Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
www.entomoljournal.com
JEZS 2020; 8(6): 1831-1834

Received: 15-08-2020
Accepted: 22-09-2020

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Efficacy of insecticides on larval population of fall armyworm, *Spodoptera frugiperda* on maize

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Abstract
The field experiments were conducted during *Rabi* 2018-19 to evaluate the effect of seven newer insecticide molecules *viz*., sprofenophos 50 EC@ 30 ml, indoxacarb 14.5 SC @ 8.5 ml, emamectin benzoate 5 SG@ 4 g, spinosad 45SC @ 4 ml, thiamethoxam 12.6 + lambdacyhalothrin 9.5@ 2.5 ml, chlorantraniliprole 18.5 SC 3 ml and flubendiamide 49.35 SC @ 2.5 per 10 lit. of water respectively. Among the insecticides spraying, emamectin benzoate 5 SG was most effective treatment over control followed by chlorantraniliprole 18.5 SC, flubendiamide 39.35 SC, indoxacarb 14.5 SC, thimethoxam 12.6 + lambda cyhalothrin 9.5 ZC, spinosad 45 SC and profenophos 50 EC. The highest yield was recorded in the treatment emamectin benzoate 5 SG @ (42.5 q/ha) followed by chlorantraniliprole 18.5% SC (40.01 q/ha), flubendiamide 39.35 SC (38.5 q/ha) and thimethoxam 12.6 + lambda cyhalothrin 9.5 ZC (37.6 q/ha).

Keywords: Efficacy, maize, fall armyworm, *Spodoptera frugiperda*, rabi, yield, chlorantraniliprole, flubendiamide, indoxacarb, thiamethoxam + lambda cyhalothrin

1. Introduction
Maize (Zea *mays*) is the third major cereal crop extensively grown in temperate, subtropical and tropical regions of the world. It grows well in loamy soil but surplus or poor rain adversely affects yield as well as quality [7]. India ranks sixth in global maize production and fifteenth position in its productivity in world, contributing to 2.4 per cent of world production with almost 5 per cent share in world harvested area. In India, *Rabi* maize was sown in around 7.22 lakh hectares as of 30th November 2018 which was lower than 8.34 lakh hectares during corresponding period last year [1]. Recently introduced pest fall armyworm (*Spodoptera frugiperda)* is of serious concern due to its notorious and polyphagous behavior. The main reason for its fast spread might be its strong capacity to fly and disperse long distance annually during the summer months [6]. The severity of the problem is compounded by the ability of the fall armyworm to harm a variety of vegetative structures of reproductive plants, creating the opportunity to cause crop yield loss. *Spodoptera frugiperda* is a highly polyphagous insect pest that attacks more than 80 plant species, including maize, sorghum, millet, sugarcane, and vegetable crops. Young larvae mainly feed on epidermal leaf tissue and also make holes in leaves. In India, *Spodoptera frugiperda* is recently reported in Karnataka Tamilnadu and Telangana infesting maize crop. It is also found in Maharashtra of Solapur district [8]. Also identified on molecular basis that the insect pest creating the menace on maize is *Spodoptera frugiperda* and also reported in the month of September its feeding on two months old sugarcane crop, variety (Co 86032) at Ghogaon village of Sangli District (Maharashtra) [3]. To overcome resistance problems, reduce doses of insecticides with selective mode of action and persistence against target pest. The present study efficacy of the newer insecticides on larval population fall armyworm, *Spodoptera furgiperda*.

2. Materials and Methods
The experiment was laid out in a Randomized Block Design with three replications. The whole area of experimental field was divided into three replications and each block was again divided into eight plots. The observations on total number of nymphs of aphid were recorded at one day before, 2, 7, and 14 days after application of insecticides for each spraying.

2.2. The details of experiments are given below

Table 1: Experimental and Randomized block

Experimental design	Randomized block design
Season	*Rabi* 2018 – 19
Plot size	6.0 x 3.6 m^2
Variety	Komal
Spacing between plants	60 x 30 cm^2

The quantity of water required for spraying the plots was calculated by spraying water on the plot of treatment of water spray. Then Spraying solution was prepared with profenophos 50 EC @ 30 ml, indoxacarb 14.5 SC @ 8.5 ml, emamectin benzoate 5 SG@ 4 g, spinosad 45 SC @ 4 ml, thiamethoxam 12.6 + lambda cyhalothrin 9.5 @ 2.5 ml, chlorantraniliprole 18.5 SC 3 ml and flubendiamide 49.35 SC @ 2.5 per 10 lit. of water respectively. For spraying purpose required quantity of insecticides is calculated and measured by measuring cylinder. Finally Spraying was carried out to test the effectiveness of the insecticides against major insect pests of maize.

3. Results and Discussion

The result revealed that the pre count of fall armyworm, *S. frugiperda* was non-significant showing even distribution of plant infestation before spraying (Table No. 2). Observation recorded at 2 DAS after first spraying, all the insecticides were found significantly superior over untreated control in reducing larval population of maize fall armyworm after first application of insecticides. Emamectin Benzoate 5 SG (3.00 larva/10 plant) recorded minimum larval population of fall armyworm and it was at par with chlorantraniliprole 18.5 SC (3.66 larva/10 plant). Next best treatments in order of effectiveness were flubendiamide 39.35 SC (4.66 larva/10 plant), thiamethoxam 12.6 + lambda cyhalothrin 9.5 ZC (6.00 larva/10 plant), indoxacarb 14.5 SC (6.66 larva/10 plant), spinosad 45 SC (7.00 larva/10 plant) and profenophos 50 EC (9.00 larva/10 plant). The results at 7 days after first spraying indicated that chlorantraniliprole 18.5% SC (2.33 larva/10 plant) recorded minimum larval population infestation of fall armyworm and it was at par with flubendiamide 39.35 SC (3.00 larva/10 plant), emamectin Benzoate 5 SG (4.00 larva/10 plant). Thimethoxam 12.6 + lambda cyhalothrin 9.5 ZC (5.33 larva/10 plant), indoxacarb 14.5 SC (5.66 larva/10 plant), spinosad 45 SC (6.00 larva/10 plant) and profenophos 50EC (7.66 larva/10plant) were also effective in reducing the larval infestation and water spray registered highest population (19.00 larva/10 plant). The observations recorded on 14 days after first spraying revealed that emamectin benzoate 5 SG (4.00 larva/10 plant) recorded minimum larval infestation of fall armyworm and it was at par with chlorantraniliprole 18.5SC (4.33 larva/10plant), flubendiamide 39.35 SC (4.33 larva/10 plant). Thimethoxam 12.6 + lambda cyhalothrin 9.5 ZC (7.00 larva/10 plant), indoxacarb 14.5 SC (8.00 larva/10 plant), spinosad 45 SC (8.00 larva/10 plant) and profenophos 50EC (11.66 larva/10 plant) were also effective in order of reducing the larval infestation and water spray (19.30 larva/10 plant) recorded increase in infestation.

Table 2: Effect of insecticides on larval population of fall armyworm *Spodoptera frugiperda* on maize during *Rabi*- 2018 (First spray)

Tr. No.	Treatment	No. of larvae/10 plant				
		Dose (ml or gm)/ha	Pre-count	2 DAS	7 DAS	14 DAS
T_1	Profenophos 50 EC	1500 ml	17.00 (4.24)	9.00 (3.16)	7.66 (2.94)	11.66 (3.55)
T_2	Indoxacarb 14.5 SC	425 ml	18.00 (4.35)	6.66 (2.76)	5.66 (2.58)	8.00 (2.99)
T_3	Emamectin benzoate 5 SG	200 g	17.33 (4.27)	3.00 (1.98)	4.00 (2.18)	4.00 (2.22)
T_4	Spinosad 45 SC	200 ml	18.66 (4.43)	7.00 (2.82)	6.00 (2.64)	8.00 (2.99)
T_5	Thiamethoxam 12.6 + Lambda cyhalothrin 9.5	125 ml	17.66 (4.31)	6.00 (2.64)	5.33 (2.50)	7.00 (2.82)
T_6	Chlorantraniliprole 18.5 SC	150 ml	16.66 (4.19)	3.66 (2.15)	2.33 (1.82)	4.33 (2.30)
T_7	Flubendiamide 49.35 SC	125 ml	17.33 (4.27)	4.66 (2.36)	3.00 (1.98)	4.33 (2.30)
T_8	Water spray		17.00 (4.24)	18.33 (4.39)	19.00 (4.47)	19.30 (4.49)
	SE (m)		N/S	0.12	0.16	0.11
	CD at 5%			0.37	0.51	0.36
	CV (%)			7.64	10.83	6.98

*Figure in parenthesis are square root transformed value

The data regarding effect of different insecticides on number of larval population of fall armyworm on 2, 7 and 14 days after second spray is presented in Table No. 3 and the results revealed that all the insecticides were found significantly superior over water spray in reducing larval population of fall armyworm after second spraying of insecticides. The results at 2 day after second spraying indicated that emamectin benzoate 5 SG (2.00 larva/10 plant) recorded minimum larval population infestation of fall armyworm and it was at par with chlorantraniliprole 18.5 SC (3.00 larva/10plant) and flubendiamide 39.35 SC (3.33 larva/10 plant). The next best treatments were thimethoxam 12.6 + lambda cyhalothrin 9.5 ZC (5.66 larva/10 plant), spinosad 45 SC (6.00 larva/10 plant), indoxacarb 14.5 SC (6.33 larva/10 plant) and profenophos 50 EC (6.33 larva/10plant) respectively. The highest infestation was recorded in water spray (20.00 larva/10 plant).The results at 7 day after second spraying indicated that emamectin benzoate 5 SG (1.33 larva/10 plant) recorded minimum larval infestation of fall armyworm and it was at par with chlorantraniliprole 18.5 SC (2.00 larva/10plant). Order of effectiveness of other insecticidal treatments was flubendiamide 39.35 SC (2.66 larva/10 plant), thimethoxam 12.6 + lambda cyhalothrin 9.5 ZC (3.66 larva/10 plant), spinosad 45 SC (4.33 larva/10 plant), indoxacarb 14.5 SC (4.66 larva/10 plant) and profenophos 50EC (5.00larva/10plant). At 14 day after second spraying indicated that water spray (25.33 larva/10 plant) recorded highest population of fall armyworm and among insecticidal treatments emamectin benzoate 5 SG (2.66 larva/10 plant) recorded minimum larval population infestation of fall armyworm and it was at par with chlorantraniliprole 18.5% SC (3.66 larva/10plant), flubendiamide 39.35 SC (4.00 larva/10 plant). The next best insecticidal treatments were thimethoxam 12.6 + lambda cyhalothrin 9.5 ZC (6.00 larva/10 plant), spinosad 45 SC (6.33 larva/10 plant), indoxacarb 14.5 SC (8.33larva/10 plant) and profenophos 50EC (11.00 larva/10plant).

Table 3: Effect of insecticides on larval population of fall armyworm on maize (Second spray)

Tr. No.	Treatment	No. of larvae/10 plant			
		Dose (ml or gm)/ha	2 DAS	7 DAS	14 DAS
T_1	Profenophos 50 EC	1500 ml	6.33 (2.70)	5.00 (2.44)	11.00 (3.34)
T_2	Indoxacarb 14.5 SC	425 ml	6.33 (2.70)	4.66 (2.37)	8.33 (3.05)
T_3	Emamectin benzoate 5 SG	200 g	2.00 (1.71)	1.33 (1.52)	2.66 (1.88)
T_4	Spinosad 45 SC	200 ml	6.00 (2.64)	4.33 (2.30)	6.33 (2.70)
T_5	Thiamethoxam 12.6 + Lambda cyhalothrin 9.5	125 ml	5.66 (2.56)	3.66 (2.15)	6.00 (2.60)
T_6	Chlorantraniliprole 18.5 SC	150 ml	3.00 (1.98)	2.00 (1.71)	3.66 (2.15)
T_7	Flubendiamide 49.35 SC	125 ml	3.33 (2.07)	2.66 (1.91)	4.00 (2.22)
T_8	Water spray	--	20.00 (4.58)	20.66 (4.65)	25.33 (5.11)
	SE (m)		0.14	0.11	0.17
	CD at 5%		0.43	0.35	0.52
	CV (%)		9.39	8.41	10.20

*Figure in parenthesis are square root transformed value

Data regarding the impact of various insecticides on the no. of fall armyworm larval infestation are presented in Table No. 4 after the third spray. The results showed that all insecticides were found to be substantially superior to untreated control in reducing the number of larval fall armyworm infestations after the third spray of insecticides on 2, 7, and 14 days. The results of the second day after the third spray showed that water spray (18.33 larva/10 plant) recorded maximum infestation whereas emamectin benzoate 5 SG (1.33 larva/10 plant) showed minimum larval infestation of fall armyworm and was approximately equivalent to chlorantraniliprole 18.5 SC (1.66 larva/10 plant), flubendiamide 39.35 SC (2.33 larva/10 plant). The results of seven day after third spraying indicated that emamectin benzoate 5 SG (0.66 larva/10 plant) recorded minimum larval population infestation of fall armyworm among all the treatments and it was at par with chlorantraniliprole 18.5% SC (1.33 larva/10plant), flubendiamide 39.35 SC (1.66 larva/10 plant). On 14 days after third spray among treatments water spray (9.66 larva/10 plant) was having highest infestation and emamectin benzoate 5 SG (1.66 larva/10 plant) registered minimum larval infestation of fall armyworm and it was at par with chlorantraniliprole 18.5 SC (2.33 larva/10plant) and flubendiamide 39.35 SC (3.00 larva/10 plant).

Table 4: Effect of insecticides on larval population of fall armyworm *Spodoptera frugiperda* on maize (Third spray)

Tr. No.	Treatment	No. of larvae/10 plant			
		Dose (ml or gm)/ha	2 DAS	7 DAS	14 DAS
T_1	Profenophos 50 EC	1500 ml	4.00 (2.22)	3.33 (2.07)	5.00 (2.44)
T_2	Indoxacarb 14.5 SC	425 ml	3.66 (2.13)	3.00 (1.98)	3.33 (2.07)
T_3	Emamectin benzoate 5 SG	200 g	1.33 (1.52)	0.66 (1.27)	1.66 (1.62)
T_4	Spinosad 45SC	200 ml	4.00 (2.22)	3.66 (2.15)	5.33 (2.49)
T_5	Thiamethoxam 12.6 + Lambda cyhalothrin 9.5	125 ml	3.66 (2.15)	3.33 (2.07)	4.00 (2.22)
T_6	Chlorantraniliprole 18.5 SC	150 ml	1.66 (1.62)	1.33 (1.52)	2.33 (1.82)
T_7	Flubendiamide 49.35 SC	125 ml	2.33 (1.82)	1.66 (1.57)	3.00 (1.98)
T_8	Water spray		18.33 (4.39)	12.66 (3.68)	9.66 (3.25)
	SE (m)		0.13	0.16	0.14
	CD at 5%		0.40	0.48	0.43
	CV (%)		10.09	13.53	10.99

The data displayed in Table no. 5 pertaining to cumulative effect of newer insecticides against fall armyworm at two days after spray revealed that chlorantraniliprole 18.5 SC (3.44 Larva/10 plant) proved effective in recording the infestation of fall armyworm. However, this treatment was found statistically equal with emamectin benzoate 5 SG (3.66 Larva/10 plant), flubendiamide 39.35 SC (3.99 Larva/10 plant). Whereas, the treatments thimethoxam 12.6 + lambda cyhalothrin 9.5 ZC (6.11 Larva/10 plant) and indoxacarb 14.5 SC (6.77 Larva/10 plant) found at par with each other and with spinosad 45 SC (7.00 Larva/10 plant) and profenophos 50 EC (9.44 Larva/10 plant) respectively. The data on cumulative effect of different treatments against fall armyworm at seven days after spray showed that application of emamectin benzoate 5 SG (1.99 Larva/10 plant) recorded minimum infestation. This treatment was closely followed by chlorantraniliprole 18.5 SC (2.88 Larva/10 plant). Among the different treatments cumulative per cent infestation recorded at fourteen days after spray (Table No. 4) was minimum in the plots treated with emamectin benzoate 5 SG (1.21 Larva/10 plant). This treatment was found at par with chlorantraniliprole 18.5 SC (1.77 Larva/10 plant). The next effective treatment was flubendiamide 39.35 SC (2.33 Larva/10 plant), followed by indoxacarb 14.5 SC (3.33 Larva/10 plant) and thimethoxam 12.6 + lambda cyhalothrin 9.5 ZC (3.66 Larva/10 plant).

The cumulative mean data showed that after sprays treatment with emamectin benzoate 5 SG (2.28 Larva/10 plant) proved effective with minimum infestation of fall armyworm and found at par with chlorantraniliprole 18.5 SC (2.69 Larva/10 plant). Flubendiamide 39.35 SC (3.21 Larva/10 plant), thimethoxam 12.6 + lambda cyhalothrin 9.5 ZC (4.95 Larva/10 plant), indoxacarb 14.5 SC (5.47 Larva/10 plant), spinosad 45 SC (5.62 Larva/10 plant) and profenophos 50 EC (6.96 Larva/10 plant) appeared as next better treatments in this respect respectively. Maximum infestation of fall armyworm was recorded in water spray (18.1 Larva/10 plant).

Table 5: Cumulative effect of newer insecticides against *S. frugiperda*

Tr. No.	Treatment	1st spray	2nd spray	3rd spray	Mean
T_1	Profenophos 50 EC	9.44 (3.22)	7.33 (2.85)	4.11 (2.25)	6.96 (2.89)
T_2	Indoxacarb 14.5 SC	6.77 (2.78)	6.33 (2.69)	3.33 (2.08)	5.47 (2.52)
T_3	Emamectin Benzoate 5 SG	3.66 (2.15)	1.99 (1.72)	1.21 (1.48)	2.28 (1.79)
T_4	Spinosad 45 SC	7.00 (2.82)	5.55 (2.55)	4.33 (2.30)	5.62 (2.56)
T_5	Thimethoxam 12.6 + Lambda cyhalothrin 9.5 ZC	6.11 (2.66)	5.10 (2.46)	3.66 (2.15)	4.95 (2.43)
T_6	Chlorantraniliprole 18.5 SC	3.44 (2.09)	2.88 (1.96)	1.77 (1.66)	2.69 (1.91)
T_7	Flubendiamide 39.35 SC	3.99 (2.22)	3.33 (2.07)	2.33 (1.81)	3.21 (2.04)
T_8	Water spray	18.77 (4.44)	21.99 (4.78)	13.55 (3.78)	18.1 (4.35)
SE (m)		0.07	0.09	0.14	0.09
CD at 5%		0.24	0.27	0.42	0.29
CV (%)		4.77	5.87	10.70	6.40

The present finding are more less parallel to the finding of other workers like he concluded that spinetoram recorded 98.13 per cent reduction over control at seven days after treatment followed by emamectin benzoate and spinosad recording 96.26 per cent reduction while, thiamethoaxam 0.25% WG and fipronil 0.5 SC were least effective (68.65 and 73.14% mortality, respectively) [5]. Chlorantraniliprole and cyantraniliprole as seed treatments in soya reduced the need for foliar sprays against FAW in soya. In laboratory tests, thiodicarb and clothianidin reduced the number of plants cut or insured by FAW, but chlorpyrifos, fipronil and thiamethoxam were not effective. Status of fall armyworm (*Spodoptera frugiperda*), biology and control measures on maize crop in Ethiopia [2]. Fall armyworm mortality on treated diets with chlorantraniprole, lambda-cyhalothrin, spinetoram and flubendiamide were significantly higher (90.6 to 100 per cent) than non-treated control three days after treatment application [4].

The data in respect of effect of insecticides on yield of maize is presented in Table No. 3. The results indicated that all the insecticide treatments were significantly superior in yield of maize over the treatment of water spray. The marketable yield ranged from 42.05 to 24.01 q/ha. In all the treatments highest yield (42.05 q/ha) was recorded in the treatment emamectin benzoate 5 SG@ (42.5 q/ha) which was at par with the treatment chlorantraniliprole 18.5% SC (40.01 q/ha), flubendiamide 39.35 SC (38.5 q/ha) and thimethoxam 12.6 + lambda cyhalothrin 9.5 ZC (37.6 q/ha), spinosad 45 SC (36.5 q/ha), indoxacarb 14.5 SC (36.4 q/ha) were next treatments with fairly highest cob yield. Among insecticidal treatments, the lowest cob yield was recorded in the treatment of profenophos 50 EC (33.03 q/ha) and water spray (24.1 q/ha).

4. Conclusion

Among the insecticides spraying, emamectin benzoate 5 SG was most effective for management of fall armyworm. The next effective insecticides were chlorantraniliprole 18.5 SC, flubendiamide 39.35 SC, indoxacarb 14.5 SC and thimethoxam 12.6 + lambda cyhalothrin 9.5 ZC. The highest yield was found in the treatment emamectin benzoate 5 SG followed by chlorantraniliprole 18.5 SC, flubendiamide 39.35 SC and thimethoxam 12.6 + lambda cyhalothrin 9.5 ZC.

5. References

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