that all tested insecticides outperformed the control plot in terms of reducing fall armyworm larval populations and minimizing maize damage. Among the insecticides evaluated Spinetoram and Emamectin benzoate exhibited the most favourable control outcome in reducing the larval population of FAW in maize. However, after the second round of treatment application, the final larval load was minimal in Spinetoram and Chlorantraniliprole. Regarding leaf damage reduction after the first application, treatments of Spinetoram and Chlorantraniliprole have shown the maximum reduction. In contrast, the Emamectin benzoate treated plots have shown the maximum reduction over control followed by Spinetoram after the second round of application. The efficacy of Spinetoram was consistent throughout the crop period and, Emamectin benzoate as well as Chlorantraniliprole also served the purpose with a similar level of control. The above three treatments can be best incorporated into IPM modules for effective management of FAW. Since resistance development in FAW is a major bottleneck in the chemical control of FAW, the above insecticides can be rotated in a single crop season. Our results follow similar trends of Bharadwaj *et al.*, 2020^[3]; Thumar *et al.*, 2020^[16]; Tayde and Ramesh, 2022^[15].

Table 1: Treatment details

S. No	Insecticide	Trade name®	Source	Dose (g/ml per lit)
1	Emamectin benzoate 5 SG	Proclaim	Syngenta India Pvt. Ltd.	0.6
2	Spinosad 45 SC	Tracer	Corteva Agri Science India Pvt. Ltd.	0.3
3	Chlorantraniliprole 18.5 SC	Coragen	FMC India Pvt. Ltd.	0.3
4	Spinetoram 11.7 SC	Delegate	Corteva Agri Science India Pvt. Ltd.	0.4
5	Indoxacarb 14.5 SC	Avant	FMC India Pvt. Ltd.	0.5
6	Imidacloprid 17.8 SL	Confidor	Bayer Crop Science Ltd	0.3

Table 2: The larval population of maize fall armyworm, as influenced by various insecticide treatments (First spray)

S. No.	Treatment details	Dosage (g/ml per liter)	*No. of larva (e) per 5 plants at indicated sprays and days								% reduction over control
			PTC	1	3	5	7	10	14	Mean	
1	Emamectin benzoate 5 SG	0.6	6.83 (2.7)	1.83a (1.52)	1.17a (1.28)	1.17a (1.28)	1.83ab (1.52)	1.83a (1.52)	2.50abc (1.67)	1.72a (1.49)	71.61
2	Spinosad 45 SC	0.3	5.17 (2.38)	1.5a (1.38)	1.17a (1.28)	1.5a (1.41)	2.83ab (1.80)	2.83a (1.80)	3.50bc (1.99)	2.22a (1.65)	63.36
3	Chlorantraniliprole 18.5 SC	0.3	4.17 (2.16)	2.17a (1.61)	1.50a (1.38)	1.5a (1.38)	1.5a (1.41)	2.5a (1.69)	1.50a (1.38)	1.78a (1.51)	70.62
4	Spinetoram 11.7 SC	0.3	5.17 (2.37)	1.50a (1.41)	1.17a (1.28)	1.5a (1.38)	1.83a (1.47)	2.5a (1.72)	1.83ab (1.52)	1.72a (1.49)	71.61
5	Indoxacarb 14.5 SC	0.4	7.50 (2.82)	1.50a (1.38)	1.17a (1.28)	1.17a (1.24)	2.5ab (1.62)	3.17a (1.91)	3.17bc (1.91)	2.11a (1.62)	65.18
6	Imidacloprid 17.8 SL	0.3	5.50 (2.44)	2.50a (1.73)	2.50a (1.72)	3.5b (1.95)	3.83b (2.08)	3.83ab (2.07)	3.83c (2.08)	3.33b (1.96)	45.04
7	Control	--	5.17 (2.38)	6.50b (2.64)	6.17b (2.58)	5.83c (2.51)	5.17c (2.35)	6.17b (2.58)	6.50d (2.64)	6.06c (2.56)	--
	SE (d)		0.20	0.21	0.25	0.29	0.30	0.27	0.25	0.94	
	CD ($p<0.01\%$)		0.61	0.65	0.78	0.88	0.93	0.84	0.77	0.25	

PTC- Pre-treatment count

*Mean of three replications; DAS-Days After Spraying

Means were analysed after square root transformation (values inside the parentheses).

Means followed by the same letter(s) are not statistically different by Tukey's test ($p<0.01\%$)**Table 3:** The larval population of maize fall armyworm, as influenced by various insecticide treatments (Second spray)

S. No.	Treatment details	Dosage (g/ml per liter)	*No. of larva (e) per 5 plants at indicated sprays and days								% reduction over control
			PTC	1	3	5	7	10	14	Mean	
1	Emamectin benzoate 5SG	0.6	2.50abc (1.67)	0.5a (0.7)	0.83ab (1.14)	0.83a (0.87)	0.83a (0.87)	1.5ab (1.22)	2.17ab (1.63)	1.11ab (1.25)	81.63
2	Spinosad 45SC	0.3	3.50bc (1.99)	0.83ab (0.87)	0.83ab (1.14)	0.83a (0.87)	1.83ab (1.34)	2.16abc (1.46)	2.17ab (1.63)	1.44b (1.38)	76.23
3	Chlorantraniliprole 18.5 SC	0.3	1.50a (1.38)	0.5a (0.7)	0.83ab (1.14)	0.83a (0.87)	0.83a (1.14)	1.17ab (1.28)	1.17a (1.28)	0.89a (1.19)	86.30
4	Spinetoram 11.7 SC	0.3	1.83ab (1.52)	0.5a (0.7)	0.50a (1.00)	0.83a (0.87)	0.83a (0.7)	1.1a (0.99)	1.17a (1.24)	0.83a (1.14)	86.30
5	Indoxacarb 14.5 SC	0.4	3.17bc (1.91)	1.83ab (1.26)	1.83c (1.52)	2.16b (1.46)	2.16ab (1.22)	2.5bc (1.56)	2.83b (1.82)	2.22c (1.65)	63.36
6	Imidacloprid 17.8 SL	0.3	3.83c (2.08)	1.83b (1.34)	1.83c (1.52)	3.5b (1.52)	2.83b (1.41)	3.83cd (1.94)	3.50bc (1.99)	2.89d (1.82)	52.31
7	Control	--	6.50d (2.64)	6.5c (2.51)	6.50d (2.64)	6.16c (2.47)	6.16c (2.42)	5.83d (2.40)	5.17c (2.37)	6.06e (2.56)	--
	SE (d)		0.25	0.26	0.14	0.26	0.28	0.25	0.25	0.08	
	CD ($p<0.01\%$)		0.77	0.81	0.32	0.80	0.86	0.78	0.78	0.24	

PTC- Pre-treatment count

*Mean of three replications; DAS – Days After Spraying

Means were analysed after square root transformation (values inside the parentheses).

Means followed by the same letter (s) are not statistically different by Tukey's test ($p<0.01\%$)

Table 4: The leaf damage of maize due to fall armyworm, as influenced by various insecticide treatments (First spray)

S. No.	Treatment details	Dosage (g/ml per liter)	*No. of damaged leaves/ 5 plants at indicated sprays and days								% reduction over control
			PTC	1	3	5	7	10	14	Mean	
1	Emamectin benzoate 5 SG	0.6	41.99 (40.39)	41.39 (40.04)	38.59d (38.40)	36.20bc (36.99)	24.68a (29.5)	19.78a (26.40)	22.31abc (28.14)	30.49a (33.52)	35.07
2	Spinosad 45 SC	0.3	38.71 (38.47)	39.36 (38.86)	27.53a (31.61)	27.93ab (31.90)	25.98a (30.63)	22.17a (28.00)	25.64abc (30.34)	28.10a (32.01)	40.16
3	Chlorantraniliprole 18.5 SC	0.3	40.12 (39.3)	40.15 (39.32)	29.28ab (32.75)	24.15a (29.41)	24.27a (29.30)	19.81a (26.40)	20.64ab (27.02)	26.38a (30.91)	43.82
4	Spinetoram 11.7 SC	0.3	39.4 (38.88)	40.23 (39.36)	31.07abc (33.86)	24.48a (29.64)	20.22a (26.66)	17.97a (25.02)	20.31a (26.34)	25.71a (30.47)	45.25
5	Indoxacarb 14.5 SC	0.4	41.1 (39.18)	40.16 (39.32)	33.96cd (35.63)	34.28abc (35.82)	27.90ab (31.87)	20.60a (26.94)	30.96bc (33.78)	31.31ab (34.02)	33.32
6	Imidacloprid 17.8 SL	0.3	39.91 (39.18)	39.37 (38.86)	33.91bcd (35.61)	38.20bc (38.15)	36.18b (36.96)	42.14b (40.46)	32.1c (34.49)	36.98b (37.460)	21.25
7	Control	--	40.86 (39.74)	41.41 (40.05)	44.43e (41.80)	43.59c (41.25)	49.20c (44.54)	53.68c (47.12)	49.45d (44.69)	46.96c (43.26)	--
	SE (d)		1.19	4.34	1.32	3.08	2.78	2.13	0.48	1.97	
	CD ($p<0.01\%$)		3.64	13.28	4.03	9.41	8.50	6.53	1.48	5.43	

PTC- Pre-treatment count

*Mean of three replications; DAS-Days After Spraying

Means were analysed after arc sin transformation (values inside the parentheses).

Means followed by the same letter(s) are not statistically different by Tukey's test ($p<0.01\%$)**Table 5:** The leaf damage of maize due to fall armyworm, as influenced by various insecticide treatments (Second spray)

S. No.	Treatment details	Dosage (g/ml per liter)	*No. of damaged leaves/ 5 plants at indicated sprays and days								% reduction over control
			PTC	1	3	5	7	10	14	Mean	
1	Emamectin benzoate 5SG	0.6	22.31abc (28.14)	22.76a (28.46)	16.79a (24.07)	14.98a (22.74)	11.64a (20.61)	10.08a (17.89)	19.06a (25.74)	15.89a (23.49)	66.91
2	Spinosad 45SC	0.3	25.64abc (30.34)	21.21a (27.33)	24.71a (29.66)	26.21abc (30.56)	20.54ab (24.01)	19.87ab (26.39)	20.41a (26.80)	22.16cd (28.08)	53.85
3	Chlorantraniliprole 18.5 SC	0.3	20.64ab (27.02)	21.40a (27.53)	19.40a (25.96)	18.44ab (25.39)	18.69ab (24.25)	20.50ab (26.91)	18.29a (25.15)	19.45bc (26.17)	59.49
4	Spinetoram 11.7 SC	0.3	20.31a (26.34)	20.56a (26.93)	17.50a (24.73)	16.75ab (24.14)	17.97ab (22.43)	14.47a (22.31)	14.47a (22.31)	16.95ab (24.31)	64.70
5	Indoxacarb 14.5 SC	0.4	30.96bc (33.78)	24.79a (29.86)	22.93a (28.57)	26.79bc (31.07)	20.37ab (26.97)	25.61bc (30.25)	23.39ab (28.43)	23.98d (29.32)	50.06
6	Imidacloprid 17.8 SL	0.3	32.1c (34.49)	32.56b (34.79)	35.21b (36.37)	31.02c (33.78)	26.95bc (31.98)	35.95c (36.67)	36.14bc (36.79)	32.97e (39.04)	31.34
7	Control	--	49.45d (44.69)	52.08c (46.20)	50.89c (45.51)	44.64d (41.86)	45.18c (39.44)	48.63d (44.22)	46.69c (43.08)	48.02f (43.86)	--
	SE (d)		0.25	1.81	2.97	3.63	4.51	3.19	4.36	1.10	
	CD ($p<0.01\%$)		0.78	5.52	9.08	11.09	13.78	9.75	13.32	3.04	

PTC- Pre-treatment count

*Mean of three replications; DAS – Days after Spraying

Means were analysed after arc sin transformation (values inside the parentheses).

Means followed by the same letter(s) are not statistically different by Tukey's test ($p<0.01\%$)**Table 6:** Effect of different insecticides on cob damage and yield of maize

S. No.	Treatment details	Dosage (g/ml/liter water)	Mean of three replications		
			*% Cob damage	% reduction over control	**Yield (kg/ha)
1	Emamectin benzoate 5SG	0.6	15.28bc (22.99)	58.65	2213.33ab
2	Spinosad 45SC	0.3	15.84bc (23.40)	57.13	2133.33b
3	Chlorantraniliprole 18.5 SC	0.3	13.06ab (21.16)	64.65	2360ab
4	Spinetoram 11.7 SC	0.3	10.28a (18.65)	72.18	2480a
5	Indoxacarb 14.5 SC	0.4	18.61cd (25.51)	49.63	2186.67b
6	Imidacloprid 17.8 SL	0.3	22.78d (28.48)	38.35	1880c
7	Control		36.95e (37.42)		1586.67d
	SE (d)		1.58		0.02
	CD ($p<0.01\%$)		4.83		0.07

*Means were analysed after arc sin transformation (values inside the parentheses)

**Means were analysed after log transformation (values inside the parentheses)

Means followed by the same letter(s) are not statistically different by Tukey's test ($p<0.01\%$)

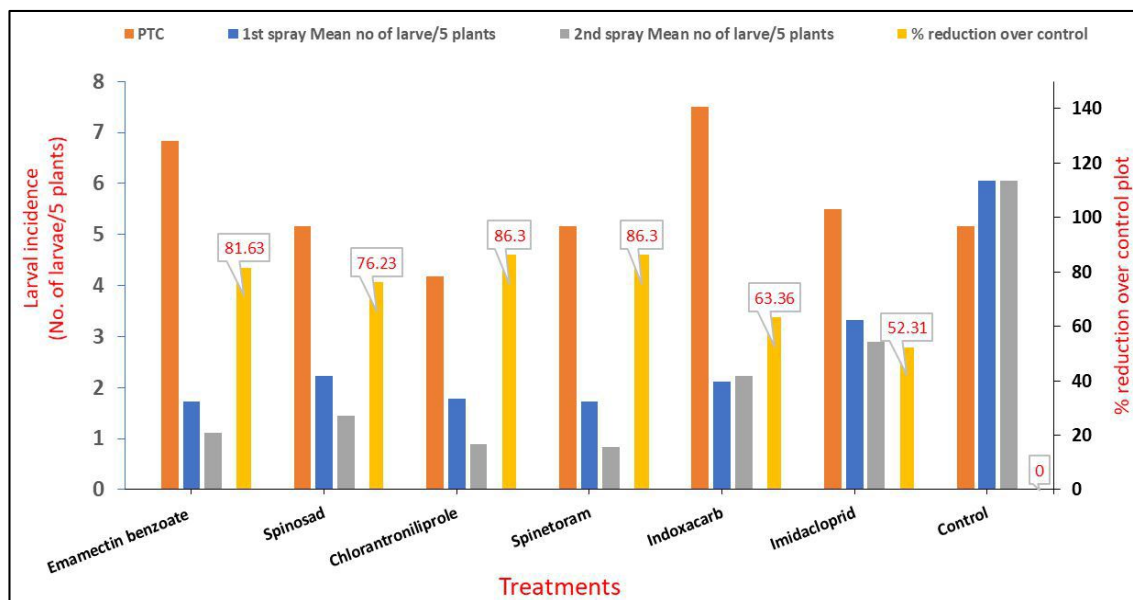


Fig 1: Efficacy of different insecticides in controlling fall armyworm larval population in maize – Rabi 2022-23

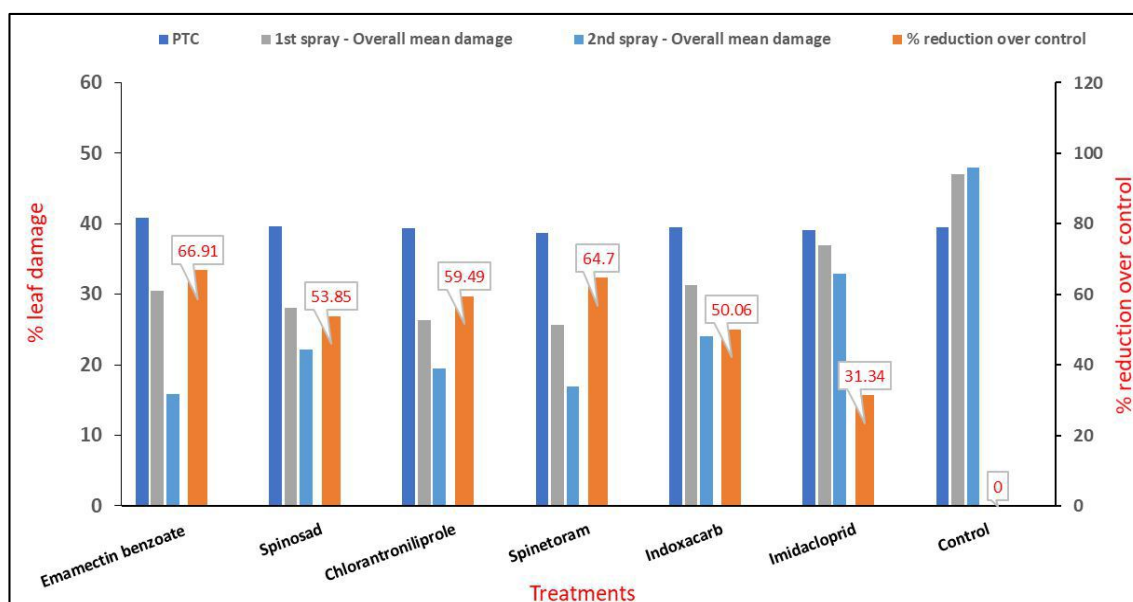


Fig 2: Efficacy of different insecticides in reducing the leaf damage of maize due to fall armyworm – Rabi 2022-23

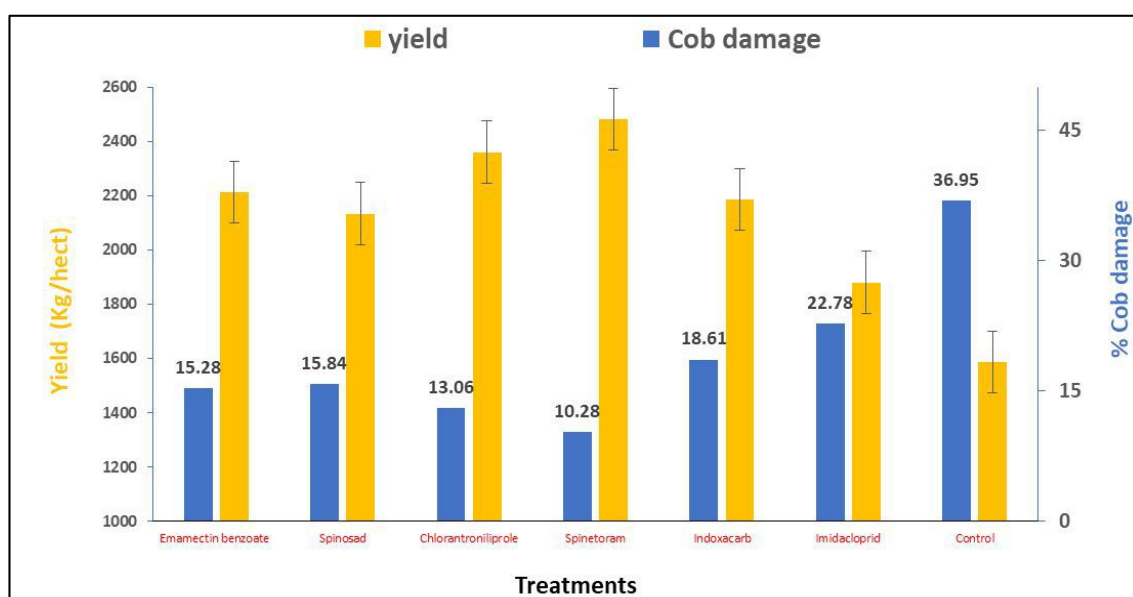


Fig 3: Cob damage and yield of maize influenced by different insecticidal treatments – Rabi 2022-23

Conclusion

Overall, the six different frequently used insecticides for FAW control were evaluated at field level for their efficacy in controlling FAW on maize crop. Spinetoram showed the best results among all, followed by Emamectini benzoate and Chlorantraniliprole. These three chemicals can be best utilized for FAW control and can be included in the IPM package of FAW of the Chhattisgarh region.

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