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Evaluation of Field Efficacy of Different Insecticides against *Spodoptera frugiperda* (Fall Armyworm) on Maize at Raipur, Chhattisgarh (India)

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Abstract: The present investigation was conducted during the Rabi season of 2021-22 and 2022-23 at the Instructional Research Farm of Kalinga University, Raipur (Chhattisgarh, India). The data on number of larvae/plant recorded after first and second spray during 2022-23 showed that Lambda cyhalothrin 4.9% CS recorded the lowest larvae (0.50 larvae/plant) and substantially superior to all other treatments. The second best treatment was Chlorantraniliprole 18.5% SC (0.68 larvae/plant) followed by Spinosad 45%SC (0.88 larvae/plant), Fipronil 5% SC (1.03 larvae/plant), Flubendiamide 39.35% SC (1.05 larvae/plant), Emamectin benzoate 5% SG (1.28 larvae/plant), and Bifenthrin 10% EC (1.42 larvae/plant). In control plot maximum 4.57 larvae/plant were recorded.

Keywords: Bifenthrin, Fipronil, Lambda cyhalothrin, Chlorantraniliprole, Bifenthrin, Emamectin, Fipronil

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Introduction

Maize or corn (*Zea mays* L.) is a crop of global importance, which holds a unique position in world agriculture. Maize belongs to the family of Poaceae, originated from South America, from where it was taken to all parts of the world. Maize production and distribution is a cosmopolitan (Egas *et al.*, 2017). In India, maize after rice and wheat is the 3rd most important food crops accounting for about 20% of the global area under cereals (Anonymous, 2005). In India, maize production estimated about 24.21 MMT in an area of 9.9 million hectares in 2020-21. In Chhattisgarh, it is well informed in an area of 226.79 hectare with productivity of 2458 kg/ha of Kharif season and 74.45 hectare area with 1950 kg/ha productivity in Rabi season in 2017-18 (Annual report 2017-18).

Fall armyworm, *Spodoptera frugiperda* (Smith)

(Lepidoptera: Noctuidae) is native to the Americas. Fall armyworm caterpillars are major pests of cereals and forage grasses and are recorded on 186 plant species from 42 families (Augusto *et al*., 2010). Fall armyworm (FAW) is one of the most serious pests of maize in the America. Yield losses can reach 40% in Honduras and 72% in Argentina (Murua *et al.*, 2006). In addition to maize, fall armyworm attacks many other economically important plants, *e.g.* rice, sugarcane, sorghum, beet, tomato, potato, cotton and pasture grasses (Abrahams *et al.*, 2017). Therefore fall armyworm could pose a risk to subsistence and cash crops in large parts of the world.

The larval stage of FAW usually feed on leaves creating windows and moistened sawdust-like frass near the funnel and upper leaves. During daylight, young larvae hide in the funnel, becoming active during the night. Older larvae stay in the funnel where they are protected from insecticide application and natural enemies, making it difficult to control them (Prasanna *et al.*, 2018).

Insects are a dominant component of agricultural ecosystems, and they impact crop yields in many ways. Several species are pests and horticultural crops, reducing yields by the transmission of diseases or by direct damage. Other insects are natural enemies of pest species, and can be used as biological control agents for reducing pest organisms. Insects are considered indicators of biodiversity, providing a means of determining the effects of agricultural practices on whole communities or on abundance and dynamics of individual species.

The scenario with respect to insect pests of this crop has changed a lot in the recent past owing to increased area under single cross hybrids and monocropping practiced by the farmers using indiscriminate use of insecticides and chemical fertilizers. Insects attack maize throughout the cropping cycle and during storage, resulting in as little as 10% to complete loss (Bergvinson *et al.*, 2002).

Indiscriminate use of chemical pesticides in the past has created a number of problems like insecticide resistance, insecticide residues, pest resurgence, environmental pollution and direct and indirect hazards to human beings etc. To avoid or minimize these adverse effects, recently, emphasis has been given to explore new techniques for the management of insect pest with minimum use of pesticides at appropriate time or at vulnerable stage of insect biology.

An experiment was carried out in the field to evaluate the efficacy of seven insecticides against fall armyworm, *Spodoptera frugiperda* on maize crop during the year 2021-22 and 2022-23 on farmers field at Bahigaon District Kondagaon.

Materials and Methods

Evaluation of insecticides under field conditions:

An experiment was carried out in the field to evaluate the efficacy of seven insecticides against fall armyworm, *Spodoptera frugiperda* on maize crop during the year 2021-22 and 2022-23 on farmers field at Bahigaon District Kondagaon. The experiment was carried out by sowing hybrid maize on January 22, 2021 and January 23, 2021 in randomized block design (RBD) with three replications. Row to row and plant to plant spacing was 75 cm and 25 cm, respectively. The size of the plot was 4 x 3 m^2.

Application of insecticides:

Insecticides was applied in the form of foliar sprays when the attack of larvae of *Spodoptera frugiperda* were observed. Insecticidal solutions were diluted in water (375-500 L/ha) and applied using knapsack sprayer (16 L) with hollow cone nozzle. In all, two rounds of applications were given. Observations were recorded one day before spray (pre-count) and 7 and 14 days after spray.

Observations on different plant damage parameters:

The pre-treatment observation on fall army worm (number of larvae per plant) was taken 24 h before spraying, while post-treatment observation

was made after 7 and 14 days after spraying on five randomly selected plants from each replication. The yield data of each treatment was recorded replication wise and subjected to statistical analysis to test the significance of mean yield in different treatments. Per cent increase in yield over untreated control (PYOUC) was also calculated by following formula (Gomez and Gomez, 1994):

$$PYOUC = \frac{\text{Yield in treatment- Yield in untreated control}}{\text{Yield in untreated control}} \times 100$$

Results and Discussion

A field experiment was conducted at Instructional Research Farm of Kalinga University, Raipur (Chhattisgarh, India) during Rabi 2021-22 and 2022-23 under field condition to determine the field efficacy of different insecticides against *Spodoptera frugiperda*.

Efficacy of different insecticides on larvae of Spodoptera frugiperda in maize during 2021-22:

First Spray:

The data on number of larvae/plant was recorded at one day before first spray during 2021-22 are presented in Table 1 and Figure 1. It was observed that average fall armyworm survival of larval population per plant ranged from 2.07 to 3.00.

The data on number of larvae/plant recorded at seven day after first spray during 2021-22 are presented in Table 1 and Figure 1. It showed that average fall armyworm survival of larval population per plant ranging from 0.60 to 1.27. After other pestcide treatment, Chlorantraniliprole 18.5 % SC recorded the lowest larvae -- 0.60 larvae/plant and was shown to be substantially superior to all other treatments which were at par with Flubendiamide 39.35 % SC -- 0.67 larvae/plant and Lambda cyhalothrin 4.9% CS -- 0.80 larvae/plant. The other best treatment was Fipronil 5 % SC-- 0.87 larvae/plant which was at par with Spinosad 45% SC-- 0.93 larvae/plant followed by Bifenthrin 10 % EC-- 1.07 larvae/plant and Emamectin benzoate 5% SG-- 1.27 larvae/plant. In control plot maximum 4.80 larvae/plant were found.

The data on number of larvae/plant recorded at fourteen day after first spray during 2021-22 are illustrated in Table 1 and Figure 1. It was observed that average fall armyworm survival of larval population per plant ranged from 0.27 to 1.00. In pesticide treatment, Lambda cyhalothrin 4.9% CS and Spinosad 45% SC recorded the lowest larvae-- 0.27 larvae/plant and was shown to be substantially superior to all other treatments. The next best treatment was Emamectin benzoate 5% SG- 0.47 larvae/plant which was at par with Chlorantraniliprole 18.5 % SC and Fipronil 5 % SC-- 0.53 larvae/plant. The next best treatment was Flubendiamide 39.35 % SC -0.73 larvae/plant followed by Bifenthrin 10 % EC-- 1.00 larvae/plant. In control plot maximum 5.93 larvae/plant were recorded.

Second Spray:

The data on number of larvae/plant recorded at one day before second spray during 2021-22 are presented in Table 1 and Figure 2. It showed that average fall armyworm survival of larval population per plant ranged from 1.60 to 4.00. The data on number of larvae/plant recorded at seven day after second spray during 2021-22 are illustrated in Table 1 and Figure 2 which recorded that average fall armyworm survival of larval population per plant ranged from 0.73 to 1.40. After pesticide treatment, Lambda cyhalothrin 4.9% CS recorded the lowest larvae -- 0.73 larvae/plant and was substantially superior to all other treatments which was at par with Chlorantraniliprole 18.5 % SC-- 0.80 larvae/plant and Spinosad 45% SC --0.93 larvae/plant. The next best treatment was Fipronil 5 % SC-- 1.00 larvae/plant which was at par with Flubendiamide 39.35 % SC-- 1.13 larvae/plant and Emamectin benzoate 5% SG- 1.20 larvae/plant followed by Bifenthrin 10 % EC-- 1.40 larvae/plant. In control plot maximum 4.33 larvae/plant were found.

The data on number of larvae/plant recorded at fourteen day after second spray during 2021-22

Table 1: Efficacy of different insecticides on larvae of *Spodoptera frugiperda* in maize during 2021-22

Treatments	Pooled mean of number of larvae/plant (average of 15 plants)								Per cent reduction over control	
	Spray I				Spray II					
	Pre-treatment population	7 DAT	14 DAT	Mean	Pre-treatment population	7 DAT	14 DAT	Mean	After Spray I	After Spray II
Lambda cyhalothrin 4.9% CS	2.80 (1.95)	0.80 (1.34)	0.27 (1.13)	**0.53**	2.07 (1.75)	0.73 (1.32)	0.27 (1.13)	**0.50**	90.06	90.68
Spinosad 45%SC	2.67 (1.91)	0.93 (1.38)	0.27 (1.12)	**0.60**	1.80 (1.67)	0.93 (1.38)	0.47 (1.21)	**0.70**	88.82	86.96
Flubendiamide 39.35 % SC	2.87 (1.97)	0.67 (1.29)	0.73 (1.31)	**0.70**	4.00 (2.23)	1.13 (1.46)	0.67 (1.29)	**0.90**	86.96	83.23
Fipronil 5 % SC	2.47 (1.85)	0.87 (1.36)	0.53 (1.24)	**0.70**	1.60 (1.61)	1.00 (1.40)	0.60 (1.25)	**0.80**	86.96	85.09
Emamectin benzoate 5% SG	2.33 (1.81)	1.27 (1.51)	0.47 (1.21)	**0.87**	2.67 (1.91)	1.20 (1.48)	1.00 (1.41)	**1.10**	83.85	79.50
Chlorantraniliprole 18.5 % SC	2.07 (1.75)	0.60 (1.26)	0.53 (1.24)	**0.57**	2.33 (1.83)	0.80 (1.34)	0.27 (1.13)	**0.53**	89.44	90.06
Bifenthrin 10 % EC	2.93 (1.98)	1.07 (1.42)	1.00 (1.41)	**1.03**	2.27 (1.81)	1.40 (1.54)	1.07 (1.44)	**1.23**	80.75	77.02
Untreated control	3.00 (1.99)	4.80 (2.41)	5.93 (2.63)	**5.37**	4.20 (2.28)	4.33 (2.31)	4.60 (2.37)	**4.47**	-	-
SEM (±)	**0.087**	**0.094**	**0.053**		**0.082**	**0.077**	**0.053**			
CD (P= 0.05)	**N/A**	**0.288**	**0.163**		**0.251**	**0.235**	**0.163**			
CV (%)	**7.950**	**10.906**	**6.519**		**7.525**	**8.712**	**6.519**			

DAT- Days after treatment

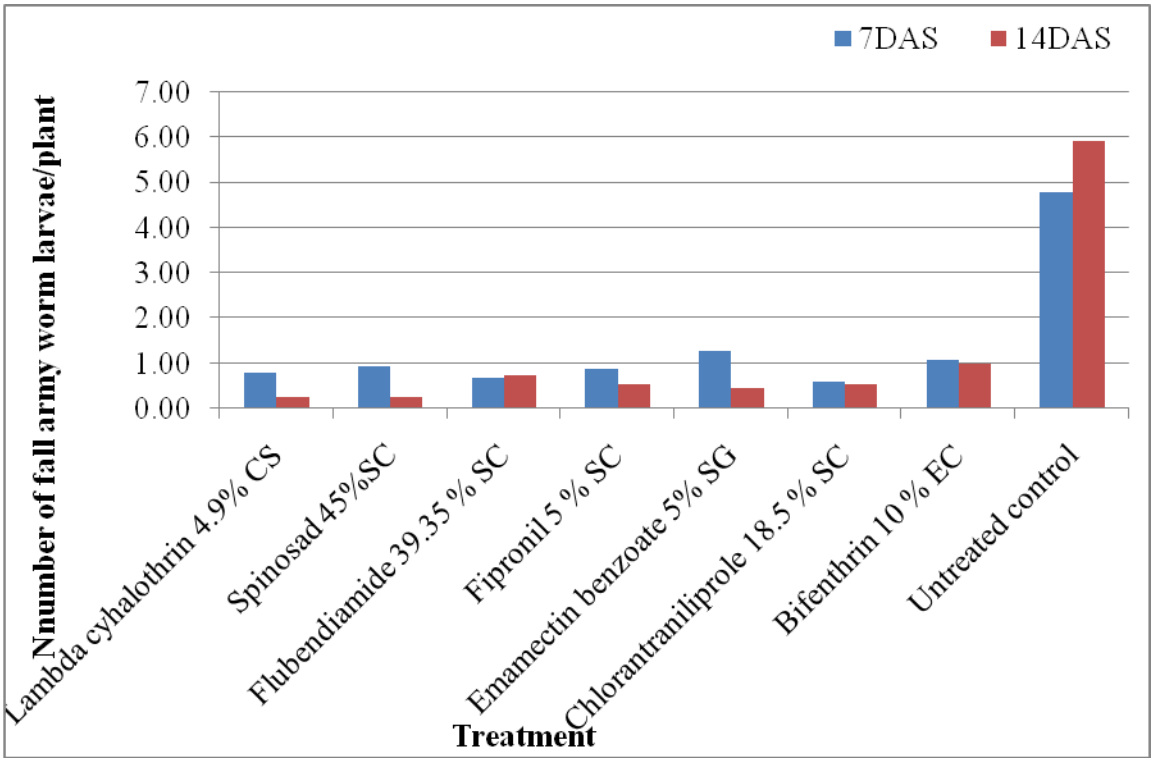

Fig. 1: Number of fall army worm larvae/plant after first spray during 2021-22 (DAS- Days after spraying).

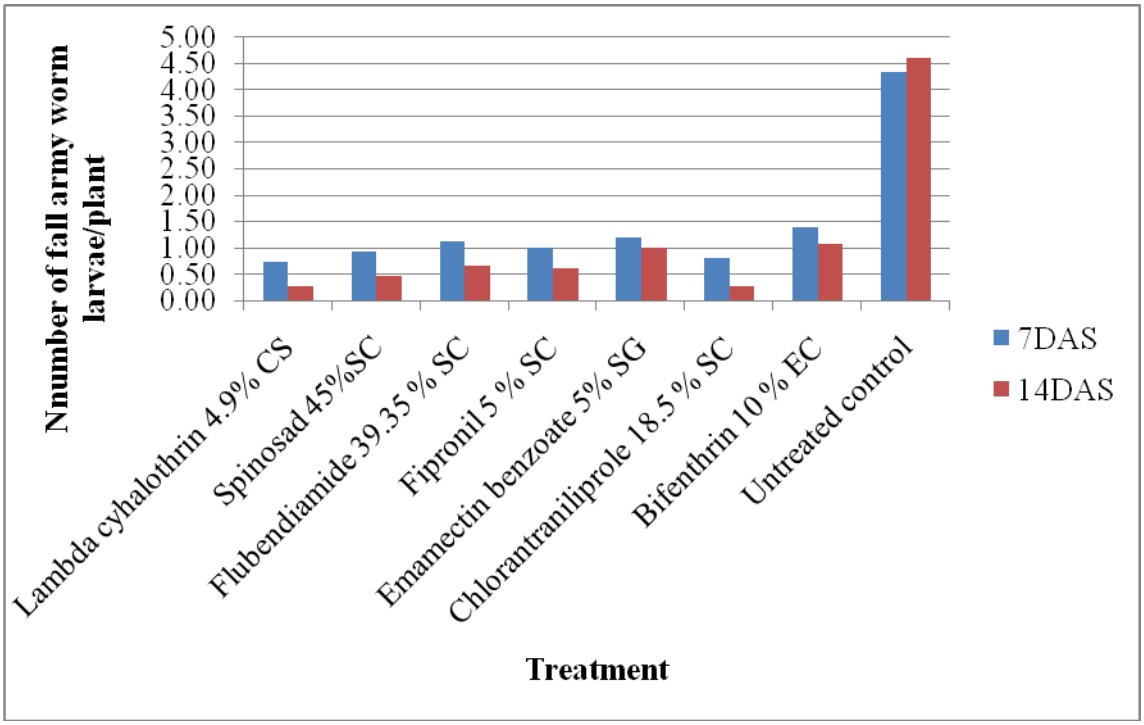

Fig. 2: Number of fall army worm larvae/plant after second spray during 2021-22 (DAS- Days after spraying).

Table 2: Effect of different insecticides on fall army worm (*Spodoptera frugiperda*)in maize during 2021-22 (Avg. of first and second spray)

S. No.	Treatment	Overall mean After Spray I	Overall mean After Spray II	Overall mean (Avg. of first and second spray)
T1	Lambda cyhalothrin 4.9% CS	0.53	0.50	0.52
T2	Spinosad 45%SC	0.60	0.70	0.65
T3	Flubendiamide 39.35 % SC	0.70	0.90	0.80
T4	Fipronil 5 % SC	0.70	0.80	0.75
T5	Emamectin benzoate 5% SG	0.87	1.10	0.98
T6	Chlorantraniliprole 18.5 % SC	0.57	0.53	0.55
T7	Bifenthrin 10 % EC	1.03	1.23	1.13
T8	Untreated control	5.37	4.47	4.92

are presented in Table 1 and Figure 2. The average fall armyworm survival of larval population per plant ranged from 0.27 to 1.07. After pesticide treatment, Lambda cyhalothrin 4.9% CS and Chlorantraniliprole 18.5 % SC recorded the lowest larvae -- 0.27 larvae/plant which was substantially superior to all other treatments. The other treatment was Spinosad 45% SC-- 0.47 larvae/plant which was at par with Fipronil 5% SC-- 0.60 larvae/plant. The next best treatment was Flubendiamide 39.35 % SC-- 0.67 larvae/plant followed by Emamectin benzoate 5% SG-- 1.00 larvae/plant which were at par with Bifenthrin 10 % EC-- 1.07 larvae/plant. In control plot maximum 4.60 larvae/plant were found.

Overall mean of number of larvae/plant (*average of two spray*):

The data on number of larvae/plant recorded after first and second spray during 2021-22 showed that Lambda cyhalothrin 4.9% CS recorded the lowest larvae (0.52 larvae/plant) which was substantially superior to all other treatments.

The second best treatment was Chlorantraniliprole 18.5 % SC (0.55 larvae/plant) followed by Spinosad 45%SC (0.65 larvae/plant), Fipronil 5 % SC (0.75 larvae/plant), Flubendiamide 39.35 % SC (0.80 larvae/plant), Emamectin benzoate 5% SG (0.98 larvae/plant), and Bifenthrin 10 % EC (1.13 larvae/plant). In control plot maximum 4.92 larvae/plant were found.

Efficacy of different insecticides on larvae of Spodoptera frugiperda in maize during 2022-23:

First Spray:

The data on number of larvae/plant recorded at one day before first spray during 2022-23 and presented in Table 3 and Figure 3 which showed that average fall armyworm survival of larval population per plant was between 2.40 and 3.40. The data on number of larvae/plant recorded at seven day after first spray during 2022-23 are presented in Table 3 and Figure 3. It has been recorded that average fall armyworm survival of larval population per plant ranged from 0.87 to 1.60. After pesticide treatment, Lambda cyhalothrin 4.9% CS recorded the lowest larva-- (0.87 larvae/plant which was substantially superior to all other treatments and at par with Chlorantraniliprole 18.5 % SC-- 1.07 larvae/plant. The next best treatment was Spinosad 45%SC-- 1.20 larvae/plant which was at par with Flubendiamide 39.35 % SC-- 1.27 larvae/plant and Fipronil 5 % SC-- 1.33 larvae/plant. The other best treatment was Emamectin benzoate 5% SG-- 1.53 larvae/plant which was at par with Bifenthrin 10 % EC-- 1.60 larvae/plant. In control plot maximum 3.73 larvae/plant were found.

The data on number of larvae/plant recorded at fourteen day after first spray during 2022-23 are shown in Table 3 and Figure 3 which showed that average fall armyworm survival of larval population per plant was from 0.47 to 1.20. Lambda cyhalothrin 4.9% CS recorded the lowest larvae-- 0.47 larvae/plant which was substantially superior to all other treatments. The next best

Table 3: Efficacy of different insecticides on larvae of *Spodoptera frugiperda* in maize during 2022-23

Treatments	Pooled mean of number of larvae/plant (average of 15 plants)								Percent reduction over control	
	Spray I				Spray II					
	Pre-treatment population	7 DAT	14 DAT	Mean	Pre-treatment population	7 DAT	14 DAT	Mean	After Spray I	After Spray II
Lambda cyhalothrin 4.9% CS	2.67 (1.92)	0.87 (1.34)	0.47 (1.21)	**0.67**	2.53 (1.88)	0.60 (1.26)	0.07 (1.03)	**0.33**	87.52	93.85
Spinosad 45%SC	2.40 (1.84)	1.20 (1.38)	0.87 (1.35)	**1.03**	3.07 (2.01)	0.80 (1.34)	0.67 (1.29)	**0.73**	80.81	86.40
Flubendiamide 39.35 % SC	2.87 (1.97)	1.27 (1.29)	0.93 (1.39)	**1.10**	3.60 (2.14)	0.93 (1.39)	1.07 (1.44)	**1.00**	79.50	81.37
Fipronil 5 % SC	3.00 (2.00)	1.33 (1.36)	0.93 (1.39)	**1.13**	3.20 (2.04)	1.00 (1.41)	0.87 (1.35)	**0.93**	78.94	82.67
Emamectin benzoate 5% SG	3.20 (2.04)	1.53 (1.51)	1.07 (1.44)	**1.30**	3.93 (2.21)	1.13 (1.46)	1.40 (1.54)	**1.27**	75.78	76.34
Chlorantraniliprole 18.5 % SC	3.00 (2.00)	1.07 (1.26)	0.73 (1.32)	**0.90**	3.53 (2.13)	0.73 (1.32)	0.20 (1.10)	**0.47**	83.23	91.24
Bifenthrin 10 % EC	3.40 (2.10)	1.60 (1.42)	1.20 (1.48)	**1.40**	3.27 (2.05)	1.47 (1.57)	1.40 (1.55)	**1.44**	73.91	73.17
Untreated control	3.27 (2.06)	3.73 (2.41)	4.20 (2.28)	**3.97**	5.00 (2.45)	5.07 (2.46)	5.27 (2.50)	**5.17**	-	-
S.Em (±)	**0.058**	**0.085**	**0.078**		**0.109**	**0.052**	**0.060**			
CD (P= 0.05)	**N/A**	**0.259**	**0.238**		**N/A**	**0.158**	**0.184**			
CV (%)	**5.058**	**9.270**	**9.080**		**8.895**	**5.849**	**7.071**			

DAT- Days after treatment

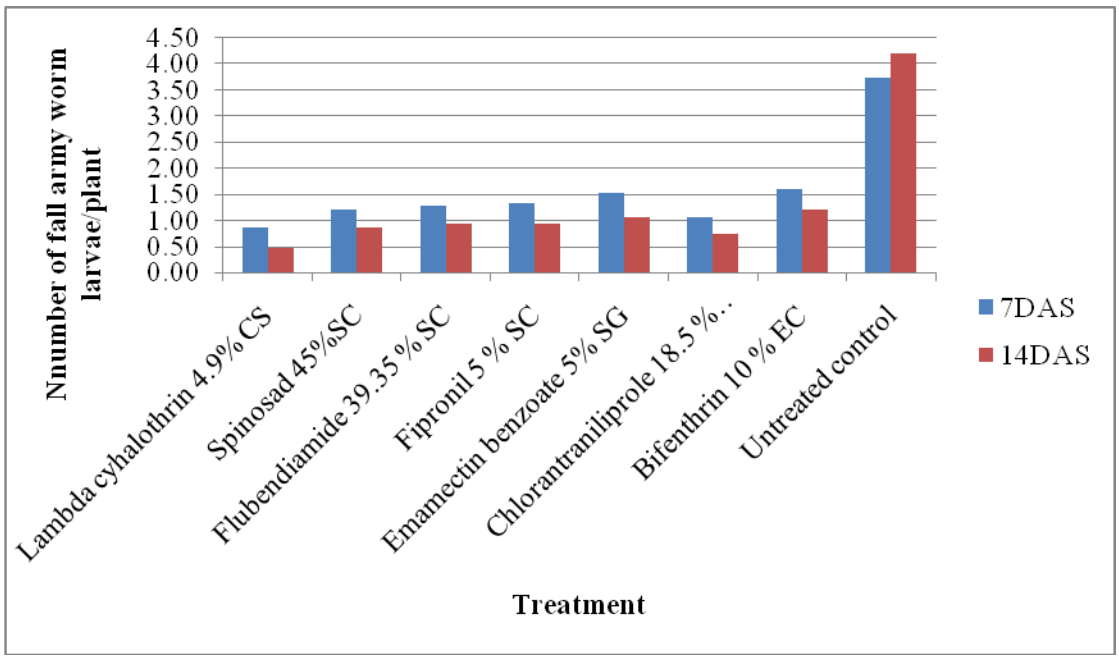

Fig. 3: Number of fall army worm larvae/plant after first spray during 2022-23 (DAS- Days after spraying).

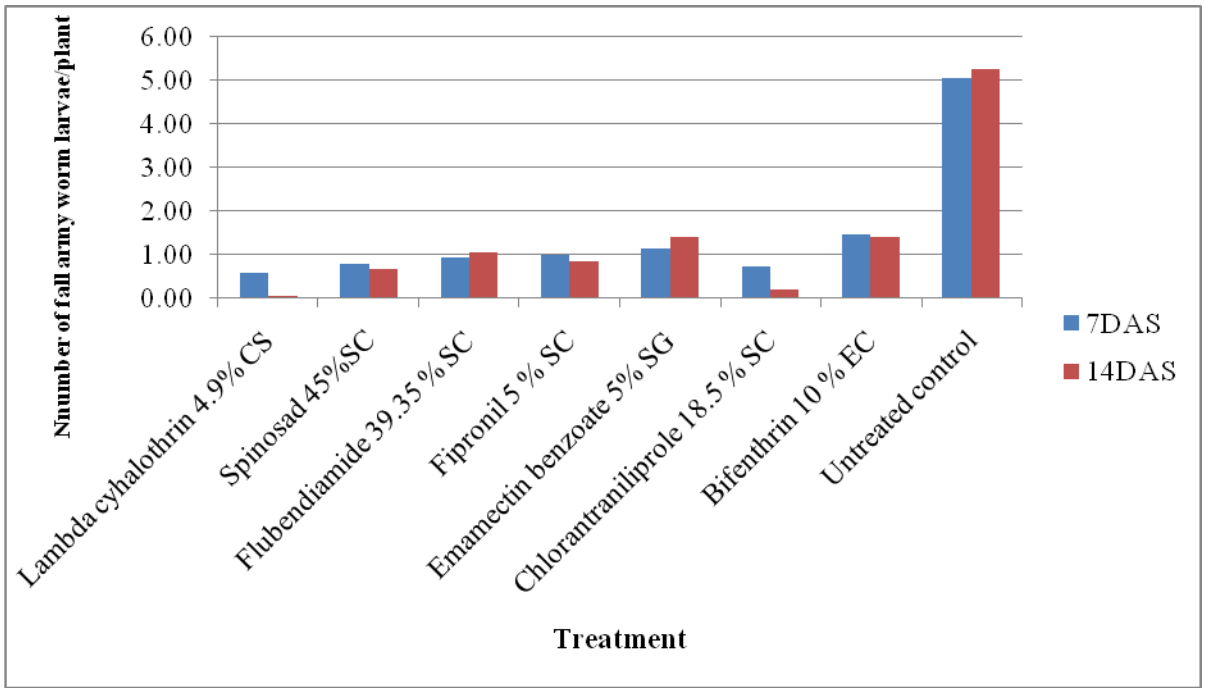

Fig. 4: Number of fall army worm larvae/plant after second spray during 2022-23 (DAS- Days after spraying).

Table 5: Yield and economics of different insecticides applied for the management of *Spodoptera frugiperda* on maize

Treatments	Seed yield (q./ha)	Increased yield over Control (q./ha)	Price q or kg /ha)	Price of increased Yield over control (Rs./ha)	Cost of Treatment (Rs./ha)	Net profit (Rs./ha)	Cost Benefit Ratio
Lambda cyhalothrin 4.9% CS	32.70	13.13	2000	26260	3100	23160	1:7.47
Spinosad 45%SC	30.80	11.23	2000	22460	5260	17200	1:3.27
Flubendiamide 39.35 % SC	29.53	9.96	2000	19920	4590	15330	1:3.34
Fipronil 5 % SC	29.20	9.63	2000	19260	3840	15420	1:4.02
Emamectin benzoate 5% SG	24.17	4.6	2000	9200	3240	5960	1:1.84
Chlorantraniliprole 18.5 % SC	32.10	12.53	2000	25060	3120	21940	1:7.03
Bifenthrin 10 % EC	22.67	3.1	2000	6200	3200	3000	1:0.94
Untreated control	19.57	0	2000	0	0	0	-

treatment was Chlorantraniliprole 18.5 % SC-- 0.73 larvae/plant which was at par with Spinosad 45% SC-- 0.87 larvae/plant , Flubendiamide 39.35 % SC and Fipronil 5 % SC-- 0.93 larvae/plant. The other best treatment was Emamectin benzoate 5% SG-- 1.07 larvae/plant which was at par with Bifenthrin 10 % EC-- 1.20 larvae/plant. In control plot maximum 4.20 larvae/plant were found.

Second Spray:

The data on number of larvae/plant recorded at one day before second spray during 2022-23 are presented in Table 3 and Figure 4 which showed that average fall armyworm survival of larval population per plant was between 2.53 and 5.00. The data on number of larvae/plant recorded at seven day after second spray during 2022-23 are shown in Table 3 and Figure 4 which depicted that average fall armyworm survival of larval population per plant ranged from 0.60 to 1.47. After pesticide treatment, Lambda cyhalothrin 4.9% CS recorded the lowest larvae-- 0.60 larvae/plant and was substantially superior to all other treatments which was at par with Chlorantraniliprole 18.5 % SC-- 0.73 larvae/plant. The other best treatment was Spinosad 45% SC-- 0.80 larvae/plantwhich was at par with Flubendiamide 39.35% SC-- 0.93 larvae/plant. The next best treatment was Fipronil 5 % SC-- 1.00 larvae/plant which was at par with Emamectin benzoate 5% SG-- 1.13 larvae/plant followed by Bifenthrin 10% EC-- 1.47 larvae/plant. In control plot maximum 5.07 larvae/plant were found.

The data on number of larvae/plant recorded at fourteen day after second spray during 2022-23 are illustrated in Table 3 and Figure 4 which depicted that average fall armyworm survival of larval population per plant ranged from 0.07 to 1.40. Lambda cyhalothrin 4.9% CS recorded the lowest larvae-- 0.07 larvae/plant and was substantially superior to all other treatments which were at par with Chlorantraniliprole 18.5 % SC-- 0.20 larvae/plant. The next best treatment was Spinosad 45% SC-- 0.67 larvae/plant followed by Fipronil 5% SC-- 0.87 larvae/plant, Flubendiamide 39.35 % SC-- 1.07 larvae/plant, Emamectin benzoate 5% SG and Bifenthrin 10 % EC-- 1.40 larvae/plant. In control plot maximum 5.27 larvae/plant were found.

Overall mean of number of larvae/plant (*average of two spray*):

The data on number of larvae/plant recorded after first and second spray during 2022-23 showed that Lambda cyhalothrin 4.9% CS recorded the lowest larvae-- 0.50 larvae/plant which was substantially superior to all other treatments. The second best treatment was Chlorantraniliprole 18.5% SC-- 0.68 larvae/plant followed by Spinosad 45% SC-- 0.88 larvae/plant, Fipronil 5% SC-- 1.03 larvae/plant, Flubendiamide 39.35% SC-- 1.05 larvae/plant, Emamectin benzoate 5% SG-- 1.28 larvae/plant, and Bifenthrin 10% EC-- 1.42 larvae/plant. In control

plot maximum 4.57 larvae/plant were found.

The present findings are in agreement with the observations of Bajracharya *et al.* (2020) who evaluated five selected commercial formulations of insecticides against newly introduced fall armyworm, *Spodoptera frugiperda* at Gaindakot of Nepal during June 2019. The treatments included were Spinosad, Chlorantraniliprole, Emmamectin benzoate, Imidacloprid and Azadirachtin. On the basis of per cent foliar damage, Spinosad, Chlorantraniliprole and Emmamectin benzoate were found promising for *Spodoptera frugiperda* management in maize, though Imidacloprid and Azadirachtin were also found effective statistically. More or less the present findings are also in agreement with the Bird *et al.* (2020) who reported that Emamectin benzoate was the most efficacious insecticide followed by chlorantraniliprole, spinetoram, spinosad, and methoxyfenozide. Indoxacarb was the least toxic selective insecticide on *S. frugiperda*.

All the insecticidal treatments recorded good yield. The maximum yield was obtained for insecticide Lambda cyhalothrin 4.9% CS (32.70 q/ha.) followed by Chlorantraniliprole 18.5 % SC (32.10 q/ha.), Spinosad 45%SC(30.80 q/ha.), Flubendiamide 39.35 % SC (29.53 q/ha.), Fipronil 5 % SC (29.20 q/ha.), Emamectin benzoate 5% SG (24.17 q/ha.), and Bifenthrin 10 % EC (22.67 q/ha.). In control plot 19.57 q/ha. seed yield was obtained.

The B:C ratio of different pesticidal treatments applied for the management of fall armyworm has been worked out. The highest cost benefit ratio was found in treatment Lambda cyhalothrin 4.9% CS (1:7.47) followed by Chlorantraniliprole 18.5 % SC (1:7.03) (Table 5).

Conclusion

The data on number of larvae/plant recorded after first and second spray during 2022-23 showed that Lambda cyhalothrin 4.9% CS recorded the lowest larvae (0.50 larvae/plant) which was substantially superior to all other treatments. The second best treatment was Chlorantraniliprole 18.5 % SC (0.68 larvae/plant) followed by Spinosad 45%SC (0.88 larvae/plant). In control plot maximum 4.57 larvae/plant were found.

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