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Field evaluation of insecticides against fall armyworm infesting maize

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Abstract
The present investigation was conducted to evaluate the bio-efficacy of insecticides against *Spodoptera frugiperda* infesting maize under field condition at Zonal Agriculture Research Station, JNKVV, Chandangaon, Chhindwara (M.P.) during *Kharif*, 2019-20. Among the tested insecticides, Spinetoram 11.7% SC was observed to be most effective in reducing the larval population, followed by Emamectin benzoate 5SG (2.16 larvae per plant). Hence, insecticides can prove to be highly effective for the management of fall armyworm.

Keywords: Maize, *Spodoptera frugiperda,* bio-efficacy, spinetoram, emamectin benzoate, yield

1. Introduction
Maize (*Zea mays* L.), a member of the Poaceae family, is one of the world's most important cereal crops, contributing to food security in the majority of poor countries. After rice and wheat, maize is India's third most important crop. Its significance stems from the fact that it is utilised not only as human food and animal feed, but also in the corn starch industry, corn oil production and as baby corn in various recipes. It includes a number of important phytochemicals including carotenoids, phenolic compounds and phytosterols, all of which are beneficial in the prevention of certain chronic diseases (Singh, 2014) [8].

Around the world, maize is grown in about 193.07 million hectares (mha), with production and productivity of 1147.07 million metric tonnes (mmt) and 5.75 million tonnes per hectare (mt/ha), respectively (https://www.fao.org/faostat/en) [1]. In India, during 2019-20, maize was grown in about 9.72 mha, with yield and productivity of 29 mt and 2945 kg/ha, respectively. Maize area, production and productivity in Madhya Pradesh during 2019-20 were 1.34 mha, 3.91 mt and 2921 kg/ha, respectively (http://www.mospi.gov.in) [5].

The fall armyworm (FAW), *Spodoptera frugiperda* (Smith) (Noctuidae: Lepidoptera**)** is one of the serious insect pest on variety of crops around the world. It is a polyphagous pest that causes significant losses to many agricultural crops and is reported to damage more than 353 plant species belonging to 76 families (Montezano *et al*., 2018) [6]. FAW was first reported from the African continent in January 2016 (Goergen *et al.*, 2016) [2]. In India, *S. frugiperda was* reported for the first time in the maize fields of University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka during May, 2018 (Sharanabasappa *et al*., 2018) [7]. In Madhya Pradesh FAW infestation was first reported on maize during 2020 (Vishwakarma *et al.*, 2020) [10].

2. Material and Methods
The research was carried out at the Zonal Agriculture Research Station, JNKVV, Chandangaon, Chhindwara (M.P) during *kharif,* 2019-20. The trial was set up in RBD with plot size of 30 m^2 and 60 x 20 cm spacing. The maize crop variety was JM-215 and the sowing was done on July 12, 2019. The pre-treatment observation of FAW (*i.e.*, number of larvae per plant) were recorded 1 day before spraying and the post-treatment observations were taken at 1, 3, 7, and 10 days after spraying by destructive sampling method (Hardke *et al.*, 2011) [3] on five randomly selected plants per plot. Nine insecticides *viz.*, Acephate 75 SP @ 1.5 gm, Chlorantraniliprole 18.5 SC @ 0.4 ml, Deltamethrin @ 2.8 EC 1.00 ml, Emamectin benzoate 5SG @ 0.4 gm, Flubendiamide 480 SC @ 0.2 ml, Spinetoram 11.7 SC @ 0.5 ml, Spinosad 45SC @ 0.3 ml, Thiamethoxam 12.6 + Lambda cyhalothrin 9.5ZC @ 0.5 ml and Lambda cyhalothrin 4.6 + Chlorantraniliprole 9.3 ZC @ 0.5 ml per lit of water were evaluated against

fall armyworm. Two sprays were applied, initiating at first appearance of the pest and repeated after 15 days.

3. Result and Discussion

The observations revealed that the data on *S. frugiperda* larval population was consistent across all the treatments prior to the application of the insecticides, indicating that the pest was distributed evenly throughout the experimental plots (Table 3.1).

The post treatment observations showed that all the insecticides were significantly superior to the untreated control. Results of the pooled data after first spray indicated that significantly lowest larval population was recorded in plots treated with Spinetoram 11.7 SC (2.40 larvae/plant), followed by Emamectin benzoate 5 SG (2.69 larvae/plant), Lambda cyhalothrin 4.6 + Chlorantraniliprole 9.3 ZC (2.91 larvae/plant) and Chlorantraniliprole 18.5 SC (2.93 larvae/plant), but non-significant differences were observed between them. While it was maximum in untreated control (4.41 larvae/plant) and the least effective treatments were Spinosad 45SC, Thiamethoxam 12.6 + Lambda cyhalothrin 9.5 ZC, Deltamethrin 2.8 EC and Acephate 75 SP (3.48, 3.66, 3.70 and 3.70 larvae/plant, respectively), but statistically at par with each other.

Further, analysis of the pooled data after second spray indicated that significantly lowest larval population was recorded in Spinetoram 11.7 SC (1.29 larvae/plant), followed by Emamectin benzoate 5SG (1.63 larvae/plant), but they did not differ significantly from each other. While it was maximum in untreated control (4.88 larvae/plant) and the least effective treatments were Spinosad 45 SC (2.52 larvae/plant) followed by Flubendiamide 480, Thiamethoxam 12.6 + Lambda cyhalothrin, Acephate 75 SP and Deltamethrin 2.8 EC (2.54, 2.73, 2.98 and 3.00 larvae/plant, respectively), but were found to be non significant.

After two sprays, significantly lowest larval population was observed in Spinetoram 11.7 SC (1.84 larvae/plant), followed by Emamectin benzoate 5SG (2.16 larvae/plant), but were at par with each other. Whereas it was maximum in untreated control (4.64 larvae/plant) and the least effective treatments were Spinosad 45 SC and Flubendiamide 480 SC (both 3.00 larvae/plant) followed by Thiamethoxam 12.6 + Lambda cyhalothrin 9.5 ZC Acephate 75 SP and Deltamethrin 2.8 EC (3.19, 3.38 and 3.40 larvae/plant, respectively), but they did not differ significantly from each other.

The pooled data after two sprays indicated that the reduction of *S. frugiperda* larval population ranged from 26.87 (Deltamethrin 2.8 EC) to 60.34% (Spinetoram 11.7 SC) (Fig 3.1).

The present findings confirms the findings of Mallapur *et al.*, (2019) [4] and Thumar *et al.*, (2020) [9], as they also reported that Spinetoram 11.7 SC was most effective against *S. frugiperda*, followed by Emamectin benzoate 5 SG, respectively.

Table 3.1: Bio-efficacy of insecticides against *Spodoptera frugiperda* infesting maize (*Kharif* 2019-20).

Treatments	Dose (g / ml per ha)	Before spray (Larvae/plant)	Mean no. of FAW larvae/ plant*										Mean of two sprays	Reduction in larval population over control (after two sprayings) (%)
			Days after Ist spraying				Mean of first spray	Days after IInd spraying				Mean of second spray		
			1	3	7	10		1	3	7	10			
Acephate 75 SP	750	4.70 (2.17)	4.17 (2.04)^{a}	3.90 (1.97)^{a}	3.66 (1.91)^{b}	3.45 (1.86)^{b}	3.79 (1.95)^{ab}	3.30 (1.82)^{b}	3.10 (1.76)^{b}	2.80 (1.67)^{b}	2.70 (1.64)^{b}	2.98 (1.72)^{b}	3.38 (1.84)^{b}	27.10 (31.36)
Chlorantraniliprole 18.5 SC	200	4.47 (2.11)	3.13 (1.75)^{bc}	3.01 (1.72)^{bc}	2.82 (1.67)^{cde}	2.76 (1.66)^{bcd}	2.93 (1.70)^{cd}	2.54 (1.59)^{bc}	2.44 (1.56)^{bc}	2.00 (1.41)^{cde}	1.17 (1.08)^{d}	2.04 (1.42)^{cd}	2.49 (1.57)^{cd}	46.51 (42.97)
Deltamethrin 2.8 EC	500	4.63 (2.15)	4.20 (2.05)^{a}	3.92 (1.98)^{a}	3.65 (1.91)^{b}	3.40 (1.84)^{b}	3.79 (1.95)^{ab}	3.25 (1.80)^{b}	3.15 (1.77)^{b}	2.85 (1.69)^{b}	2.75 (1.66)^{b}	3.00 (1.73)^{b}	3.40 (1.84)^{b}	26.87 (31.21)
Emamectin benzoate 5SG	200	4.50 (2.12)	2.90 (1.69)^{c}	2.73 (1.64)^{c}	2.65 (1.62)^{de}	2.47 (1.57)^{cd}	2.69 (1.63)^{d}	2.14 (1.43)^{c}	1.98 (1.38)^{cd}	1.62 (1.26)^{ef}	0.77 (0.87)^{e}	1.63 (1.26)^{de}	2.16 (1.46)^{de}	53.56 (47.11)
Flubendiamide 480 SC	100	4.50 (2.12)	3.87 (1.97)^{ab}	3.65 (1.91)^{ab}	3.30 (1.82)^{bcd}	3.02 (1.74)^{bc}	3.46 (1.86)^{bc}	3.00 (1.73)^{b}	2.80 (1.67)^{b}	2.35 (1.53)^{bcd}	2.00 (1.41)^{c}	2.54 (1.59)^{bc}	3.00 (1.73)^{bc}	35.42 (36.51)
Spinetoram 11.7 SC	250	4.63 (2.15)	2.67 (1.63)^{c}	2.43 (1.56)^{c}	2.28 (1.50)^{e}	2.21 (1.48)^{d}	2.40 (1.54)^{d}	2.03 (1.40)^{c}	1.67 (1.27)^{d}	1.17 (1.08)^{f}	0.30 (0.54)^{f}	1.29 (1.12)^{e}	1.84 (1.35)^{e}	60.34 (51.01)
Spinosad 45 SC	150	4.37 (2.09)	3.90 (1.97)^{ab}	3.63 (1.91)^{ab}	3.35 (1.83)^{bc}	3.04 (1.73)^{bc}	3.48 (1.86)^{bc}	2.95 (1.72)^{b}	2.82 (1.68)^{b}	2.37 (1.54)^{bcd}	1.95 (1.40)^{c}	2.52 (1.59)^{bc}	3.00 (1.73)^{bc}	35.36 (36.47)
Thiamethoxam 12.6 + Lambda cyhalothrin 9.5 ZC	250	4.50 (2.12)	3.98 (2.00)^{a}	3.85 (1.96)^{a}	3.55 (1.88)^{b}	3.25 (1.80)^{bc}	3.66 (1.91)^{ab}	3.10 (1.76)^{b}	3.03 (1.72)^{b}	2.60 (1.61)^{bc}	2.20 (1.48)^{c}	2.73 (1.65)^{b}	3.19 (1.79)^{b}	31.18 (33.91)
Lambda cyhalothrin 4.6 + Chlorantraniliprole 9.3 ZC	250	4.40 (2.10)	3.17 (1.76)^{bc}	2.93 (1.70)^{bc}	2.79 (1.66)^{cde}	2.76 (1.66)^{bcd}	2.91 (1.70)^{cd}	2.55 (1.59)^{bc}	2.43 (1.56)^{bc}	1.96 (1.37)^{de}	1.17 (1.08)^{d}	2.03 (1.42)^{cd}	2.47 (1.57)^{cd}	46.80 (43.13)
Untreated control		4.00 (2.00)	4.33 (2.08)^{a}	4.35 (2.09)^{a}	4.47 (2.11)^{a}	4.47 (2.11)^{a}	4.41 (2.10)^{a}	4.75 (2.18)^{a}	4.83 (2.20)^{a}	4.90 (2.21)^{a}	5.03 (2.24)^{a}	4.88 (2.21)^{a}	4.64 (2.15)^{a}	-
SEm±		NS	0.07	0.07	0.06	0.07	0.06	0.09	0.08	0.07	0.05	0.06	0.05	3.45
CD at 5%		NS	0.22	0.22	0.19	0.21	0.18	0.25	0.23	0.21	0.15	0.17	0.16	10.43

NS=Non-significant,

* Figures in the parentheses are square root transformed values

Treatment means with the same letter were not significant by DMRT at 5% level of significance

Table 3.2: Economics of insecticides against *Spodoptera frugiperda* infesting maize (*Kharif* 2019-20).

Treatments	Grain yield (q/ha)	% Increase in yield over control (q/ha)	Cost of insecticides (Rs/ha)	Cost of increased yield over control (Rs/ha)*	Cost of treatment (Rs/ha)**	Net profit (Rs/ha)	Cost Benefit ratio
Acephate 75 SP	43.46	11.15	945.00	7676.86	3440.00	4236.86	1:1.23
Chlorantraniliprole 18.5 SC	49.54	26.70	2683.30	18370.21	6916.67	11453.54	1:1.66
Deltamethrin 2.8 EC	43.80	12.02	1100.00	8272.00	3750.00	4522.00	1:1.21
Emamectin benzoate 5SG	50.51	29.18	820.00	20090.01	3190.00	16900.01	1:5.30
Flubendiamide 480 SC	47.03	20.28	1610.00	13964.69	4770.00	9194.69	1:1.93
Spinetoram 11.7 SC	51.43	31.27	3625.00	21697.59	8800.00	12897.59	1:1.47
Spinosad 45SC	46.80	19.69	2440.00	13552.00	6430.00	7122.00	1:1.11
Thiamethoxam 12.6 + Lambda cyhalothrin 9.5ZC	44.47	10.77	659.40	9443.31	2868.75	6574.56	1:2.29
Lambda cyhalothrin 4.6 + Chlorantraniliprole 9.3 ZC	49.85	27.49	1984.40	18927.11	5518.75	13408.36	1:2.43
Untreated control	39.10	-	-	-	-	-	-
SEm±	2.44	-	-	-	-	-	-
CD at 5%	7.30	-	-	-	-	-	-

*Price of maize = 1760 Rs/quintal
** Labour cost = 2 labours/ha for one day @ Rs. 375/ day

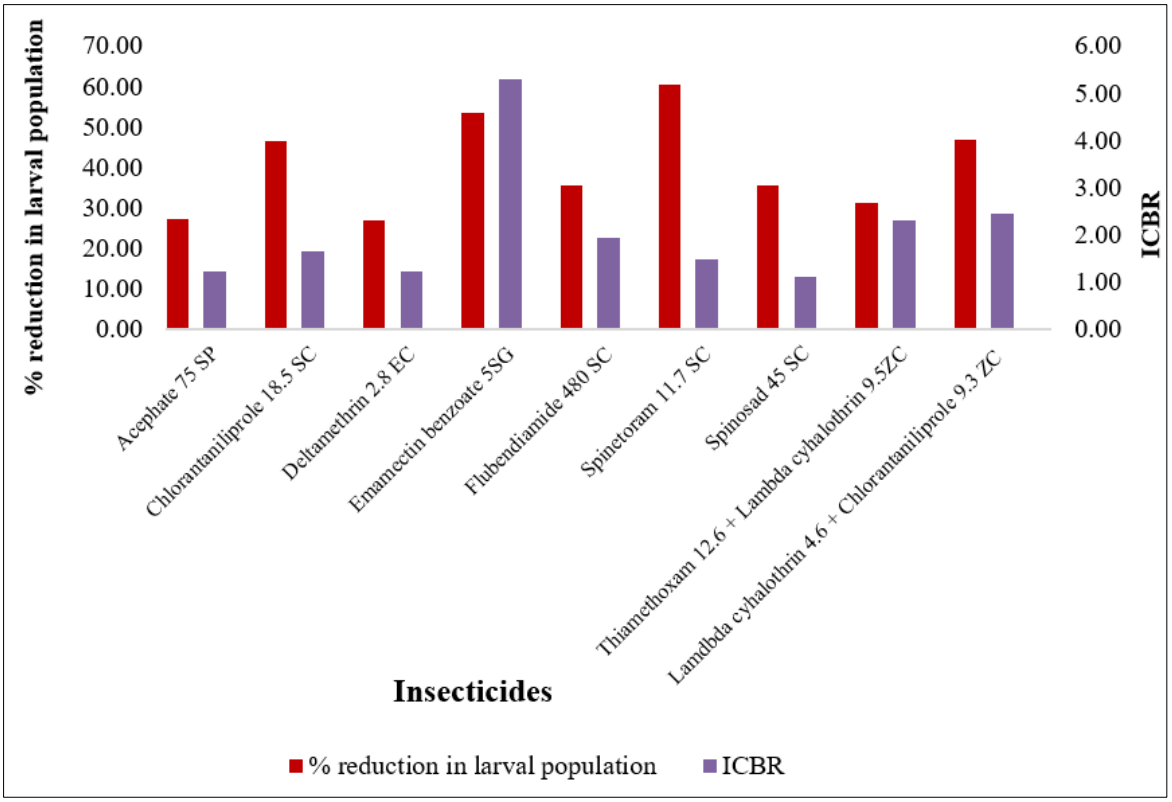

Fig 3.1: Bio-efficacy and economics of insecticides against FAW in maize.

3.1. Grain yield

Significantly highest grain yield was registered by Spinetoram 11.7 SC (51.43 q/ha), which was followed by Emamectin benzoate 5SG (50.51 q/ha), Lambda cyhalothrin 4.6 + Chlorantraniliprole 9.3 ZC (49.85 q/ha) and Chlorantraniliprole 18.5 SC (49.54 q/ha), while Acephate 75 SP recorded the lowest grain yield (43.46 q/ha) (Table 3.2).

3.2. Economics of different insecticides against fall armyworm

Perusal of data the in Table 2 revealed that maximum net profit was obtained from Emamectin benzoate 5SG (16900/- per ha), followed by Lambda cyhalothrin 4.6 + Chlorantraniliprole 9.3 ZC (13408.36/- per ha), Spinetoram 11.7 SC (12897.59/- per ha) and Chlorantraniliprole 18.5 SC (11453.54/- per ha), respectively.

However, the highest cost benefit ratio (1:5.30) was obtained from the treatment Emamectin benzoate 5SG which was obviously due to its low price as compared to the other insecticides, followed by Lambda cyhalothrin 4.6 + Chlorantraniliprole 9.3 ZC (1:2.43) and Thiamethoxam 12.6 + Lambda cyhalothrin 9.5 ZC (1:2.29), respectively (Fig 3.1).

4. Conclusion

The application of Spinetoram 11.7 SC @ 0.5 ml/lit was found to be most effective in managing the larval population of *S. frugiperda* and also recorded highest grain yield, however highest cost benefit ratio was obtained by the application of Emamectin benzoate 5SG.

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