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Management of Fall Armyworm, *Spodoptera frugiperda* in Kharif Sorghum

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ABSTRACT: Fall armyworm *Spodoptera frugiperda* was recently introduced pest in India causing more damage to sorghum, maize and other C4 plants. Larvae of the fall armyworm damages the whorl portion of the sorghum plants and causes window pane like symptoms on leaves which reduces the photosynthetic activity of leaves and reduces the yield of the plants. The contributions I made in the study was application of insecticides on the whorl region of the plant because the larvae mostly concentrated on this region. The investigation was carried out under field conditions at Sorghum Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *kharif* 2022. The least damage score was recorded in treatment *Beauveria bassiana* spray at 20 DAE followed with chlorantraniliprole spray. The low plant damage at 45, 60 and 75 DAE was recorded in treatment chlorantraniliprole spray at 20 DAE followed with emamectin benzoate spray at 30 DAE and emamectin benzoate spray at 20 DAE followed with chlorantraniliprole spray at 30 DAE. Similarly, the average plant damage was minimum recorded in chlorantraniliprole spray at 20 DAE followed with emamectin benzoate spray at 30 DAE and in treatment emamectin benzoate spray at 20 DAE followed with chlorantraniliprole spray at 30 DAE. The highest grain yield and fodder yield were recorded in treatment emamectin benzoate spray at 20 DAE followed with chlorantraniliprole spray at 30 DAE and grain yield and fodder yield in this was on par with yield in chlorantraniliprole spray at 20 DAE followed in emamectin benzoate spray at 30 DAE. The highest incremental cost benefit ratio (ICBR) was recorded in treatment chlorantraniliprole spray at 20 DAE followed with emamectin benzoate 5 spray at 30 DAE with 1:5.97 followed by 1:5.93 in treatment emamectin benzoate spray at 20 DAE followed with chlorantraniliprole spray at 30 DAE.

Key words: Sorghum, fall armyworm, *Spodoptera frugiperda*.

INTRODUCTION

Maharashtra ranks first in sorghum production in India and share 34.42% production. Sorghum is grown on area of 1.59 million ha with 1.45 million tons of production and productivity of 911 kg/ha (Anonymous, 2022-23). As compared to the area, production is low in state due to various reasons like environmental conditions, scarcity of water, seed viability, fertilizers, damage due to insect pests and diseases, etc.

Sorghum harbors nearly 150 species of insects in different agroecosystems of India. In Maharashtra, about 18 important pests are reported to damage the sorghum crop. Some of these are shoot fly (*Atherigona soccata*) stem borer (*Chilo partellus*) and gall midge (*Stenodiplosis sorghicola*) has attained the major pest status in India and accounts to the yield loss of nearly 32% in India (Nwanze, 1995). The recently introduced pest, fall armyworm (*Spodoptera frugiperda*) has become a great threat to cereal production in the world (Day *et al.* 2017) and causing 16% yield loss in sorghum (Abrahams *et al*. 2017).

Adult's has strong flying ability of 100 km/night, 2000 km during its life time and has high fecundity with adult female laying eggs in clusters of 50 to 200 on young leaves or base of the tender plants. The fall armyworm incidence on Sugarcane was first recorded on 22nd September 2018 in the Ghogaon Village of Sangli District in Maharashtra on 60 days old Sugarcane cultivar Co 86032 with an infestation up to 5% (Chormule *et al.* 2019). FAW newly hatched larvae move upward on the leaves and usually are found on the upper plant parts where they feed on the outer layer of leaf tissue. Young larvae often produce silk-like threads and drop by these to other parts. Older fall armyworm larvae prefer to feed deep in the whorl of a plant and they are characterized by typical inverted 'Y' shaped structure on fore head (Plate 1) and four square shaped dots on eighth abdominal segment (Plate 2). Thus, they are protected from natural enemies and insecticides are less than when applied to larvae feeding on the surface of upper leaves. Fall armyworms are cannibalistic and usually one late instar larva survives in the whorl of the plant. The fall armyworm, causes

damage to whorls of the plant and keeps shot holes on the sorghum leaves, in whorls of the plants the damage may goes from 55 to 85% of the damage to sorghum grain production. In Maharashtra also, the damage of FAW is increasing and causing losses in sorghum production. Therefore, the experiment was planned to manage this invasive insect pest on sorghum with view to study the effect of insecticides and to find out the economical treatment for the management of fall armyworm.

MATERIAL AND METHODS

The present investigation was carried out on the field of Sorghum Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during *kharif 2022* with a view to study the effect of insecticides on fall armyworm in *kharif* sorghum and to find out the economical treatment for management of fall armyworm. The trial was sown in kharif in Randomized Block Design with eight treatments replicated three times. The effect of insecticides and biopesticides sprays were assessed in sequence as spray schedules. *Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit water was mixed thoroughly in bucket by stirring with wooden stick. The spray solution thus obtained was used for spraying. The chemical insecticides *viz*., chlorantraniliprole 18.5% SC and emamectin benzoate 5% SG in the proportion of 4.0 ml and 4.0 gm in 10 liters of water mixed separately stirring using wooden stick in bucket and suspension thus obtained was used for spraying. Number of plants per plot in six rows of sorghum lines, four rows were evaluated for fall armyworm damage score at 30, 45, 60 and 75 days after crop emergence. Plant percent damage also recorded on four sorghum lines at 30, 45, 60 and 75 days after crop emergence. The whorl damage rating in the scale 1 to 9 were recorded 30, 45, 60 and 75 days after emergence (Davis and Williams 1992). The total number of plants in four rows and total number of plants showing fall armyworm damage symptoms were counted 30, 45, 60 and 75 days after emergence and percent plant damage were carried out using formula.

$$\% \text{ Plant damage} = \frac{\text{Number of plants damaged}}{\text{Total number of plants}} \times 100$$

Grain and fodder yield from each plot was recorded by weighing them using electronic balance. The fodder yield also recorded in each plot. The data obtained were converted to appropriate transformations and were subjected to statistical analysis to test the level of significance (Gomez and Gomez 1983).

Plate 1. Identification marks of fall armyworm larvae; inverted 'Y' shaped structure on fore head.

Plate 2. Identification marks of fall armyworm larvae; four square shaped spots on eighth abdominal segment.

Plate 3. Fall armyworm: saw dust like frass of larvae on sorghum leaves.

Plate 4. Fall armyworm: foliar damage by larvae, the ragged appearance.

Plate 5. Fall armyworm: silvery transparent membrane structures on the leaves due to feeding by neonate larvae.

RESULTS AND DISCUSSION

A. Plant damage score

Fall armyworm damage score at 30 DAE ranged from 1.58 to 2.17 (Table 1). The lowest damage score (1.58) was recorded in the treatment *Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit spray at 20 DAE followed with chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 30 DAE (T2) followed by 1.67 damage score in treatment *Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit spray at 20 DAE followed with emamectin benzoate 5% SG @ 4 g/10 lit spray at 30 DAE (T1). The highest damage score (2.17) was noted in untreated control (T8). At 45 DAE the damage score was ranged between 1.67 to 3.00. The minimum damage score (1.67) was recorded in the treatment *Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit spray at 20 DAE followed with chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 30 DAE (T2) followed by 1.92 damage score recorded in two treatments *viz*., emamectin benzoate 5% SG @ 4 g/10 lit spray at 20 DAE followed with *Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit spray at 30 DAE (T3) and chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 20 DAE followed with *Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit spray at 30 DAE (T4). The highest damage score (3.00) was recorded in untreated control (T8).

Similar was the trend at 60 DAE (Table 1) the least damage score (2.00) was noticed in treatment *Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit spray at 20 DAE followed with chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 30 DAE (T2) followed by 2.25 damage score recorded in two treatments i.e., emamectin benzoate 5% SG @ 4 g/10 lit spray at 20 DAE followed with *Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit spray at 30 DAE (T3) and chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 20 DAE followed with *Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit spray at 30 DAE (T4). The highest damage score (5.25) was recorded in untreated control (T8). At 75 DAE (Table 1) the damage score was ranged between 2.33 to 6.25 at 75 DAE. The minimum damage score (2.33) was recorded in treatment *Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit spray at 20 DAE followed with chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 30 DAE (T2). The highest damage score (6.25) was recorded in untreated control (T8). The highest damage score (6.25) was recorded in untreated control (T8).

In case of average leaf damage score (Table 1) lowest leaf damage score i.e., 1.90 was recorded in treatment *Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit spray at 20 DAE followed with chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 30 DAE (T2) followed by 2.17 score in treatment *Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit spray at 20 DAE followed with emamectin benzoate 5% SG @ 4 g/10 lit spray at 30 DAE (T1) and highest leaf damage score was 4.17 recorded in untreated control (T8).

In present findings the average plant damage score recorded lowest in treatment with *Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit spray at 20 DAE followed with chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 30 DAE.

B. Plant damage percent

Plant damage per cent at 30 DAE within the treatments were non-significant (Table 2). However, least plant damage i.e., 3.41% was noted in *Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit spray at 20 DAE followed with chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 30 DAE (T2) followed by 3.47% in treatment *Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit spray at 20 DAE followed with emamectin benzoate 5% SG @ 4 g/10 lit spray at 30 DAE (T1). The highest plant damage per cent was noticed in untreated control (4.54%). Plant damage at 45 DAE (Table 2, Plate 3) was statistically significant within the treatments and ranged from 4.19 to 14.10 per cent. The lowest plant damage (4.19%) was observed in treatment chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 20 DAE followed with emamectin benzoate 5% SG @ 4 g/10 lit spray at 30 DAE (T6) and damage in this was at par with 4.25 per cent and 6.36 per cent noted in treatments emamectin benzoate 5% SG @ 4 g/10 lit spray at 20 DAE followed with chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 30 DAE (T5) and chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 20 DAE followed with *Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit spray at 30 DAE (T4). The highest plant damage was 14.10% noted in untreated control (T8).

Table 1: Leaf damage score in various treatments.

Treatment	Leaf damage score				
	30 DAE	45 DAE	60 DAE	75 DAE	Average
T-1	1.67	2.00	2.33	2.67	2.17
T-2	1.58	1.67	2.00	2.33	1.90
T-3	1.75	1.92	2.25	2.92	2.21
T-4	1.75	1.92	2.25	2.92	2.21
T-5	2.00	2.00	2.33	2.67	2.25
T-6	2.00	2.00	2.33	2.67	2.25
T-7	2.00	2.00	2.33	2.67	2.25
T-8	2.17	3.00	5.25	6.25	4.17

Plant damage at 60 DAE (Table 2) (Plate 5) ranged from 6.34 to 22.96%. Significantly least plant damage i.e., 6.34 per cent was noted in treatment emamectin benzoate 5% SG @ 4 g/10 lit spray at 20 DAE followed with chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 30 DAE (T5) and damage in this was statistically at par with damage in treatments *viz*., chlorantraniliprole lit spray at 20 DAE followed with emamectin benzoate spray at 30 DAE (T6); *Beauveria bassiana* spray at 20 DAE followed with emamectin benzoate 5% SG @ 4 g/10 lit spray at 30 DAE (T1) and *Beauveria bassiana* spray at 20 DAE followed with chlorantraniliprole spray at 30 DAE (T2) observed 6.50, 7.65 and 7.77 per cent, respectively. The highest plant damage 22.96% was noticed in untreated control (T8). Plant damage at 75 DAE (Plate 4) ranged from 8.08 to 28.90%. Significantly least plant damage (8.08) per cent was observed in treatment emamectin benzoate 5% SG @ 4 g/10 lit spray at 20 DAE followed with chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 30 DAE (T5) and damage in this was statistically at par with 8.26 per cent in chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 20 DAE followed with emamectin benzoate 5% SG @ 4 g/10 lit spray at 30 DAE (T6). Highest plant damage was 28.90% registered in untreated control (T8).

Significantly least average plant damage (Table 2 and Fig. 1) i.e., 5.67% was recorded in treatment chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 20 DAE followed with emamectin benzoate 5% SG @ 4 g/10 lit spray at 30 DAE (T6) which was at par with 5.71% in treatment emamectin benzoate 5% SG @ 4 g/10 lit spray at 20 DAE followed with chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 30 DAE (T5) and the highest plant damage 17.62% was recorded in untreated control (T8).

Table 2: Treatment effects on plant damage (%) by fall armyworm.

Treatment	First application 20 DAE	Second application 30 DAE	Plant damage (%)				
			30 DAE	45 DAE	60 DAE	75 DAE	Av
T-1	*Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit	Emamectin benzoate 5% SG @ 4 g/10 lit	3.47 (1.85) *	7.06 (2.65)*	7.65 (2.75)*	12.21 (20.37)**	7.60 (15.98)**
T-2	*Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit	Chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit	3.41 (1.84)	6.81 (2.61)	7.77 (2.78)	12.22 (20.42)	7.55 (15.94)
T-3	Emamectin benzoate 5% SG @ 4 g/ 10 lit	*Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit	3.82 (1.94)	7.16 (2.67)	12.08 (3.45)	13.97 (21.93)	9.26 (17.69)
T-4	Chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/ 10 lit	*Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit	3.74 (1.91)	6.36 (2.51)	11.72 (3.41)	12.38 (20.55)	8.55 (17.00)
T-5	Emamectin benzoate 5% SG @ 4 g/10 lit	Chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit	4.20 (2.04)	4.25 (2.06)	6.34 (2.51)	8.08 (16.50)	5.71 (13.82)
T-6	Chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit	Emamectin benzoate 5% SG (200 g a.i./ha) @ 4 g/10 lit	3.73 (1.93)	4.19 (2.04)	6.50 (2.54)	8.26 (16.63)	5.67 (13.75)
T-7	*Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit	*Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit	4.53 (2.12)	9.28 (3.01)	14.99 (3.87)	19.56 (26.23)	12.09 (20.33)
T-8	Untreated control		4.54 (2.13)	14.10 (3.75)	22.96 (4.77)	28.90 (32.39)	17.62 (24.77)
	SE (M) ±		0.11	0.16	0.23	1.17	0.66
	CD at 5%		-	0.506	0.70	3.55	2.04
	CV (%)		9.50	10.48	12.26	9.26	6.61

*Corresponding square root transformed values; **corresponding arcsine transformed values

In present study the plant damage percent 75 DAE as well as average plant damage percent were significantly least in treatments chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 20 DAE followed with emamectin benzoate 5% SG @ 4 g/10 lit spray at 30 DAE and emamectin benzoate 5% SG @ 4 g/10 lit spray at 20 DAE followed with chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 30 DAE than damage in rest of the treatments. Poul *et al*., (2020) carried out field experiment to evaluate the efficacy of newer insecticide molecules on fall armyworm on sorghum and observed that mean larval population noted lowest and at par with emamectin benzoate 5% SG @ 4 g/10lit and chlorantraniliprole 18.5% SC @ 3 ml/10 lit confirms the present findings. The present investigations were also supported by findings of Sangle *et al*. (2020) and Ahir *et al*. (2021) who conducted the field experiments on maize and they noted effectiveness of chlorantraniliprole 18.5% SC and emamectin benzoate 5 SG against *Spodoptera frugiperda*. Similarly, effectiveness of chlorantraniliprole 0.4% GR against *Spodoptera frugiperda* was observed by Suthar *et al.* (2020). Our study is also in agreement with results of Thumar *et al.*, (2020), Bharadwaj *et al*. (2020) and Mallapur *et al.* (2019) who noted best results with emamectin benzoate 5 SG against *Spodoptera frugiperda* on maize. However, Ramesh and Tayde (2022), Kumar and Mohan (2020).

C. Grain and fodder yield

The highest grain yield i.e., 39.86 q/ha was noted in treatment emamectin benzoate 5% SG @ 4 g/10 lit spray at 20 DAE followed with chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 30 DAE (T5) and grain yield in this was on par with chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 20 DAE followed with emamectin benzoate 5% SG @ 4 g/10 lit spray at 30 DAE (T6) with 39.68 q/ha (Table 3).

The fodder yield in various treatments also differed significantly (Table 3). The highest fodder yield i.e., 134.52 q/ha was recorded in treatment emamectin benzoate 5% SG @ 4 g/10 lit spray at 20 DAE followed with chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 30 DAE (T5) which was statistically on par with 133.93 q/ha yield in chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 20 DAE followed with emamectin benzoate 5% SG @ 4 g/10 lit spray at 30 DAE (T6).

In present study the highest grain and fodder yield was registered by emamectin benzoate 5% SG @ 4 g/10 lit spray at 20 DAE followed with chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 30 DAE and chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 20 DAE followed with emamectin benzoate 5% SG @ 4 g/10 lit spray at 30 DAE. These findings are in agreement with findings of Poul *et al*. (2020) who conducted the field experiment at Sorghum Research Station, Parbhani, Maharashtra during kharif 2019-20 on Sorghum and noted highest grain and fodder yield in treatment emamectin benzoate 5% SG @ 4g/10 lit followed by chlorantraniliprole 18.5% SC @ 3ml/10 lit, flubendiamide 39.35% SC @ 2.5 ml/10 lit. Similar type of results on maize were noted by Sangle *et al*. (2020) who carried out field trial to evaluate the effect of seven newer insecticide molecules at Parbhani and noticed highest grain yield in treatment emamectin benzoate 5 SG @ 200 g/ha followed in chlorantraniliprole 18.5% SC @ 150 ml/ha, flubendiamide 39.35 SC @ 125 ml/ha and thiamethoxam 12.6 + lambda cyhalothrin 9.5 ZC @ 125 ml/ha. and by Suthar *et al*. (2020) who conducted experiment at three different locations and noted highest pooled mean grain and fodder yield in plots treated with chlorantraniliprole 0.4% GR @ 80 g a.i./ha which was at par with fipronil 0.6% GR @ 120 g a.i./ha. Present investigations are also in agreement with results of Thumar *et al.* (2020) who evaluated different insecticides against fall armyworm experiment on maize crop and observed highest mean grain yield in the treatment spinetoram 11.7 SC @ 0.006% which was at par with emamectin benzoate 5 SG @ 0.0025%, chlorantraniliprole 18.5 SC @ 0.006% and thiodicarb 75 WP @ 0.11%. Similarly, the authors noted highest fodder yield in the treatment spinetoram 11.7 SC @ 0.006% followed in emamectin benzoate 5 SG @ 0.0025% followed by chlorantraniliprole 18.5 SC @ 0.006%; Ahir *et al.* (2021) who conducted a two years study field experiment on maize noticed that chlorantraniliprole 18.5 SC recorded highest mean seed yield followed in emamectin benzoate and spinosad 45 SC.

Ramesh and Tayde (2022) studied insecticidal effect against fall armyworm on maize in Prayag Raj, Uttar Pradesh. The authors found the highest grain yield was recorded in the treatment spinetoram 11.7% SC @ 0.9 ml/lit followed in chlorantraniliprole 18.5% SC @ 0.4 ml/lit followed in flubendiamide 39.35% SC @ 0.24 ml/lit followed by emamectin benzoate 5% SG @ 0.4 g/lit are confirmed by our investigations.

Our studies are partial fulfilment of findings of Kumar and Mohan (2020) who carried out research to study the effect of insecticides against fall armyworm on yield of Maize during rabi, and observed that the plot treated with spinetoram 11.7 SC @ 30 g a.i./ha recorded highest yield followed by novaluron 10 EC @ 10 g a.i./ha, chlorantraniliprole 18.5 SC @ 27.75 g a.i./ha, thiodicarb 75 WP @ 750 g a.i./ha and in emamectin benzoate 5 SG @ 10 g a.i./ha.

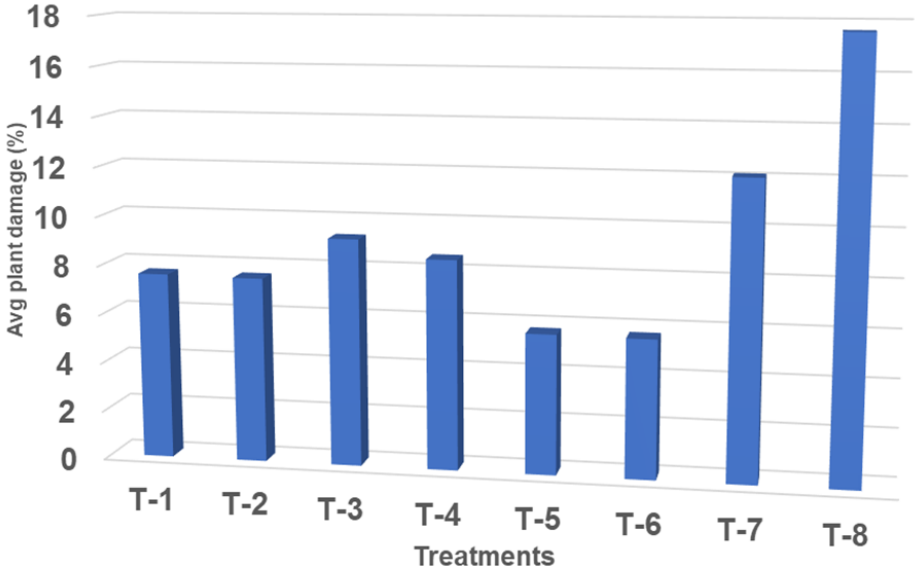

Fig. 1. Treatmenr effect on plant damage(%) by fall armyworm average.

Table 3: Treatment effects on grain yield and fodder yield in kharif 2022.

Treatment	First application 20 DAE	Second application 30 DAE	Grain yield (q/ha)	Fodder yield (q/ha)	ICBR
T-1	*Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit	Emamectin benzoate 5% SG @ 4 g/10 lit	33.94	114.53	1:4.80
T-2	*Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit	Chlorantraniliprole 18.5% SC @ 4 ml/10 lit	34.33	115.84	1:2.82
T-3	Emamectin benzoate 5% SG @ 4 g/ 10 lit	*Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit	34.17	115.31	1:4.94
T-4	Chlorantraniliprole 18.5% SC @ 4 ml/ 10 lit	*Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit	34.29	115.74	1:2.84
T-5	Emamectin benzoate 5% SG @ 4 g/10 lit	Chlorantraniliprole 18.5% SC @ 4 ml/10 lit	39.86	134.52	1:5.93
T-6	Chlorantraniliprole 18.5% SC @ 4 ml/10 lit	Emamectin benzoate 5% SG @ 4 g/10 lit	39.68	133.93	1:5.97
T-7	*Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit	*Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit	29.04	98.00	1:0.77
T-8	Untreated control		27.85	94.01	-
	SE (M) $\pm$		1.71	5.76	
	CD at 5%		5.17	17.47	
	CV (%)		8.65	8.66	

D. Incremental cost benefit ratio

The incremental cost benefit ratio (ICBR) in various treatments computed and presented in table 3 indicates that ICBR ranged between 1:0.77 to 1:5.97. The highest ICBR was registered by treatment chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 20 DAE followed with emamectin benzoate 5% SG @ 4 g/10 lit spray at 30 DAE (T6) i.e., 1:5.97 and it was followed by treatment emamectin benzoate 5% SG @ 4 g/10 lit spray at 20 DAE followed with chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 30 DAE (T5) 1:5.93. The treatments emamectin benzoate 5% SG @ 4 g/10 lit spray at 20 DAE followed with *Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit spray at 30 DAE (T3), *Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit spray at 20 DAE followed with emamectin benzoate 5% SG @ 4 g/10 lit spray at 30 DAE (T1), chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 20 DAE followed with *Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit spray at 30 DAE (T4) and *Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit spray at 20 DAE followed with chlorantraniliprole 18.5% SC (@ 40 g a.i./ha) @ 4 ml/10 lit spray at 30 DAE (T2) had ICBR 1:4.94, 1:4.80. 1:2.84 and 1:2.82, respectively. The lowest ICBR i.e., 1:0.77 was for treatment two sprays of *Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit spray at 20 DAE and 30 DAE (T7) indicating this treatment was most effective over control.

In the current study, the higher Incremental Cost Benefit Ratio (ICBR) were noted with chemical insecticides which was also confirmed by the early researchers. The results were also in conformity with the results of Kalleshwaraswamy *et al*. (2022) who noted highest incremental cost benefit with insecticides

viz., emamectin benzoate 5% SG and chlorantraniliprole 18.5% SC.

CONCLUSIONS

Emamectin benzoate 5% SG @ 4.0 g/10 lit and chlorantraniliprole 18.5% SC @ 4.0 ml/10 lit effectively manage fall armyworm, *Spodoptera frugiperda* and reduce the plant damage. Biopesticide *Beauveria bassiana* was cheaper and hence incurred least expenditure on spray application but least effective against *Spodoptera frugiperda*. Emamectin benzoate 5% SG @ 4.0 g/10 lit spray at 20 DAE followed by chlorantraniliprole 18.5% SC @ 4.0 ml/10 lit spray at 30 DAE and vice versa increases the grain and fodder yield. The spray applications with Emamectin benzoate 5% SG @ 4.0 g/10 lit spray at 20 DAE followed by chlorantraniliprole 18.5% SC @ 4.0 ml/10 lit spray at 30 DAE and vice versa increases gross income and gives higher incremental cost benefit. *Beauveria bassiana* (1×10^8 CFU/g) @ 50 ml/10 lit spray at 20 DAE followed by emamectin benzoate 5% SG @ 4.0 g/10 lit at 30 DAE and vice versa is the next option which helps in reducing the use of chemical insecticides and gives better incremental cost benefits.

FUTURE SCOPE

Emamectin benzoate and Chlorantraniliprole are the insecticides which are found effective in reducing the plant damage per cent of fall armyworm larvae. Use of these insecticides and especially placing these insecticides in whorl region helps in the reduction of fall armyworm population.

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