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Evaluation of novel insecticides against lepidopteron insect pests of sorghum fall armyworm, *Spodoptera frugiperda* and earhead worm, *Helicoverpa armigera*

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Abstract
The field investigations were carried out to evaluate the efficacy of seven newer insecticide molecules during *Kharif* 2019-20. The results revealed that all the insecticidal treatments were significantly effective against thrips over untreated control. Emamectin benzoate 5 SG most effective against the fall armyworm, *Spodoptera frugiperda* which was at par with chlorantraniliprole 18.5 SC, flubendiamde 39.35 SC and thiamethoxam 12.5 + lambda cyhalothrin 9.5. While in case of earhead worm, *Helicoverpa armigera* lowest number of larvae recorded in the treated with chlorantraniliprole 18.5 SC followed by flubendiamde 39.35 SC and emamectin benzoate 5 SG. The significantly maximum grain and fodder yield was recorded in emamectin benzoate 5 SG which was followed by chlorantraniliprole 18.5 SC and flubendiamide 39.35 SC.

Keywords: Efficacy, sorghum, fall armyworm, *S. frugiperda*, earhead worm, *H. armigera*

1. Introduction
Sorghum [*Sorghum bicolor* (L.) Monech] is the fifth major cereal crop after rice, wheat, maize and barley [12]. Prominent sorghum growing states in India are Maharashtra, Karnataka, Gujarat, Rajasthan, Madhya Pradesh, Andhra Pradesh and Tamil Nadu for grain sorghum whereas UP, Uttarakhand, Haryana and Delhi for purpose of forage sorghum. About 70% of total sorghum area in India is included in two states *viz*. Maharashtra (53%) and Karnataka contribute (18%). Meanwhile it is second largest grain crop in India till green revolution, presently occupies third place among food grains in terms of acreage and production [3]. In India during *Kharif* 2017-18 area was 5.86 lakh hectares with production of 4.63 lakh tones and productivity of 980 kg/ha. In Maharashtra region during 2017-18 area was 4.10 lakh hectares with production of 4.17 and productivity of 1018 kg/ha [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 [8]. 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. The important sorghum earhead insect-pests damaging sorghum reported are sorghum midge, earhead bugs and earhead caterpillars. Earhead caterpillar (*Helicoverpa armigera*, Hubner) is one of the serious polyphagous pest attacking more than 180 plants. The caterpillar cause major damage to the crops as it attacks reproductive parts and growing tips. The damaged ears have chalky appearance. The management of *Helicoverpa armigera* is very difficult in many crops, including sorghum, cotton, pigeon pea, and relies heavily on the use of chemical insecticides [10]. To overcome resistance problems, reduce doses of insecticides with selective mode of action and persistence against target pest. The present study to evaluate different novel insecticides against sorghum fall armyworm, *Spodoptera frugiperda* and Earhead caterpillar, *Helicoverpa armigera*.

2. Materials and Methods

The field experiment was conducted at the AICSIP, Sorghum Research Station, VNMKV, Parbhani (MS) during *Kharif* 2019-20 on sorghum variety Parbhani Shweta (PKV-801).

The experiment was laid out in Randomized Block Design with three replications and seven treatments including untreated control. The field was prepared following the recommended packages of practices with spacing of 45 X 15 cm with plot size 6.75 X 2.5m. The observation on dead hearts due to stem borer and larval population of fall armyworm were recorded from randomly selected 3 rows of 1 m length and number of larvae of earhead worm recorded per plot from randomly selected five plants. The pretreatment observations were recorded one day before insecticidal spray and post treatments observations were taken on 3, 7 and 14 days after each spray. The grain yield kg/plot was recorded, converted and expressed as quintals ha^{-1}. The data on grain yield was analyzed using analysis of variance and finally gross and net returns were worked out for each chemical.

2.1. Details of insecticides used in experiment

Table 1: Details of insecticides

Tr. No.	Treatment details	Conc. (%)	Dose (ml or g/10 lit. water)
T_1	Profenophos 50% EC	0.15	30
T_2	Cyantraniliprole 10.26% OD	0.014	10
T_3	Emamectin benzoate 5% SG	0.002	4
T_4	Spinosad 45% SC	0.018	4
T_5	Thiamethoxam 12.5% + Lambda cyhalothrin 9.5% ZC	0.011	5
T_6	Chlorantraniliprole18.5% SC	0.005	3
T_7	Flubendiamide 39.35% SC	0.009	2.5
T_8	Untreated control	-	-

3. Results and Discussion

Fall armyworm, *Spodoptera frugiperda*

The data recorded on one day before insecticidal spray revealed that the larval population ranged from 1.70 to 1.87 larvae / m row, which was statistically non-significant, indicating a uniform distribution of the larval population (Table no. 2 and Fig. no. 1). The observations recorded at 3 day after insecticide spray varied from 0.43 to 1.83 larvae/m row. The significantly less incidence of fall armyworm was observed in the treatment emamectin benzoate 5 SG (0.43 larvae/m row), which was at par with chlorantraniliprole 18.5 SC (0.50 larva/m row), flubendiamide 39.35% SC (0.57 larvae/m row), thiamethoxam 12.5 + lambda cyhalothrin 9.5 ZC (0.60 larva/m row), spinosad 45 SC (0.70 larvae/m row) and cyantraniliprole 10.26 OD (0.80 larvae/m row). The highest infestation was observed in the untreated control (1.83 larvae/m row). The observation recorded at 7 and 14 day after spray, significantly less incidence of fall armyworm was observed in the treatment emamectin benzoate 5 SG (0.30 and 0.39 larvae/m row), which was at par with chlorantraniliprole 18.5 SC (0.33 and 0.43 larva/m row), flubendiamide 39.35 SC (0.40 and 0.53 larvae/m row) and thiamethoxam 12.5 + lambda cyhalothrin 9.5 ZC (0.47 and 0.60 larva/m row). Mean population of fall armyworm after spray revealed that untreated control recorded significantly highest larval population and the treatment emamectin benzoate 5 SG was most effective which recorded the lowest larval population (0.37 larvae/m row). The next effective insecticides were chlorantraniliprole 18.5 SC (0.42 larvae/m row), flubendiamide 39.35 SC (0.50 larvae/m row), thiamethoxam 12.6 + lambda cyhalothrin 9.5 ZC (0.55 larvae/m row), spinosad 45 SC (0.71 larvae/m row), cyantraniliprole 10.26 OD (0.72 larvae/m row) and profenophos 50 EC (1.03 larvae/m row).

The findings of present investigations are in the conformity with above research workers. The significant reduce the larval numbers and crop damage in the insecticide treatment emamectin benzoate [2]. Chlorantraniliprole 18.5 SC was highly effective against the fall armyworm, *Spodoptera frugiperda* of second instar larvae [5]. The treatment Chlorantraniliprole 18.5% SC was effective in 90.43% reduction in fall armyworm larval population over untreated control [7].

Table 2: Evaluation of different insecticides against fall armyworm, *S. frugiperda* on sorghum

Tr. No.	Treatment	Conc. (%)	Doses /10 lit of water	No. of larvae/m row				
				1 DBS	3 DAS	7 DAS	14 DAS	Mean
T_1	Profenophos 50% EC	0.15	30 ml	1.83 (1.53)	1.10 (1.26)	0.77 (1.13)	1.23 (1.23)	1.03 (1.24)
T_2	Cyantraniliprole 10.26% OD	0.014	10 ml	1.70 (1.48))	0.80 (1.14)	0.57 (1.03)	0.80 (1.14)	0.72 (1.10)
T_3	Emamectin benzoate 5% SG	0.002	4 g	1.80 (1.52)	0.43 (0.96)	0.30 (0.89)	0.39 (0.94)	0.37 (0.93)
T_4	Spinosad 45% SC	0.018	4 ml	1.87 (1.54)	0.70 (1.10)	0.59 (1.04)	0.83 (1.15)	0.71 (1.10)
T_5	Thaimethoxam 12.6% + Lambda cyhalothrin 9.5% ZC	0.011	5 ml	1.83 (1.53)	0.60 (1.05)	0.47 (0.98)	0.60 (1.05)	0.55 (1.02)
T_6	Chlorantraniliprole 18.5% SC	0.005	3 ml	1.73 (1.49)	0.50 (1.00)	0.33 (0.91)	0.43 (0.96)	0.42 (0.96)
T_7	Flubendiamide 39.35% SC	0.009	2.5 ml	1.73 (1.49)	0.57 (1.03)	0.40 (0.95)	0.53 (1.01)	0.50 (1.00)
T_8	Untreated control	--	--	1.70 (1.48)	1.83 (1.53)	1.76 (1.50)	1.82 (1.52)	1.81 (1.52)
	S.E.±			0.06	0.05	0.03	0.05	0.04
	C. D.@ 5%			NS	0.15	0.09	0.15	0.12
	CV%			6.33	6.62	8.30	10.47	9.1

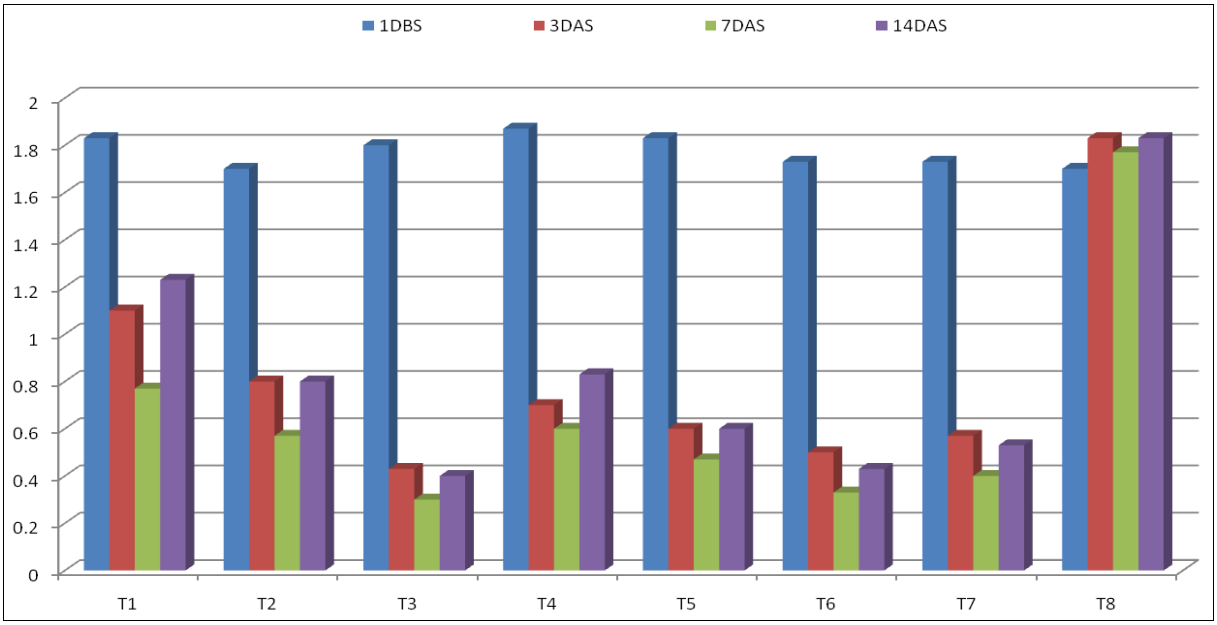

Fig 1: Evaluation of different insecticides against fall armyworm, *S. frugiperda* on sorghum

Earhead worm, *Helicoverpa armigera*

The data recorded at the milking stage one day before insecticide spray revealed that the earhead worm population ranged from 3.17 to 3.77/earhead, which was statistically non-significant, indicating a uniform distribution of the pest population (Table no. 3 and Fig. no. 2). The observation recorded at 3 day after insecticide spray (at milking stage of crop) varied from 1.70 to 3.90/earhead. The lowest incidence of earhead worm was observed in the treatment chlorantraniliprole 18.5 SC (1.70/earhead) which was at par with flubendiamide 39.35 SC (1.80/earhead), emamectin benzoate 5 SG (2.27/earhead) and spinosad 45 SC (2.43/earhead). However the next best treatments in their order of effectiveness were cyantraniliprole 10.26 OD (2.63/earhead), profenophos 50 EC (2.77/earhead) and thiamethoxam 12.6% + lambda cyhalothrin 9.5 ZC (2.97/earhead). The larval population was significantly highest in untreated control (3.90/earhead). On 7 and 14 day after insecticide spray the larval population varied from 0.83 to 4.03/earhead. Significantly less incidence of earhead worm was observed in treatment chlorantraniliprole 18.5 SC (0.83 and 1.12/earhead) which was at par with flubendiamide 39.35 SC (1.07 and 1.27/earhead), emamectin benzoate 5 SG (1.20 and 1.37/earhead), spinosad 45 SC (1.43 and 1.57/earhead), cyantraniliprole 10.26 OD (1.67 and 1.82/earhead) and profenophos 50 EC (1.67 and 2.00/earhead).

The mean population of earhead worm after spray reported that the significantly highest larval population (4.08 larvae/ earhead) was recorded by untreated control and the treatment chlorantraniliprole 18.5 SC (1.22 larvae/ earhead) was most effective with the lowest larval population. flubendiamide 39.35 SC (1.38 larvae/earhead), emamectin benzoate 5 SG (1.61 larvae/earhead), spinosad 45 SC (1.81 larvae/earhead), profenophos 50 EC (2.08 larvae/earhead), cyantraniliprole 10.26 OD (2.09 larvae/earhead) and thiamethoxam 12.6 + lambda cyhalothrin 9.5 ZC (2.48 larvae/earhead) were the next effective insecticides.

These results are in the line of the research workers such as chlorantraniliprole 18.5 SC was most effective against earhead worm at milking stage on sorghum [11]. Emamectin benzoate 5 SG @ 3.5g/ 10 lit. of water recorded the lowest earhead worm population (0.82 ear head worm/panicle [9]. Spinosad has been effective in reducing the number of chickpea larvae in *Helicoverpa armigera* [6]. Flubendiamide 0.007%, spinosad 0.009% and emamectin benzoate 0.0015% were found to be the most effective in reducing the population of *Helicoverpa armigera* and chickpea pod damage [4].

Table 3: Evaluation of different insecticides against earhead worm, *H. armigera* on sorghum at milking stage

Tr. No.	Treatment	Conc. (%)	Doses /10 lit of water	No. of larvae/earhead				
				1 DBS	3 DAS	7 DAS	14 DAS	Mean
T1	Profenophos 50% EC	0.15	30 ml	3.70 (2.05)	2.77 (1.81)	1.67 (1.47)	2.00 (1.58)	2.08 (1.61)
T2	Cyantraniliprole 10.26% OD	0.014	10 ml	3.57 (2.02)	2.63 (1.77)	1.67 (1.47)	1.82 (1.52)	2.09 (1.61)
T3	Emamectin benzoate 5% SG	0.002	4 g	3.37 (1.97)	2.27 (1.66)	1.20 (1.30)	1.37 (1.37)	1.61 (1.45)
T4	Spinosad 45% SC	0.018	4 ml	3.17 (1.92)	2.43 (1.71)	1.43 (1.39)	1.57 (1.44)	1.81 (1.52)
T5	Thaimethoxam 12.6% + Lambda cyhalothrin 9.5% ZC	0.011	5 ml	3.60 (2.02)	2.97 (1.86)	1.97 (1.57)	2.50 (1.73)	2.48 (1.73)
T6	Chlorantraniliprole 18.5% SC	0.005	3 ml	3.27 (1.94)	1.70 (1.48)	0.83 (1.15)	1.12 (1.27)	1.22 (1.31)
T7	Flubendiamide 39.35% SC	0.009	2.5 ml	3.67 (2.04)	1.80 (1.52)	1.07 (1.25)	1.27 (1.33)	1.38 (1.37)
T8	Untreated control	--	--	3.77 (2.07)	3.90 (2.10)	4.03 (2.13)	4.33 (2.20)	4.08 (2.14)
	S.E.±			0.09	0.07	0.11	0.11	0.14
	C. D. @ 5%			NS	0.22	0.35	0.35	0.44
	CV%			7.41	6.59	11.6	10.15	11.8

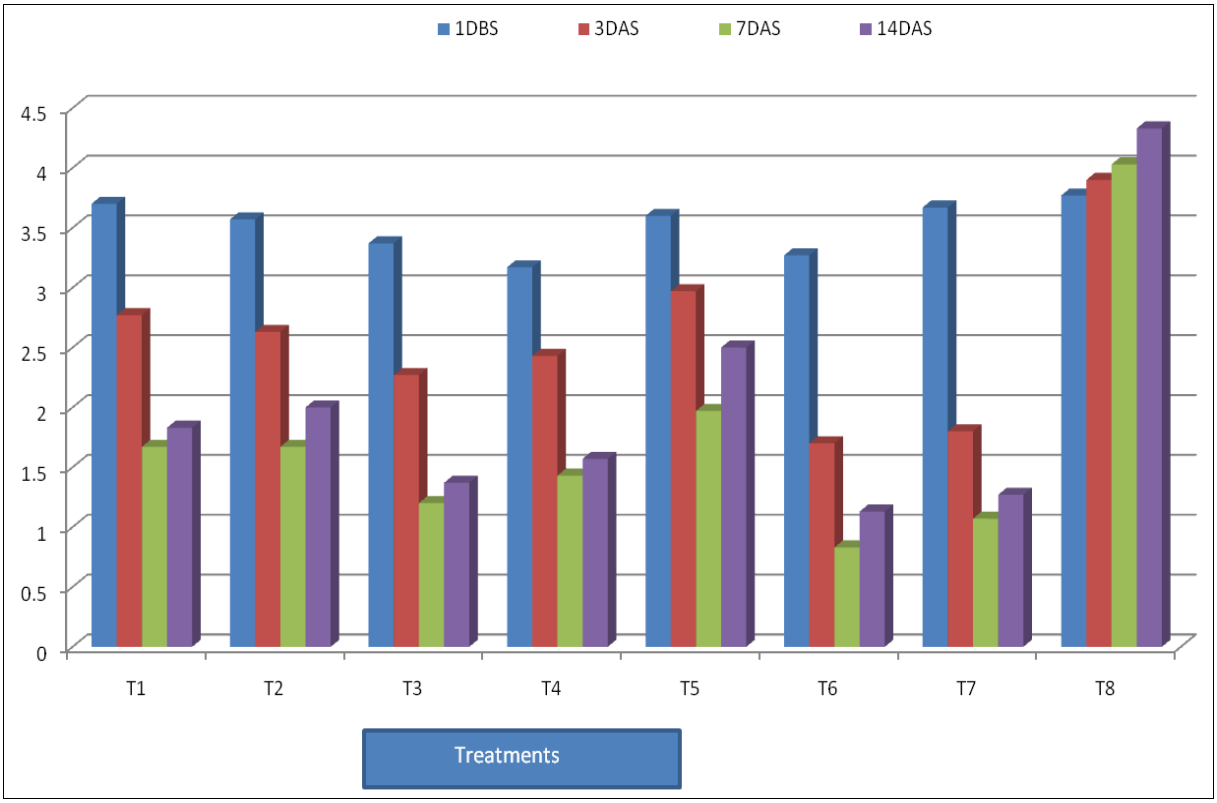

Fig 2: Evaluation of different insecticides against earhead worm, *H. armigera* on sorghum at milking stage

The data on the effect of various treatment on grain yield of sorghum suggest that the all insecticides treatments recorded significantly higher grain yield of sorghum over treatments untreated control (20.47qtha^{-1}) (Table no. 4). Among the insecticidal treatment significantly maximum grain yield (32.07 qtha^{-1}) was obtained in treatment emamectin benzoate 5 SG and lowest grain yield was observed in profenophos 50 EC (22.53 qtha-^{1}). Whereas, sorghum fodder yield showed that significantly higher sorghum fodder yield were obtained in all insecticide treatments compared to treatment untreated control (78.30 qtha^{-1}). Maximum fodder yield (115.60 qtha^{-1}) whereas lowest fodder yield was recorded in treatment untreated control (78.30 qtha^{-1}) recorded the lowest yield.

Table 4: Effect of different insecticides on grain and fodder yield of sorghum

Tr. No.	Treatment details	Conc. (%)	Doses/10 lit of water	Grain yield (q/ha)	Fodder yield (q/ha)
T_1	Profenophos 50% EC	0.15	30 ml	22.68	96.36
T_2	Cyantraniliprole 10.26% OD	0.014	10 ml	25.53	105.90
T_3	Emamectin benzoate 5% SG	0.002	4 mg	32.07	115.60
T_4	Spinosad 45% SC	0.018	4 ml	26.23	104.40
T_5	Thiamethoxam 12.6 + Lambda cyhalothrin 9.5% ZC	0.011	5 ml	28.00	107.90
T_6	Chlorantraniliprole 18.5 SC	0.005	3 ml	30.26	111.00
T_7	Flubendiamide 39.35% SC	0.009	2.5 ml	29.12	110.50
T_8	Untreated control	--	--	20.47	78.30
S.E.±				0.53	4.29
C.D. at 5%				1.15	9.17

4. Conclusion

The studies carried out on efficacy of different insecticides against fall armyworm, *S. frugiperda* and earhead worm, *H. armigera*. It concluded that the emamectin benzoate 5 SG is most effective insecticides against management of fall armyworm, while chlorantraniliprole 18.5 SC against earhead worm on sorghum. The maximum grain and fodder yield was obtained in treatment emamectin benzoate 5 SG.

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