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Sunil Kumar M
M.Sc. (Agricultural),
Department of Agricultural Entomology, CoA, VC Farm, Mandya, Karnataka, India

Dr. Basavaraju BS
Professor of Agricultural Entomology, Department of Agricultural Entomology CoA, Karekere, Hassan, Karnataka, India

Dr. Vijay Kumar L
Professor of Agricultural Entomology (OPG), Department of Agricultural Entomology, CoA, VC Farm, Mandya, Karnataka, India

Dr. Sanath Kumar VB
Professor of Plant Pathology Department of Plant Pathology CoA, VC Farm, Mandya, Karnataka, India

Dr. Thimme Gowda P
Senior Farm Superintendent, Department of Agronomy, ZARS CoA, VC Farm, Mandya, Karnataka, India

Corresponding Author:
Sunil Kumar M
M.Sc. (Agricultural),
Department of Agricultural Entomology, CoA, VC Farm, Mandya, Karnataka, India

Efficacy of new generation insecticide molecules for controlling fall armyworm, *Spodoptera frugiperda* J. E. smith, (Lepidoptera: Noctuidae) in maize

Sunil Kumar M, Basavaraju BS, Vijay Kumar L, Sanath Kumar VB and Thimme Gowda P

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Abstract
The study was conducted to know the performance of new insecticide molecules for management of invasive pest fall armyworm, *Spodoptera frugiperda* J.E. Smith in field condition at college of Agriculture, V. C. Farm, Mandya (Karnataka) during Kharif and Rabi 2019-20. Application of chlorantraniliprole 18.5 SC @ 0.3 ml l^{-1} at 15, 45 and 60 days after sowing recorded lowest larval population at 1, 3 and 7 days after spray followed by Spinosad 45 SC @ 0.15 ml l^{-1}, spinetorum 11.7 SC @ 0.30 ml l^{-1} and emamectin benzoate 5 G @ 0.15 g l^{-1}. At physiological maturity the highest plant height (2.08 m), grain (77.42 q ha^{-1}) and straw yield (13.15 t ha^{-1}) were recorded in chlorantraniliprole 18.5 SC @ 0.3 ml l^{-1} followed by Spinosad 45 SC @ 0.15 ml l^{-1}, spinetorum 11.7 SC @ 0.30 ml l^{-1} and emamectin benzoate 5 G @ 0.15 g l^{-1}. However, thiamethaxam 30 FS @ 0.6 ml kg^{-1} recorded highest larval population, lowest plant height, grain and straw yield compare to all other treatments except untreated control.

Keywords: Fall armyworm, larval population, *Spodoptera frugiperda*, kharif, Rabi, maize

Introduction
Maize is the second most important cereal grain crop globally in terms of area and is known as Queen of Cereals. This belongs to the family Poaceae. 'Global maize production has accounted approximately 1050 million mt during 2019-20, and US was the leading producer, followed by China, accounting around 37% and 22%, respectively. India accounts More than two per cent to this production map with an amount of 28.08 mt in the year 2019-20. In Indian scenario, Maize has become the third largest food crop next to rice and wheat and grown in an area of 8.69 m ha with the production of 21.8 mt and productivity was 2509 kg ha^{-1} [2]. In India, maize yields are low despite their larger importance. The incidence of insect pests is of greater importance among several factors for the lower maize yield. Maize is attacked by some 139 species of insect pests that cause various degrees of damage [9]. Insect pests are among the main factors leading to lower maize yield. Despite the use of pesticides, there are still maximum yield losses due to insect pests, particularly in developing countries [5]. Over 40 species of insect pest have been identified in maize. A number of pests have been recorded on maize, including stem borer, cob worm, aphid, leaf hopper, grasshopper, armyworms and fall armyworms. The fall armyworm (FAW) *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae), is one of the main pests in maize and known to cause severe reduction of yields. The fall armyworm is native to the tropical and sub-tropical region of Americas. In addition to maize, more than 100 other plant species were also reported to be infested. The most preferred host plants are maize, barley, sorghum and sugarcane. This pest completes multiple simultaneous generations in a year and thus capable of building up populations at high proportion in the location where it occurs. The neonate larvae of FAW mainly feed on leaf tissue while the subsequent instars feed on the leaf whorl, causing leaf holes; which a typical FAW damage symptom [3]. Developing larvae consume various parts of the host plant, depending on the crop level. Larvae are hidden in the funnel leaf whorl throughout the day, but emerge at night to feed on the leaves. Young larvae normally feed on grass, producing a

distinctive "windowing" effect and dump sawdust-like frass close to the funnel and at the upper grass. There is an urgent need to control this pest for lowers the yield loss by management strategy. Though, effect of organophosphates and other conventional insecticides are very less due to resistance mechanism developed by fall armyworm. Therefore, considering the above aspects the present study was attempted with the objective to setup a management method for mitigation of pest.

Material and methods

To study the efficacy of new insecticide molecules against fall armyworm, *Spodoptera frugiperda*, a field experiment was carried out during kharif and Rabi 2019. A maize hybrid MAH 14-5 was sown in plot size of 2 X 3 m for 10 treatments including control with three replications during Kharif and Rabi in Randomized Complete Block Design (RCBD). Crop was raised as per recommended practices and insecticides were applied at 15, 45, 60 days after sowing. Evaluation of insecticides for the management of FAW was done at CoA, V. C. Farm, Mandya. All recommended package of practices was followed for raising the crop except plant protection measures [1]. Nine new insecticide molecules were assessed for their effectiveness against *S. frugiperda* on maize.

Table 1: Treatment details for the management of *S. frugiperda* in maize

Treatment	Insecticides	Chemical group	Dose (ml or g/l)	Dose (ml or g a.i./ha)
T_1	Thiamethoxam 30 FS	Neonicotinoids	0.60	2.70
T_2	Spinetorum 11.7 SC	Spinosyns	0.30	17.55
T_3	Lambda cyahalothrin 5 EC	Pyrethroides	1.00	25.00
T_4	Chlorantriniliprole 18.5 SC	Antranilic diamides	0.13	11.56
T_5	Emamectin benzoate 5 G	Avermectins	0.15	3.75
T_6	Spinosad 45 SC	Spinosyns	0.15	33.75
T_7	*Beauveria bassiana*	Biological agents	4.00	-
T_8	Azadirachtin 50000 ppm	Terpenes	0.50	12.50
T_9	Neem oil	Terpenes	3.00	-
T_{10}	Control	-	-	-

Fall armyworm incidence was recorded on 5 randomly selected plants in each of the treatment plot. The pre-count larval observation was made on 1 day before spray, and the post-treatment observations were recorded at 1, 3 and 7 days after spraying. Observations were recorded on number larva per plant was by destructive sampling.

Since fall armyworm is fed whorl and mainly affects plant height, so, plant height was measured at 70 days after sowing. The mean data obtained on the larval population was processed by angular transformation ($\sqrt{x+0.5}$). The data from each treatment was subjected for ANOVA [6, 7] and means were separated by Tukey's HSD [12] for interpretation. The harvesting was done at physiological maturity, grain and straw yield were recorded by treatment wise and, in each treatment.

Results and Discussion

The mean of two seasons (Kharif and Rabi) observations on larval population at 1, 3 and 7 days after spray has been presented in table 2.

Table 2: Efficacy of newer insecticide on larval population of *S. frugiperda* during 2019-20 (First spray at 15 days after sowing)

Insecticides		Mean of two seasons (Kharif and Rabi) observations on number of larva/ plant											
		1 DBS			1 DAS			3 DAS			7 DAS		
		Kharif	Rabi	Mean	Kharif	Rabi	Mean	Kharif	Rabi	Mean	Kharif	Rabi	Mean
T_1	Thiamethoxam 30 FS	1.43 (1.39)	1.64 (1.46)	1.43	1.01 $(1.23)^{ab}$	1.68 $(1.47)^{ef}$	1.35	1.06 $(1.25)^{g}$	1.69 $(1.47)^{d}$	1.36	1.07 $(1.25)^{e}$	1.72 $(1.48)^{c}$	1.37
T_2	Spinetorum 11.7 SC	1.44 (1.39)	1.24 (1.11)	1.25	0.72 $(1.10)^{a}$	0.50 $(1.00)^{a}$	1.05	0.61 $(1.05)^{bc}$	0.38 $(0.94)^{ab}$	1.00	0.13 $(0.79)^{ab}$	0.31 $(0.90)^{ab}$	0.84
T_3	Lambda cyahalothrin 5 EC	1.36 (1.36)	1.36 (1.12)	1.24	0.81 $(1.14)^{ab}$	0.62 $(1.06)^{bc}$	1.10	0.74 $(1.11)^{cd}$	0.48 $(0.99)^{abc}$	1.08	0.25 $(0.87)^{bc}$	0.39 $(0.94)^{ab}$	0.90
T_4	Chlorantraniliprole 18.5 SC	1.49 (1.41)	1.41 (1.19)	1.30	0.56 $(1.03)^{a}$	0.44 $(0.97)^{a}$	0.76	0.12 $(0.79)^{a}$	0.27 $(0.88)^{a}$	0.83	0.00 $(0.71)^{a}$	0.11 $(0.78)^{a}$	0.74
T_5	Emamectin benzoate 5 G	1.44 (1.39)	1.30 (1.14)	1.27	0.79 $(1.13)^{a}$	0.52 $(1.01)^{ab}$	1.07	0.62 $(1.06)^{bc}$	0.41 $(0.95)^{ab}$	1.01	0.18 $(0.82)^{ab}$	0.32 $(0.90)^{ab}$	0.86
T_6	Spinosad 45 SC	1.33 (1.35)	1.33 (1.15)	1.25	0.65 $(1.07)^{a}$	0.49 $(0.99)^{a}$	1.03	0.43 $(0.97)^{b}$	0.35 $(0.92)^{ab}$	0.94	0.07 $(0.76)^{ab}$	0.26 $(0.87)^{ab}$	0.81
T_7	*Beauveria bassiana*	1.47 (1.40)	1.38 (1.17)	1.29	0.87 $(1.17)^{ab}$	0.76 $(1.12)^{d}$	1.15	0.86 $(1.16)^{def}$	0.59 $(1.04)^{bc}$	1.19	0.58 $(1.04)^{cd}$	0.47 $(0.98)^{ab}$	1.01
T_8	Azadirachtin 50000 ppm	1.52 (1.42)	1.40 (1.18)	1.30	0.84 $(1.16)^{ab}$	0.71 $(1.10)^{cd}$	1.13	0.76 $(1.12)^{de}$	0.53 $(1.01)^{abc}$	1.16	0.53 $(1.01)^{cd}$	0.40 $(0.95)^{ab}$	0.98
T_9	Neem oil	1.60 (1.45)	1.35 (1.16)	1.30	0.91 $(1.19)^{ab}$	0.78 $(1.13)^{de}$	1.16	0.89 $(1.17)^{ef}$	0.75 $(1.12)^{c}$	1.25	0.83 $(1.15)^{de}$	0.73 $(1.11)^{b}$	1.13
T_{10}	Untreated Control	1.49 (1.41)	1.67 (1.47)	1.44	1.52 $(1.42)^{b}$	1.73 $(1.52)^{f}$	1.39	1.87 $(1.53)^{g}$	1.92 $(1.55)^{d}$	1.54	2.18 $(1.60)^{f}$	2.01 $(1.58)^{c}$	1.59
SE m ±		NS	NS	NS	0.05	0.04	0.06	0.07	0.03	0.05	0.03	0.05	0.05
CD @ p=0.05					0.15	0.13	0.17	0.19	0.10	0.16	0.08	0.16	0.15

T_1- Seed treatment (Thiamethoxam 30 FS @ 0.6 ml/Kg); DAS- Days after spray: values followed by common letters are non-significant at p = 0.05 as per Tukey's HSD (Tukey, 1965) [12].

During first spray at 15 days after sowing larval population per plant was assessed. One day before spraying the pre count larval population was varied from 1.25 to 1.44 larva per plant. One day after spray, chlorantraniliprole 18.5 SC @ 0.13 ml l^{-1}, spinosad 45 SC @ 0.15 ml l^{-1}, spinetorum 11.7 SC @ 0.30 ml l^{-1} and emamectin benzoate 5 G @ 0.15 g l^{-1} recorded 0.76, 1.03, 1.05 and 1.07 larva per plant. At third day after spray, chlorantraniliprole 18.5 SC @ 0.13 ml l^{-1}, spinosad 45 SC @ 0.15 ml l^{-1} and spinetorum 11.7 SC @ 0.30 ml l^{-1} recorded 0.83, 0.94 and 1.00 larval population against the initial population of 1.30, 1.25 and 1.25 larva per plant. At 7 days after spray, chlorantraniliprole 18.5 SC @ 0.13 ml l^{-1}, spinosad 45 SC @ 0.15 ml l^{-1}, spinetorum 11.7 SC @ 0.30 ml l^{-1} and emamectin benzoate 5 G @ 0.15 g l^{-1} found to be very effective with the record of 0.74, 0.81, 0.84 and 0.86 larva per plant. lambda cyhalothrin 5 EC @ 1ml l^{-1} did not register good control of fall armyworm and found on par with *B. bassiana* @ 4 g l^{-1} and azdirachtin 50000 ppm @ 0.5 ml l^{-1}. The neem oil @ 3 ml l^{-1} treated plot did not prove effective in controlling the fall armyworm larval population (Table 2 and fig 1).

Second spray was taken at 45 days after sowing. A day before spraying the number of larvae was varied from 1.10 to 1.22 larva per plant. One day after spray, chlorantraniliprole 18.5 SC @ 0.13 ml l^{-1}, spinosad 45 SC @ 0.15 ml l^{-1}, spinetorum 11.7 SC @ 0.30 ml l^{-1} and emamectin benzoate 5 G @ 0.15 g l^{-1} recorded 0.97, 1.04, 1.05 and 1.07 larva per plant. At third day after spray, chlorantraniliprole 18.5 SC @ 0.13 ml l^{-1}, spinosad 45 SC @ 0.15 ml l^{-1} and spinetorum 11.7 SC @ 0.30 ml l^{-1} recorded 0.85, 0.90 and 0.92 larval population against the initial population of 1.10, 1.10 and 1.15 larva per plant. The mean larval population of both seasons at 7 days after spray has been presented in table 3. chlorantraniliprole 18.5 SC @ 0.13 ml l^{-1}, spinosad 45 SC @ 0.15 ml l^{-1}, spinetorum 11.7 SC @ 0.30 ml l^{-1} and emamectin benzoate 5 G @ 0.15 g l^{-1} found to be very effective with the record of 0.76, 0.82, 0.84 and 0.86 larva per plant. lambda cyhalothrin 5 EC @ 1ml l^{-1} did not show good control of fall armyworm and found on par with *B. bassiana* and azdirachtin 50000 ppm @ 0.5 ml l^{-1}. The neem oil @ 3 ml l^{-1} treated plot did not prove effective in controlling the fall armyworm larval population (Table 3 and fig 2).

Table 3: Efficacy of newer insecticide on larval population of *S. frugiperda* during 2019-20 (Second spray at 45 days after sowing)

Insecticides		Mean of two seasons (Kharif and Rabi) observations on number of larva/ plant											
		1 DBS			1 DAS			3 DAS			7 DAS		
		Kharif	Rabi	Mean	Kharif	Rabi	Mean	Kharif	Rabi	Mean	Kharif	Rabi	Mean
T_1	Thiamethoxam 30 FS	1.07 (1.25)	0.92 (1.19)	1.22	1.08 $(1.26)^{b}$	1.17 $(1.29)^{e}$	1.27	1.09 $(1.26)^{e}$	1.18 $(1.29)^{f}$	1.28	1.12 $(1.27)^{d}$	1.19 $(1.30)^{f}$	1.29
T_2	Spinetorum 11.7 SC	0.74 (1.11)	0.91 (1.19)	1.15	0.51 $(1.00)^{a}$	0.71 $(1.10)^{b}$	1.05	0.18 $(0.83)^{ab}$	0.53 $(1.02)^{b}$	0.92	0.14 $(0.80)^{a}$	0.29 $(0.89)^{b}$	0.84
T_3	Lambda cyahalothrin 5 EC	0.78 (1.13)	1.01 (1.22)	1.13	0.71 $(1.10)_{c}$	0.90 $(1.18)^{cd}$	1.15	0.59 $(1.04)^{c}$	0.70 $(1.09)^{cd}$	1.07	0.45 $(0.97)^{b}$	0.50 $(1.00)^{c}$	0.99
T_4	Chlorantraniliprole 18.5 SC	0.68 (1.09)	0.72 (1.11)	1.10	0.35 $(0.92)^{a}$	0.53 $(1.02)^{a}$	0.97	0.10 $(0.77)^{a}$	0.34 $(0.92)^{a}$	0.85	0.04 $(0.73)^{a}$	0.11 $(0.78)^{a}$	0.76
T_5	Emamectin benzoate 5 G	0.73 (1.11)	0.80 (1.14)	1.12	0.54 $(1.02)^{ab}$	0.77 $(1.12)^{bc}$	1.07	0.23 $(0.85)^{b}$	0.56 $(1.03)^{bc}$	0.94	0.16 $(0.81)^{a}$	0.31 $(0.88)^{b}$	0.86
T_6	Spinosad 45 SC	0.63 (1.06)	0.80 (1.14)	1.10	0.49 $(0.99)^{a}$	0.70 $(1.09)^{ab}$	1.04	0.15 $(0.80)^{ab}$	0.48 $(0.99)^{b}$	0.90	0.11 $(0.78)^{a}$	0.24 $(1.86)^{b}$	0.82
T_7	*Beauveria bassiana*	0.74 (1.11)	0.90 (1.18)	1.14	0.73 $(1.11)^{ab}$	0.89 $(1.18)^{cd}$	1.17	0.69 $(1.09)^{cd}$	0.79 $(1.13)^{de}$	1.11	0.63 $(1.06)^{bc}$	0.73 $(1.11)^{de}$	1.09
T_8	Azadirachtin 50000 ppm	0.71 (1.10)	0.94 (1.18)	1.14	0.72 $(1.10)^{ab}$	0.88 $(1.18)^{cd}$	1.15	0.61 $(1.05)^{cd}$	0.74 $(1.11)^{d}$	1.08	0.57 $(1.04)^{bc}$	0.64 $(1.07)^{d}$	1.05
T_9	Neem oil	0.75 (1.12)	0.99 (1.22)	1.14	0.74 $(1.11)^{ab}$	0.96 $(1.21)^{d}$	1.17	0.71 $(1.10)^{d}$	0.89 $(1.18)^{e}$	1.14	0.69 $(1.09)^{c}$	0.78 $(1.13)^{e}$	1.11
T_{10}	Untreated Control	1.08 (1.26)	0.95 (1.20)	1.23	1.10 $(1.26)^{b}$	1.18 $(1.30)^{e}$	1.28	1.12 $(1.27)^{f}$	1.20 $(1.30)^{g}$	1.29	1.19 $(1.30)^{d}$	1.22 $(1.31)^{g}$	1.30
SE m ± CD @ p = 0.05		NS	NS	NS	0.05 0.15	0.02 0.05	0.05 0.10	0.02 0.06	0.04 0.11	0.06 0.18	0.02 0.05	0.01 0.03	0.02 0.05

T_1- Seed treatment (Thiamethoxam 30 FS @ 0.6 ml/Kg); DAS- Days after spray: values followed by common letters are non-significant at p = 0.05 as per Tukey's HSD (Tukey, 1965) [12].

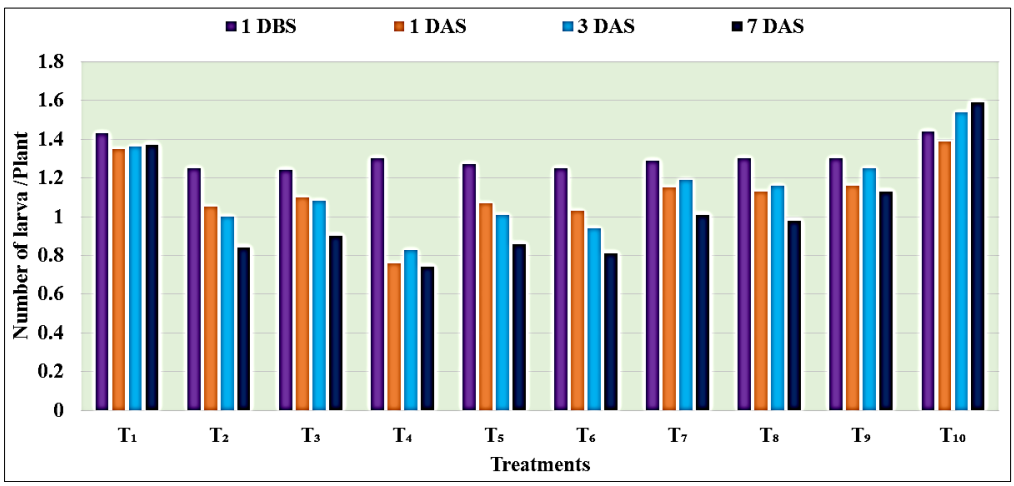
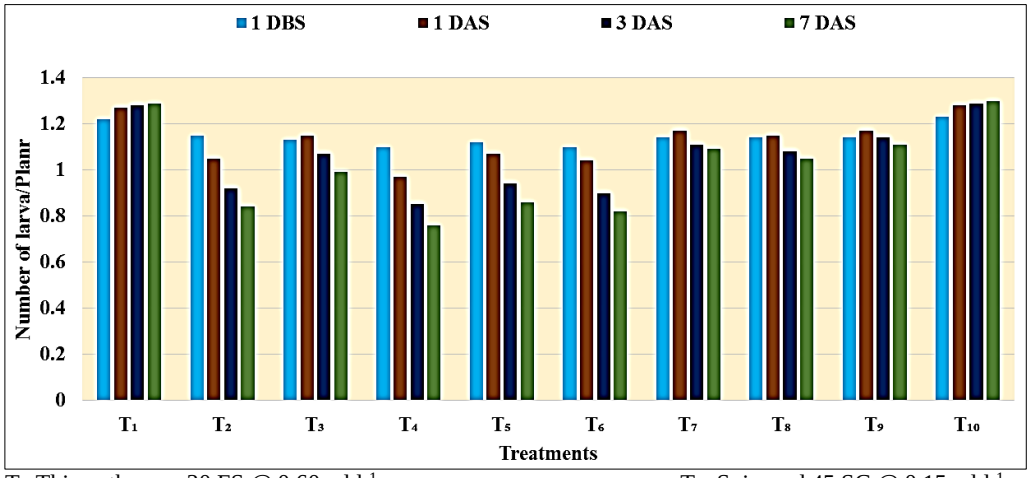


Fig 1: Effect of new insecticide molecules against *S. frugiperda* during first spray, 2019-20



T_1-Thiamethoxam 30 FS @ 0.60 ml l^{-1}
T_2-Spinetorum 11.7% SC @ 0.30 ml l^{-1}
T_3-Lambda cyhalothrin 5 EC @ 1.00 ml l^{-1}
T_4-Chlorantraniliprole 18.5 SC @ 0.13 ml l^{-1}
T_5-Emamectin benzoate 5 G @ 0.15 g l^{-1}
T_6- Spinosad 45 SC @ 0.15 ml l^{-1}
T_7- *Beauveria bassiana* @ 4 g l^{-1}
T_8-Azadirachtin 50000 ppm @ 0.5 ml l^{-1}
T_9-Neem oil @ 3 ml l^{-1}
T_{10}-Untreated Control

Fig 2: Effect of new insecticide molecules against *S. frugiperda* during second spray, 2019-20

For assessing larval population third spray was taken at 60 days after sowing. Pre spray larval count was made and results were varied from 1.12 to 1.30 larva per plant. One day after spray, chlorantraniliprole 18.5 SC @ 0.13 ml l^{-1}, spinosad 45 SC @ 0.15 ml l^{-1}, spinetorum 11.7 SC @ 0.30 ml l^{-1} and emamectin benzoate 5 G @ 0.15 g l^{-1} recorded 1.02, 1.09, 1.09 and 1.08 larva per plant. At third day after spray, chlorantraniliprole 18.5 SC @ 0.13 ml l^{-1}, spinosad 45 SC @ 0.15 ml l^{-1} and spinetorum 11.7 SC @ 0.30 ml l^{-1} recorded 0.81, 0.89 and 0.90 larval population against the initial population of 1.12, 1.15 and 1.14 larva per plant. The mean larval population of both seasons at 7 days after spray has been presented in table 4. chlorantraniliprole 18.5 SC @ 0.13 ml l^{-1}, spinosad 45 SC @ 0.15 ml l^{-1}, spinetorum 11.7 SC @ 0.30 ml l^{-1} and emamectin benzoate 5 G @ 0.15 g l^{-1} found to be very effective with the record of 0.75, 0.82, 0.83 and 0.85 larva per plant. lambda cyhalothrin 5 EC @ 1ml l^{-1} did not show good control of fall armyworm and found on par with *B. bassiana* @ 4 g l^{-1} and azdirachtin 50000 ppm @ 0.5 ml l^{-1}. The neem oil @ 3 ml l^{-1} treated plot did not prove effective in controlling the fall armyworm larval population (Table 4 and fig 3).

Table 4: Efficacy of newer insecticide on larval population of *S. frugiperda* during 2019-20 (Third spray at 60 days after sowing)

Insecticides		Mean of two seasons (Kharif and Rabi) observations on number of larva/ plant											
		1 DBS			1 DAS			3 DAS			7 DAS		
		Kharif	Rabi	Mean	Kharif	Rabi	Mean	Kharif	Rabi	Mean	Kharif	Rabi	Mean
T_1	Thiamethoxam 30 FS	1.12 $(1.27)^{c}$	1.19 $(1.30)^{bc}$	1.29	1.12 $(1.27)^{d}$	1.19 $(1.30)^{bc}$	1.29	1.13 $(1.28)^{c}$	1.20 $(1.30)^{c}$	1.29	1.13 $(1.28)^{f}$	1.20 $(1.30)^{g}$	1.29
T_2	Spinetorum 11.7 SC	0.56 $(1.03)^{a}$	1.09 $(1.26)^{a}$	1.14	0.34 $(0.92)^{bc}$	0.81 $(1.15)^{abc}$	1.09	0.15 $(0.81)^{ab}$	0.50 $(1.00)^{ab}$	0.90	0.12 $(0.79)^{b}$	0.28 $(0.88)^{bc}$	0.83
T_3	Lambda cyahalothrin 5 EC	0.60 $(1.06)^{ab}$	1.00 $(1.22)^{ab}$	1.14	0.44 $(0.97)^{bc}$	0.94 $(1.20)^{bcd}$	1.10	0.41 $(0.96)^{ab}$	0.58 $(1.04)^{b}$	1.00	0.26 $(0.87)^{cd}$	0.37 $(0.93)^{cd}$	0.90
T_4	Chlorantraniliprole 18.5 SC	0.55 $(1.02)^{a}$	1.00 $(1.22)^{a}$	1.12	0.18 $(0.82)^{a}$	0.73 $(1.11)^{a}$	1.02	0.05 $(0.74)^{a}$	0.27 $(0.88)^{a}$	0.81	0.00 $(0.71)^{a}$	0.12 $(0.78)^{a}$	0.75
T_5	Emamectin benzoate 5 G	0.58 $(1.04)^{a}$	1.03 $(1.24)^{ab}$	1.14	0.37 $(0.93)^{bc}$	0.85 $(1.16)^{abc}$	1.08	0.10 $(0.82)^{ab}$	0.51 $(1.01)^{b}$	0.91	0.16 $(0.81)^{bc}$	0.29 $(0.86)^{bc}$	0.85
T_6	Spinosad 45 SC	0.57 $(1.04)^{a}$	1.08 $(1.26)^{a}$	1.15	0.33 $(0.91)^{ab}$	0.80 $(1.14)^{ab}$	1.09	0.15 $(0.81)^{ab}$	0.43 $(0.96)^{ab}$	0.89	0.12 $(0.79)^{b}$	0.22 $(0.85)^{ab}$	0.82
T_7	*Beauveria bassiana*	0.54 $(1.02)^{ab}$	1.03 $(1.23)^{abc}$	1.13	0.49 $(0.99)^{bc}$	1.00 $(1.23)^{de}$	1.11	0.47 $(0.99)^{ab}$	0.95 $(1.20)^{c}$	1.10	0.35 $(0.92)^{de}$	0.54 $(1.02)^{ef}$	0.97
T_8	Azadirachtin 50000 ppm	0.63 $(1.06)^{ab}$	1.01 $(1.23)^{abc}$	1.15	0.47 $(0.99)^{bc}$	0.98 $(1.21)^{cde}$	1.11	0.45 $(0.97)^{ab}$	0.64 $(1.07)^{b}$	1.02	0.28 $(0.89)^{de}$	0.45 $(0.97)^{de}$	0.93
T_9	Neem oil	0.54 $(1.02)^{ab}$	1.14 $(1.28)^{abc}$	1.15	0.51 $(1.01)^{c}$	1.11 $(1.27)^{ef}$	1.14	0.50 $(1.00)^{b}$	0.99 $(1.22)^{c}$	1.11	0.46 $(0.98)^{e}$	0.59 $(1.05)^{f}$	1.01
T_{10}	Untreated Control	1.15 $(1.28)^{b}$	1.22 $(1.31)^{c}$	1.30	1.33 $(1.29)^{d}$	1.29 $(1.33)^{g}$	1.30	1.59 $(1.29)^{c}$	1.59 $(1.44)^{d}$	1.36	1.89 $(1.37)^{f}$	1.97 $(1.32)^{h}$	1.34
SE m ±		0.05	0.04	0.04	0.02	0.01	0.02	0.05	0.03	0.03	0.02	0.02	0.01
CD @ p=0.05		0.14	0.12	0.11	0.07	0.04	0.05	0.15	0.08	0.09	0.05	0.05	0.04

T_1- Seed treatment (Thiamethoxam 30 FS @ 0.6 ml/Kg); DAS- Days after spray: values followed by common letters are non-significant at p = 0.05 as per Tukey's HSD (Tukey, 1965) [12].

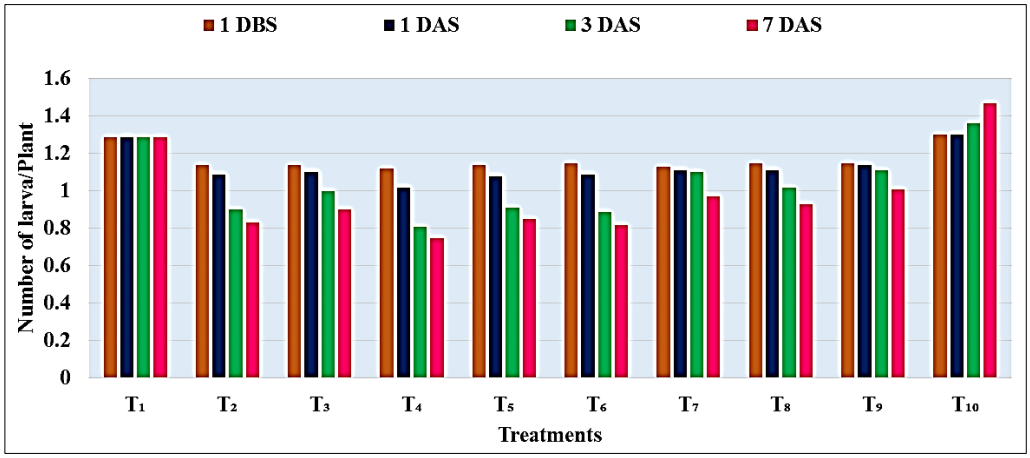


Fig 3: Effect of new insecticide molecules against *S. frugiperda* during third spray 2019-20

Based on mean of two seasonal observations on number of larvae per plant on various treatments were arranged in descending order of their relative effectiveness as chlorantraniliprole 18.5 SC @ 0.13 ml l^{-1} > spinosad 45 SC @ 0.15 ml l^{-1} > spinetorum 11.7 SC @ 0.30 ml l^{-1} emamectin benzoate 5 G @ 0.15 g l^{-1} > lambda cyhalothrin 5 EC @ 1ml l^{-1} > azdirachtin 50000 ppm @ 0.5 ml l^{-1} > *B. bassiana* @ 4 g l^{-1} > neem oil @ 3 ml l^{-1}.

The influence of various treatments on growth and yield attributing characters showed significant variation among the treatments. The mean of two season's observations on plant height showed significant difference among the treatments. Spraying of insecticides against fall armyworm on maize had significant influence on the plant height. Spraying of chlorantraniliprole 18.5 SC @ 0.13 ml l^{-1} significantly influenced the plant height up to 2.08 m whereas spinosad 45 SC @ 0.15 ml l^{-1}, spinetorum 11.7 SC @ 0.30 ml l^{-1}, emamectin benzoate 5G @ 0.15 g l^{-1} and lambda cyhalothrin 5 EC @ 1ml l^{-1} recorded 1.92, 1.83, 1.79 and 1.74 m, which are on par each other. The azadirachtin 50000 ppm @ 0.5 ml l^{-1}, *B. bassiana* @ 4 g l^{-1}, neem oil @ 3 ml l^{-1} and thiamethaxam 30 FS @ 0.6 ml l^{-1}which recorded plant height of 1.71 m, 1.66 m, 1.65 m and 1.62 m respectively. Untreated control recorded the least plant height of 1.56 m (Table 5). Among the treatments tested, significantly higher grain yield of 77.42 q ha^{-1} was recorded in chlorantraniliprole 18.5 SC @ 0.13 ml l^{-1} spinosad 45 SC @ 0.15 ml l^{-1}, spinetorum 11.7 SC @ 0.30 ml l^{-1} and emamectin benzoate 5G @ 0.15 g l^{-1}, recorded grain yield of 72.83, 70.69 and 66.75 q ha^{-1}. Similarly, lambda cyhalothrin 5 EC @ 1ml l^{-1}, azadirachtin 50000 ppm @ 0.5 ml l^{-1}, *B. bassiana* @ 4 g l^{-1}, neem oil @ 3 ml l^{-1} and thiamethoxam 30 FS 0.6 ml l^{-1} which recorded 63.14, 56.42, 51.17, 40.69 and 36.86 q ha^{-1} respectively and also were on par with each other. The lowest grain yield of 34.11 q ha^{-1} was recorded in untreated control (Table 5). Among the different treatments tested, significantly higher straw yield of 13.14 t ha^{-1} was recorded in chlorantraniliprole 18.5 SC @ 0.13 ml l^{-1} Whereas, spinosad 45 SC @ 0.15 ml l^{-1}, spinetorum 11.7 SC @ 0.30 ml l^{-1} and emamectin benzoate 5G @ 0.15 g l^{-1}, recorded straw yield of 12.04, 11.85 and 11.15 q ha^{-1}. Similarly, lambda cyhalothrin 5 EC @ 1ml l^{-1}, azadirachtin 50000 ppm @ 0.5 ml l^{-1}, *B. bassiana* @ 4 g l^{-1}, neem oil @ 3 ml l^{-1} and thiamethoxam 30 FS @ 0.6 ml kg^{-1} which recorded 9.89, 9.07, 8.13, 8.02 and 7.78 t ha^{-1} respectively and also were on par with each other. The lowest straw yield of 7.02 t ha^{-1} was recorded in untreated control (Table 5 and Fig 4).

The study of [4] showed that Spinetoram was found highly effective in reducing the larval population and leaf damage by fall armyworm, followed by chlorantraniliprole with 97.32, and 90.43 per cent reduction in larval population respectively, over untreated control. The plot treated with spinetoram recorded the highest grain yield (33.48 q ha^{-1}), and straw yield (10.89 t ha^{-1}) followed by chlorantraniliprole (31.13 q ha^{-1}) (9.76 t ha^{-1}). These studies are in accordance with the present findings.

Our present outcomes of the study were similar to studies made by [11] where he also reported that, insecticide which induces phytotoxic symptoms in respect of a particular insecticide. Chemical insecticides which also stimulate on plant growth activity which leads superior effects on both qualitative and quantitative characteristics of plant. From the above discussed finding were similar with studies of [8] [10], he concluded that the plant growth and yield attributing parameters i.e., mean plant height, and yield (q ha^{-1}) were recorded maximum in chlorantraniliprole 20 SC @ 0.3 ml l^{-1} against *C. partellus* in maize. However, the minimum mean plant height, and yield (q ha^{-1}) were recorded in untreated control.

Conclusion

From the results of present study we can conclude that larval population groeth and yield attributing parameters were recorded maximum in chlorantraniliprole 20 SC @ 0.3 ml l^{-1} followed by spinosad 45 SC @ 0.15 ml l^{-1}, spinetorum 11.7 SC @ 0.30 ml l^{-1} and emamectin benzoate 5G @ 0.15 g l^{-1} whereas, maximum larval population, maximum plant height, garain and straw yield were recorded in thiamethoxam 30 FS @ 0.6 ml kg^{-1} and untreated control, respectively.

Table 5: Impact of new insecticide molecules on grain and biomass yield of maize during 2019-20

Insecticides		Plant height (m)			Grain yield (q ha^{-1})			Straw yield (t ha^{-1})		
		Kharif	Rabi	Mean	Kharif	Rabi	Mean	Kharif	Rabi	Mean
T_1	Thiamethoxam 30 FS	1.64	1.61	1.62	38.89	34.83	36.86	7.88	7.68	7.78
T_2	Spinetorum 11.7 SC	1.85	1.81	1.83	72.72	68.66	70.69	11.98	11.72	11.85
T_3	Lambda cyahalothrin 5 EC	1.75	1.72	1.74	63.94	62.33	63.14	10.00	9.76	9.89
T_4	Chlorantraniliprole 18.5 SC	2.11	2.06	2.08	78.67	76.16	77.42	13.56	12.73	13.15
T_5	Emamectin benzoate 5 G	1.81	1.77	1.79	66.89	66.66	66.75	11.25	11.05	11.15
T_6	Spinosad 45 SC	1.94	1.90	1.92	74.17	71.50	72.83	12.13	11.93	12.04
T_7	*Beauveria bassiana*	1.68	1.65	1.66	53.33	49.00	51.17	8.28	7.98	8.13
T_8	Azadirachtin 50000 ppm	1.72	1.69	1.71	58.33	54.00	56.42	9.16	8.96	9.07
T_9	Neem oil	1.66	1.63	1.65	44.22	37.16	40.69	8.16	7.86	8.02
T_{10}	Untreated Control	1.57	1.55	1.56	35.56	32.66	34.11	7.05	6.98	7.02
SE m ±		0.05	0.05	0.04	2.18	1.76	1.36	0.37	0.30	0.25
CD @ p=0.05		0.15	0.16	0.11	6.47	5.22	4.04	1.09	0.91	0.73

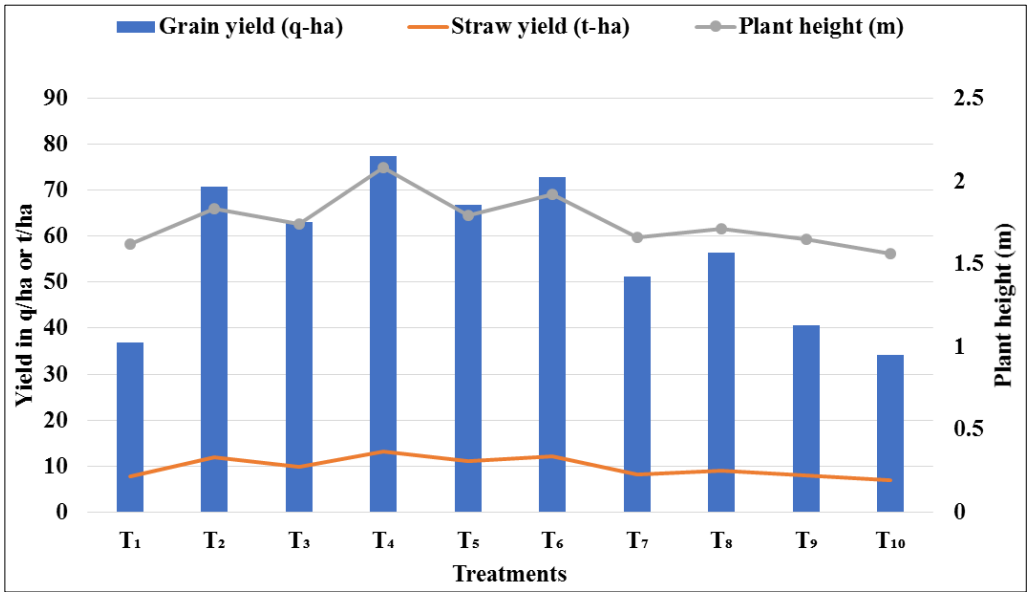


Fig 4: Effect of new insecticide molecules on plant height, grain and straw yield during 2019-20

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