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SS Patil
Ph.D. Scholar, Department of Entomology, Post Graduate Institute, MPKV Rahuri, Maharashtra, India

UB Hole
Professor of Entomology, Associate Dean, College of Agriculture, Nandurbar, Maharashtra, India

SA Vagare
Senior Research Fellow, Krishi Vigyan Kendra, Latur, Maharashtra, India

AS Bagde
Assistant Professor, Department of Entomology, RCSM College of Agriculture, Kolhapur, MPKV Rahuri, Maharashtra, India

PV Jagtap
Junior Research Fellow, Plant Biosecurity Division, National Institute of Plat Health Management, Hyderabad, India

Corresponding Author:
SS Patil
Ph.D. Scholar, Department of Entomology, Post Graduate Institute, MPKV Rahuri, Maharashtra, India

Efficacy of selected insecticides against fall armyworm, *Spodoptera frugiperda* (J.E. Smith) infesting maize

SS Patil, UB Hole, SA Vagare, AS Bagde and PV Jagtap

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Abstract
The experiments on efficacy of insecticides against fall armyworm infesting maize was conducted in field condition during Summer 2020-21 at College of Agriculture, Kolhapur. Among the evaluated insecticides in field condition, the treatment with spinetoram 11.7 SC was the most effective as compared to all other treatments in reducing the population of fall armyworm. The chlorantraniliprole 18.5 SC was the next effective treatment and this was followed by treatment with spinosad 45 SC and emamectin benzoate 5 SG.
The treatment of spinetoram 11.7 SC showed maximum B:C ratio (1: 2.33) followed by chlorantraniliprole 18.5 SC (1: 2.16), emamectin benzoate 5 SG (1:2.01) and spinosad 45 SC (1: 1.85); while the treatment of emamectin benzoate 5 SG exhibited maximum ICBR ratio (1:7.89) followed by spinetoram 11.7 SC (1:6.63) and chlorantraniliprole 18.5 SC (1:5.97).

Keywords: Fall armyworm, insecticides, maize etc.

Introduction
Maize, also known as corn, is a cereal grain that was first grown by people in Central America. In the world, it is the third very important crop among cereal and is called the **'**Queen of Cereals'. In India, more than 15 million farmers are involved in maize cultivation. It provides employment for more than 650 million people per day through farming and related business ecosystem levels.
Fall armyworm, *Spodoptera frugiperda* is native to tropical and subtropical America recently invaded India. In India, FAW is causing more damage to maize, sorghum and sugarcane. It is the pest having higher dispersal ability, higher fecundity, broad host range which makes the FAW one of the most serious economic pests. The fall armyworm has been a continuously important insect pest for a variety of crop species (Chormule *et al.*, 2019) [3]. First observation of fall armyworm *Spodoptera frugiperda* were made in early May-June 2018 in maize fields at College of Agriculture, Shivamogga, Karnataka, India. Further its presence was recorded in different districts of Karnataka (Sharanabasappa *et al.*, 2018) [8]. Later the occurrence of fall armyworm on fodder maize (*Zea mays* L), guinea grass (*Megathyrus maximus*), para grass (*Brachiaria mutica*) and green amaranth (*Amaranthus viridis* L) is reported first time from Goa, India (Maruthadurai *et al*., 2019) [6].
In African countries, at present there are no registered synthetic insecticides for fall armyworm management. The applications allowed only through an emergency label due to which there is urgent need for screening of synthetic insecticides. Farmers using synthetic insecticides complained that these insecticides are not useful against FAW. Therefore, farmers are forced to use maximum doses with multiple applications, which will lead to the insecticides accumulation in the environment and increase the chances of resistance development in fall armyworm (Birhanu *et al.*, 2019) [1]. Due to the seriousness of the pest problem and relative paucity of the information regarding their management with newer molecules of insecticides the present investigations were undertaken to study the efficacy of selected insecticides against *S. frugiperda* infesting maize under field conditions.

Materials and Methods

The experiment was conducted during Summer season 2020-2021 in the field of Agronomy farm, Rajarshee Chhatrapati Shahu Maharaj College of Agriculture, Kolhapur. It is situated at 16º 41' North Latitude, 74^0 14' East Longitude and at an altitude of 545.6 m above the mean sea level (MSL) and has tropical climate.

Experiment Details

1.	Season	:	*Summer*, 2021
2.	Crop	:	Maize
3.	Variety	:	Rajarshee
4.	Design	:	Randomised Block Design
5.	Treatments	:	9
6.	Replications	:	3
7.	Plot size	:	6 x 4 m
8.	Spacing	:	75 x 20 cm

Treatment Details

Sr. No.	Treatments	Dose g or ml/L	Trade name	Source
1	Chlorantraniliprole 18.5% SC	0.3	Coragen	FMC India Pvt. Ltd, TCG Financial Centre, 2nd Floor, C-53, Bandra Kurla Complex, Bandra (E), Mumbai-400098
2	Lambda cyhalothrin 5% EC	1.0	Lambda	Aimco Pesticides Ltd. Aimco House, 8th Road, Santacruz (E), Mumbai -400055
3	Indoxocarb 14.5% SC	1.0	King Doxa	Gharada Chemical Ltd, Regd. Office, 48 Hill Road, Bandra (W), Mumbai-400050
4	Spinosad 45% SC	0.3	Tracer	Dow Agro Sciencies India Pvt. Ltd., 1st Floor , Block B, Godrej IT Park, Pirojshanagar, L.B.S. Marg, Vikhroli, Mumbai- 400079
5	Emamectin benzoate 5% SG	0.4	Emacto	Shreeji Pesticides Pvt. Ltd. (A subsidiary of Willowood Chemicals Pvt. Ltd) Registered Office. Block No. 69P Village Manjusar, Taluka Savli, District Vadodara-391775
6	Thiodicarb 75% WP	1.0	Larvin	Bayer Crop Science Ltd. Bayer House, Central Avennue, Heeranandani Estate, Thane (west)-400607
7	Spinetoram 11.7% SC	0.5	Summit	Rallies India Ltd, 156/57, Narriman Bhavan, 15th Floor, 227 Narriman Point, Mumbai- 400021
8	Imidacloprid 17.8% SL	0.7	Tatamida	Rallies India Ltd. 23rd Floor Lodha Excelus, New Cuffe Parade, Off Eastern Free Way, Wadala, Mumbai-400037
9	Untreated control			

Methodology

Plots having 5 rows in 6 x 4 m plot. Treatments were arranged in a randomized block design with 3 replications. Insecticides were applied with a knapsack sprayer. The treatments were two times. First spray was initiated when there is more than 20% whorl damage of fall armyworm whereas second application was given 15 days after first spray. The visual observations of the number of live larva were recorded one DBS and 3, 7, 10 and 14 days after each treatment on 20 plants from each experimental unit. Treatment-wise, marketable grain yield was recorded and expressed in kg per ha (Deshmukh *et al*., 2020) [4].

Statistical Analysis

The larval mortality and the average fall armyworm live larvae per plant were subjected to root transformation. Data pertaining to larval count after their transformation was statically analyzed as per the standard analysis of variance (Panse and Sukhatme, 1954) [7].

Result and Discussion

1. First Spray

Data pertaining to the survival population of *S. frugiperda* on maize one DBS and 3, 7, 10 and 14 days after first spray was given in Table No. 1 and graphically depicted in Fig. 1

The mean survival population of *S. frugiperda* one DBS ranged from 1.25 to 1.40 larvae per plant. The pre treatment data was recorded non significant indicating the uniformity in larval population of pest throughout the experimental plot.

Observations recorded at three days after spray showed that all the treatments were significantly effective over untreated control. The treatment of spinetoram 11.7 SC (0.05 larvae/plant) was found effective and superior over all other treatments. However, this was at par with chlorantraniliprole 18.5 SC (0.07 larvae/ plant), spinosad 45 SC (0.08 larvae/plant) and emamectin benzoate 5 SG (0.12 larvae/plant). However, the highest population of *S. frugiperda* population was noticed (1.27 larvae/plant) in untreated control plot.

At seven DAS, the mean number of survival population of *S. frugiperda* ranged from 0.10 to 1.17 larvae per plant. The treatment with spinetoram 11.7 SC (0.10 larvae/plant) was found significantly superior over all treatments. The treatment of lambda cyhalothrin 5 EC (0.52 larvae/plant) and imidacloprid 17.8 SL (0.57 larvae/plant) were less effective among all treatments. The maximum survival population of *S. frugiperda* was reported (1.13 larvae/plant) in untreated control plot.

At ten DAS, the mean number of survival population of *S. frugiperda* was ranged from 0.18 to 1.13 larvae per plant. In untreated control plot, it was recorded highest (1.13 larvae/plant). Again treatment with spinetoram 11.7 SC (0.18 larvae/plant) emerged as superior over all other treatments.

The observations recorded at 14 DAS showed that, there was gradual increase in larval population in all the treatments after first spray. The mean number of survival

population of *S. frugiperda* ranged from 0.40 to 1.23 larvae per plant.

The overall results on efficacy of various treatments indicated that spinetoram 11.7 SC was (0.18 larvae/plant) the most effective as compared to all other treatments in reducing the population of fall armyworm. The chlorantraniliprole 18.5 SC (0.25 larvae/plant) was the next effective treatment, followed by spinosad 45 SC (0.27 larvae/plant), emamectin benzoate 5 SG (0.31 larvae/plant) and thiodicarb 75 WP (0.47 larvae/plant), indoxocarb 14.5 SC (0.47 larvae/plant), lambda cyhalothrin 5 EC (0.61 larvae/plant) and imidacloprid 17.8 SL (0.66 larvae/plant).

The per cent reduction over control indicated that spinetoram 11.7 SC showed 84.80 per cent reduction over control. The next treatment in order of efficacy were chlorantraniliprole 18.5 SC, spinosad 45 SC, emamectin benzoate 5 SG, thiodicarb 75 WP, indoxocarb 14.5 SC, lambda cyhalothrin 5 EC and imidacloprid 17.8 SL in which 79.38, 77.50, 74.17, 62.30, 60.42, 49.17 and 45 per cent, respectively reduction over untreated control recorded.

Table 1: Efficacy of selected insecticides against fall armyworm under field condition (First spray)

Sr. No	Treatments	Dose g or ml/10 L	Mean No. of survival larvae						Reduction over control (%)
			Pre count	First spray					
				3 DAS	7 DAS	10 DAS	14 DAS	Mean	
1	Chlorantraniliprole 18.5% SC	3	1.40 (1.18)*	0.07 (0.25)	0.15 (0.38)	0.30 (0.55)	0.47 (0.68)	0.25 (0.47)	79.38
2	Lambda cyhalothrin 5% EC	10	1.35 (1.16)	0.55 (0.74)	0.52 (0.72)	0.55 (0.74)	0.82 (0.90)	0.61 (0.77)	49.17
3	Indoxocarb 14.5% SC	10	1.30 (1.14)	0.30 (0.55)	0.43 (0.66)	0.52 (0.72)	0.65 (0.80)	0.47 (0.68)	60.42
4	Spinosad 45% SC	3	1.28 (1.13)	0.08 (0.29)	0.17 (0.41)	0.35 (0.59)	0.48 (0.69)	0.27 (0.49)	77.50
5	Emamectin benzoate 5% SG	4	1.32 (1.15)	0.12 (0.34)	0.22 (0.43)	0.38 (0.60)	0.52 (0.71)	0.31 (0.52)	74.17
6	Thiodicarb 75% WP	10	1.32 (1.14)	0.28 (0.53)	0.40 (0.63)	0.48 (0.69)	0.65 (0.80)	0.45 (0.66)	62.30
7	Spinetoram 11.7% SC	5	1.25 (1.11)	0.05 (0.18)	0.10 (0.31)	0.18 (0.63)	0.40 (0.62)	0.18 (0.38)	84.80
8	Imidacloprid 17.8% SL	7	1.32 (1.14)	0.62 (0.78)	0.57 (0.75)	0.62 (0.78)	0.83 (0.91)	0.66 (0.80)	45.00
9	Control	-	1.25 (1.11)	1.27 (1.12)	1.17 (1.08)	1.13 (1.05)	1.23 (1.11)	1.20 (1.09)	-
	SE±	-	0.07	0.05	0.05	0.06	0.06	-	-
	CD at 5%	-	NS	0.15	0.15	0.17	0.18	-	-
	CV%	-	10.37	15.82	14.61	14.57	13.18	-	-

DAS – Days after spraying *Figures in the parentheses are $\sqrt{x+.05}$ transformed values.

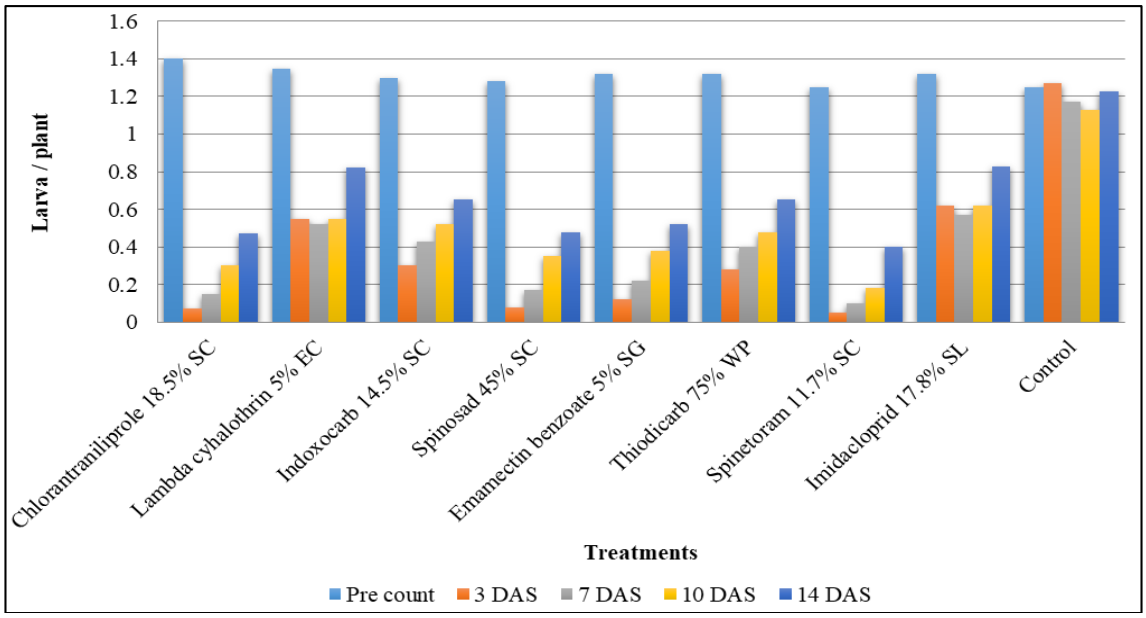

Fig 1: Efficacy of selected insecticides against *S. frugiperda* under field condition (First spray)

2. Second Spray

Data pertaining to damage of *S. frugiperda* on maize one DBS and 3, 7, 10 and 14 days after second spray was presented in Table No. 2 and graphically depicted in Fig. 2. The population of fall armyworm reached at ETL after first spray therefore, second spray was taken up at 14 days after first spray. Observations were recorded at three day after the spray; all the treatments were observed significantly superior over untreated control.

In the current study, it was found that all the treatments proved their superiority over untreated control. The mean data associated with the efficacy of different treatments against *S. frugiperda* showed that spinetoram 11.7 SC (0.7 larvae/plant) was the most effective treatment over untreated control. The reduction in fall armyworm population in different treatment was in the order of chlorantraniliprole 18.5 SC > spinosad 45% SC > emamectin benzoate 5 SG > thiodicarb 75 WP > indoxocarb 14.5 SC > lambda cyhalothrin 5 EC > imidacloprid 17.8 SL.

Table 2: Efficacy of selected insecticides against fall armyworm in field condition (2nd Spray)

S. No	Treatments	Dose g or ml/ 10 L	Mean No. of survival larvae						Reduction over control (%)
			Pre count	Second spray					
				3 DAS	7 DAS	10 DAS	14 DAS	Mean	
1	Chlorantraniliprole 18.5% SC	3	0.47 (0.68)*	0.12 (0.34)	0.07 (0.25)	0.15 (0.38)	0.20 (0.44)	0.13 (0.35)	83.29
2	Lambda cyhalothrin 5% EC	10	0.82 (0.90)	0.37 (0.61)	0.38 (0.62)	0.47 (0.68)	0.47 (0.68)	0.42 (0.65)	47.68
3	Indoxocarb 14.5% SC	10	0.65 (0.80)	0.28 (0.53)	0.33 (0.57)	0.38 (0.62)	0.37 (0.60)	0.34 (0.58)	57.90
4	Spinosad 45% SC	3	0.48 (0.69)	0.08 (0.28)	0.08 (0.29)	0.18 (0.43)	0.22 (0.46)	0.14 (0.36)	82.67
5	Emamectin benzoate 5% SG	4	0.52 (0.71)	0.10 (0.31)	0.13 (0.35)	0.17 (0.40)	0.25 (0.50)	0.16 0.39	79.88
6	Thiodicarb 75% WP	10	0.65 (0.80)	0.23 (0.48)	0.28 (0.53)	0.27 (0.51)	0.30 (0.55)	0.27 (0.52)	66.57
7	Spinetoram 11.7% SC	5	0.40 (0.62)	0.02 (0.07)	0.02 (0.07)	0.08 (0.23)	0.15 (0.38)	0.07 (0.19)	91.65
8	Imidacloprid 17.8% SL	7	0.83 (0.91)	0.38 (0.62)	0.40 (0.63)	0.52 (0.72)	0.52 (0.72)	0.45 (0.67)	43.66
9	Control	-	1.23 (1.11)	0.92 (0.96)	0.83 (0.91)	0.80 (0.89)	0.68 (0.83)	0.81 (0.90)	-
	SE±	-	0.06	0.05	0.04	0.05	0.05	-	-
	CD at 5%	-	0.18	0.14	0.13	0.15	0.11	-	-
	CV%	-	13.18	17.20	15.99	15.89	10.77	-	-

DAS – Days after spraying *Figures in the parentheses are $\sqrt{x+0.5}$ transformed values.

The maximum reduction in larval population over untreated control was noticed in spinetoram 11.7 SC (91.65%), followed by chlorantraniliprole 18.5 SC (83.29%), spinosad 45 SC (82.67%), emamectin benzoate 5 SG (79.88%), thiodicarb 75 WP (66.57%), indoxocarb 14.5 SC (57.90%), lambda cyhalothrin 5 EC (47.68%) and imidacloprid 17.8 SL (43.66%).

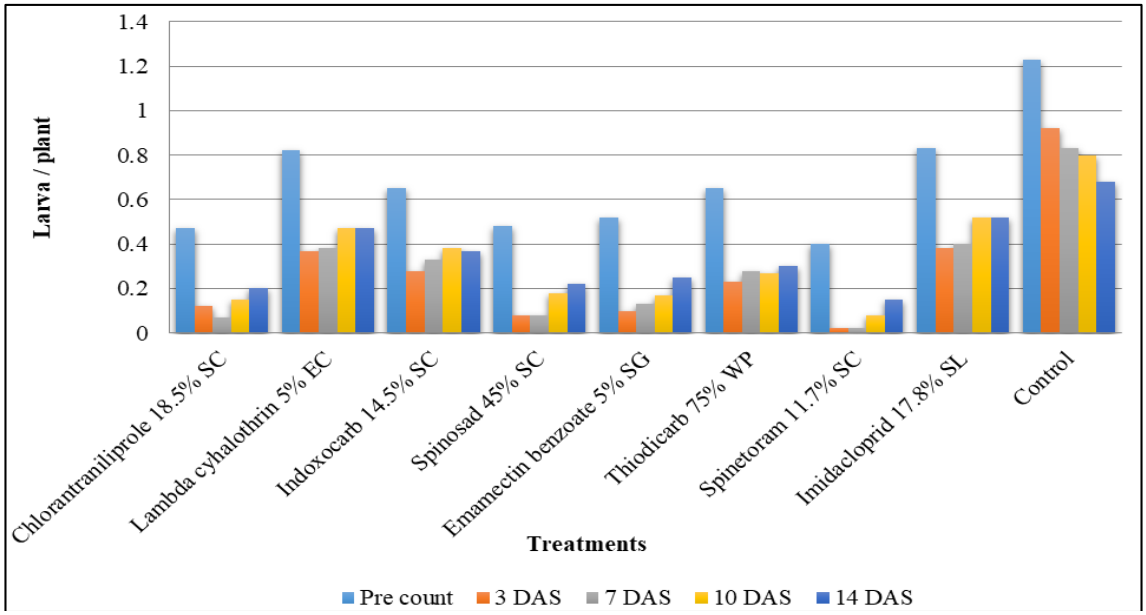

Fig 2: Efficacy of selected insecticides against *S. frugiperda* under field condition (2nd spray)

The results of the present investigations are substantially in conformity with the finding by Dileepkumar and Murali (2020) [5] resulted that the effective insecticides were spinetoram 11.7 SC followed by chlorantraniliprole 18.5 SC. Bajracharya *et al.* (2020) [2] reported that spinosad, chlorantraniliprole and emamectin benzoate were found promising for management of *S. frugiperda* which is agreement with the present investigations.

3. Efficacy of Insecticides against Fall Armyworm in Field Condition of Both Sprays

Data pertaining to damage of *S. frugiperda* on maize after first and second spray was presented in Table No. 3

The treatment with spinetoram 11.7 SC was the most effective over other treatments having 88 per cent reduction in larval population with highest yield (42.84 q/ha) however, it was on par with chlorantraniliprole 18.5 SC, spinosad 45 SC, emamectin benzoate 5 SG in which 81, 80 and 77 per cent reduction in larval population, respectively were observed.

The treatment with imidacloprid 17.8 SL recorded 45 per cent reduction in larval population over control with minimum yield 24.44 q/ha.

Table 3: Efficacy of insecticides against fall armyworm in field condition both sprays

Sr. No.	Treatments	Pre count	Mean of First spray	Mean of Second spray	Mean	Reduction over control (%)	Yield (q/ha)
1	Chlorantraniliprole 18.5% SC	1.40 (1.18)*	0.25 (0.47)	0.13 (0.35)	0.19 (0.41)	81	39.30
2	Lambda cyhalothrin 5% EC	1.35 (1.16)	0.61 (0.77)	0.42 (0.65)	0.51 (0.71)	49	26.38
3	Indoxocarb 14.5% SC	1.30 (1.14)	0.47 (0.68)	0.34 (0.58)	0.40 (0.63)	60	30.83
4	Spinosad 45% SC	1.28 (1.13)	0.27 (0.49)	0.14 (0.36)	0.20 (0.42)	80	35.13
5	Emamectin benzoate 5% SG	1.32 (1.15)	0.31 (0.52)	0.16 0.39	0.23 (0.45)	77	33.19
6	Thiodicarb 75% WP	1.32 (1.14)	0.45 (0.66)	0.27 (0.52)	0.36 (0.59)	64	29.72
7	Spinetoram 11.7% SC	1.25 (1.11)	0.18 (0.38)	0.07 (0.19)	0.12 (0.28)	88	42.84
8	Imidacloprid 17.8% SL	1.32 (1.14)	0.66 (0.80)	0.45 (0.67)	0.55 (0.73)	45	24.44
9	Control	1.25 (1.11)	1.20 (1.09)	0.81 (0.90)	1.00 (0.99)	-	20.97
	SE+	0.07	0.05	0.04	0.04	-	0.06
	CD at 5%	NS	0.16	0.13	0.14	-	0.21
	CV%	10.37	14.54	14.90	14.72	-	3.7

*Figures in the parentheses are $\sqrt{x + 0.5}$ transformed values.

4. Effect of Selected Insecticides on Yield and Cost Benefit Ratio for *S. frugiperda* Infesting Maize

The yield recorded in various treatments indicates that all the treatments recorded significantly higher yield than untreated control. The treatment with spinetoram 11.7 SC @ 5 ml per 10 L found with the highest yield of 42.84 q per ha. The treatment spinetoram 11.7 SC is at par with chlorantraniliprole 18.5 SC followed by spinosad 45 SC, emamectin benzoate 5 SG, indoxocarb 14.5 SC, thiodicarb 75 WP, lambda cyhalothrin 5 EC and imidacloprid 17.8 SL and were the next in order of yield with 39.30, 35.13, 33.19, 30.83, 29.72, 26.38 and 24.44 q per ha, respectively. Lowest yield recorded from untreated control 20.97 q per ha.

The benefit cost ratio obtained from treatments, revealed that spinetoram 11.7 recorded the highest B:C ratio of 2.33. However, the treatment of chlorantraniliprole 18.5 SC, emamectin benzoate 5 SG, spinosad 45 SC, indoxocarb 14.5 SC, thiodicarb 75 WP, lambda cyhalothrin 5 EC and imidacloprid 17.8 SL were next in order with 2.16, 2.01, 1.85, 1.73, 1.69, 1.66 and 1.52 benefit cost ratio, respectively.

Regarding the incremental cost benefit ratio, it was clear that the treatment with emamectin benzoate 5 SG was found superior over all the treatments with 7.89 ICBR. Whereas, the treatment with spinetoram 11.7 SC, chlorantraniliprole 18.5 SC, lambda cyhalothrin 5 EC, spinosad 45 SC, indoxocarb 14.5 SC, thiodicarb 75 WP and imidacloprid 17.8 SL were next in order with 6.63, 5.97, 5.47, 3.66, 3.64, 3.46 and 3.03 ICBR, respectively.

Table 4: Cost Benefit ratio of selected insecticides against fall armyworm

Sr. No.	Treat-ments	Maize yield (q/ha)	Additional yield over control (q/ha)	Additional income over control (Rs/ha)	Cost of insecticidal treatment (Rs/ha)	Total cost of cultivation (Rs/ha)	Gross marginal returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio	ICBR
1	1	39.30	18.33	34,277	5,744	33,946	73,491	39,545	1:2.16	1:5.97
2	2	26.38	5.41	10,117	1,848	29,799	49,331	19,532	1:1.66	1:5.47
3	3	30.83	9.86	18,438	5,068	33,230	57,652	24,422	1:1.73	1:3.64
4	4	35.13	14.16	26,479	7,236	35,528	65,693	30,165	1:1.85	1:3.66
5	5	33.19	12.22	22,851	2,898	30,930	62,065	31,135	1:2.01	1:7.89
6	6	29.72	8.75	16,362	4,728	32,870	55,576	22,706	1:1.69	1:3.46
7	7	42.84	21.87	40,897	6,168	34,396	80,111	45,715	1:2.33	1:6.63
8	8	24.44	3.47	6,489	2,140	30,084	45,703	15,619	1:1.52	1:3.03
9	9	20.97	-	-	-	28,918	39,214	10,296	1:1.36	-

Maize grain selling rate: Rs. 1870/- per quintal

Cost of cultivation of maize: Rs. 28918/ha

Summery and Conclusion

In the treatments with selected insecticides, spinetoram 11.7 SC found most effective for control of the fall armyworm at 3, 7, 10 and 14 days after first spray and second spray, this was followed by chlorantraniliprole 18.5 SC, spinosad 45 SC and emamectin benzoate 5 SG in field condition.

The treatment of spinetoram 11.7 SC showed maximum B:C ratio (1: 2.33) followed by chlorantraniliprole 18.5 SC (1: 2.16), emamectin benzoate 5 SG (1:2.01) and spinosad 45 SC (1: 1.85); while the treatment of emamectin benzoate 5 SG exhibited maximum ICBR ratio (1:7.89) followed by spinetoram 11.7 SC (1:6.63) and chlorantraniliprole 18.5 SC (1:5.97).

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