International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; SP-8(4): 100-104

Received: 10-05-2020
Accepted: 12-06-2020

Thumar RK
Department of Entomology, B. A. College of Agriculture, AAU, Anand, Gujarat, India

Zala MB
Agricultural Research Station, AAU, Sansoli, Gujarat, India

Varma HS
Main Maize Research Station, AAU, Godhara, Gujarat, India

Dhobi CB
Department of Entomology, B. A. College of Agriculture, AAU, Anand, Gujarat, India

Patel BN
Agricultural Research Station, AAU, Sansoli, Gujarat, India

Patel MB
Main Maize Research Station, AAU, Godhara, Gujarat, India

Borad PK
Department of Entomology, B. A. College of Agriculture, AAU, Anand, Gujarat, India

Corresponding Author:
Thumar RK
Department of Entomology, B. A. College of Agriculture, AAU, Anand, Gujarat, India

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

Thumar RK, Zala MB, Varma HS, Dhobi CB, Patel BN, Patel MB and Borad PK

DOI: https://doi.org/10.22271/chemi.2020.v8.i4b.9873

Abstract
A field experiment was carried out during *kharif*, 2019 at different experimental farms (Anand, Sansoli and Godhra) of Anand Agricultural University, Anand, Gujarat to evaluate the efficacy of different insecticides against fall armyworm, *Spodoptera frugiperda* (J. E. Smith) infesting maize. Spinetoram 11.7 SC, 0.117 %, emamectin benzoate 5 SG, 0.0025 %, chlorantraniliprole 18.5 EC, 0.006 % and thiodicarb 75 WP, 0.11 % were found more effective in checking the larval population, plant and cob damage in maize which also reflected on grain and fodder yield as well.

Keywords: Maize, FAW, *Spodoptera frugiperda*, spinetoram, emamectin benzoate, chlorantraniliprole, thiodicarb and yield

Introduction
Maize, *Zea mays* L. is regarded as the queen of cereals owing to its high potentiality and ability to produce higher biological yields in a shorter period of time. Indian cultivation of maize cover over 9.86 million hectares of area with production of 26.26 million tonnes with productivity of 2664 kg/ha (Anonymous, 2018a) [1]. In Gujarat, it occupies 4.00 lakh hectares of area producing 6.65 lakh tonnes with a productivity of 1663 kg/ha of maize (Anonymous, 2018b) [2]. It is the staple food of Asian people and is also utilized in starch, oil, food and feed industries as well as in the traditional areas by the local population in the form of *chapati*. It is attacked by nearly 130 species of insect pests in India causing considerable yield losses (Atwal and Dhaliwal, 2002) [3]. Adding to the list of new invasive pest, fall armyworm (FAW), *Spodoptera frugiperda* (Lepidoptera: Noctuidae) is native to the tropical region of the western hemisphere from the United States to Argentina. In India, it was first reported in Hassan district of Karnataka on maize (Sharanabasappa *et al.*, 2018) [7] which later spread to Tamil Nadu, Telangana and West bengal. In Gujarat, it was also reported from Anklav village, of Anand district of Gujarat (Sisodiya *et al.*, 2018) [9]. It is a cosmopolitan pest of the maize crop (Wiseman *et al.*, 1966) [13] feeding on all growth stages of maize but most frequently in the whorl of young plants up to 45 days. FAW generally feeds on foliage, but during heavy infestations, larvae also feeds on corn ears. Damage due to this pest attack can reduce corn grain yield up to 34 per cent in Brazil (Lima *et al.*, 2009) [6], 20 to 50 per cent in Africa (Early *et al*., 2018) [5] and has also caused huge yield losses in India during last year. Thus, owing to the importance of this pest, a study was conducted on multi location basis to assess the efficacy of different insecticides against this invasive pest infesting maize.

Materials and methods
In order to study the efficacy of different insecticides on *S. frugiperda* infesting maize, a multi-location field experiment was conducted at three places *viz*., Entomology farm, Department of Entomology, BACA, Anand, Main Maize Research Station, Godhara and Agricultural Research Station, Sansoli of AAU, Anand (Gujarat) during *kharif*, 2019. The experiment was laid down in Randomized Block Design with ten treatments and three replications. Maize variety GAYMH-1 was sown, with a spacing of 60 cm between two rows and 20 cm within the row in gross and net area of 6.0 x 4.8 m and 5.6 x 3.6 m, respectively. All the standard

agronomical practices were followed. The first application of insecticide was imposed at sufficient pest pressure and second at 15 days interval. For recording FAW population and its damage, 10 plants were selected randomly from each net plot. The number of larva (e) and damaged plant (s) were counted from randomly selected plants before as well as 1, 3, 5, 10 and 15 days after each application. Number of damaged cobs were also recorded at harvest from each net plot. The grain and fodder yield were recorded from each net plot and converted into kg/ha. The data obtained thus, were subjected to statistical analysis after appropriate transformation to draw valid conclusion as per Steel and Torrie (1980) [11].

Results and Discussion

Larval population (No. of larva (e)/ 10 plants)

The data on larval population pooled (Table 1 and 3) over three locations before spray of insecticides showed non-significant differences which indicated homogeneous distribution of pest in the experimental plots at three different locations *i.e.*, Anand, Sansoli and Godhra. All the tested insecticides were found significantly superior to control till 15 days of spray application in both the sprays, pooled over periods as well as pooled over periods and sprays. The data on pooled over periods of first spray differed significantly to each other. The spray application of spinetoram 11.7 SC, 0.006 % recorded the lowest (0.50 larva /10 plants) larval population which was at par with emamectin benzoate 5 SG, 0.0025 % (0.75 larva /10 plants), chlorantraniliprole 18.5 SC, 0.006 % (0.99 larva /10 plants) and thiodicarb 75 WP, 0.11 % (1.32 larvae /10 plants). The treatments of flubendiamide 48 SC, 0.015 % (1.96 larvae /10 plants), thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC, 0.01 (2.46 larvae /10 plants), spinosad 45 SC, 0.014 % (2.63 larvae /10 plants) and chlorpyriphos 50% + cypermethrin 5% EC, 0.11 % (2.74 larvae /10 plants) were found mediocre in their effectiveness against the pest. While, the highest (3.07 larvae /10 plants) larval population was observed in the treatment of chlorpyriphos 20 EC 0.04 per cent.

The data on pooled over periods of second spray indicated that the treatment of spinetoram 11.7 SC recorded significantly the lowest (0.22 larva /10 plants) larval population and it was at par with emamectin benzoate 5 SG (0.36 larva /10 plants), chlorantraniliprole 18.5 SC (0.64 larva /10 plants) and thiodicarb 75 WP (1.11 larvae /10 plants). Of the tested insecticides, chlorpyriphos 20 EC was found the least effective which recorded the highest (3.58 larvae /10 plants) larval population.

Overall, the data on pooled over periods, sprays and locations showed significantly the lowest (0.36 larva /10 plants) larval population in the treatment of spinetoram 11.7 SC than all the tested insecticides except for emamectin benzoate 5 SG (0.54 larva /10 plants), chlorantraniliprole 18.5 SC (0.82 larva /10 plants) and thiodicarb 75 WP (1.24 larvae /10 plants).

Worku and Ebabuye (2019) [14] reported that in lab bioassay chlorpyriphos, profenophos + lambda cyhalothrin, profenophos + cypermethrin and spinosad significantly provided the maximum mortality of *S. frugiperda*. Dileep Kumar (2019) [4] studied the susceptibility of FAW populations to insecticides molecules and revealed that the spinetoram (97.09%) was the most effective in reducing the FAW larval population followed by chlorantraniliprole (93.20%).

Plant damage (%)

The data on plant damage (Table 2 and 3) pooled over three locations recorded before spray of insecticides showed non-significant difference in all the experimental plots as evident from the observations recorded before imposing insecticidal spray at three locations *i.e.*, Anand, Sansoli and Godhra. All the insecticidal treatments were found significantly superior to control till 15 days of spray application in both the sprays, pooled over periods as well as pooled over periods and sprays. The data on pooled over periods of first spray differed significantly to each other. The treatment of spinetoram 11.7 SC recorded the lowest (8.02 %) plant damage and it was at par with emamectin benzoate 5 SG (11.20 %). While, the treatment of chlorantraniliprole 18.5 SC (15.94 %) and thiodicarb 75 WP (19.12 %) stood second in plant damage. The treatment of flubendiamide 48 SC (22.00 %) found at par with thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC (24.38 %) and spinosad 45 SC (26.80 %). The highest (28.30 %) plant damage was recorded in the treatment of chlorpyriphos 50% + cypermethrin 5% followed by chlorpyriphos 20 EC (27.64 %).

The data on pooled over periods of second spray indicated that spinetoram 11.7 SC recorded the lowest (0.76%) plant damage and it was at par with emamectin benzoate 5 SG (2.36 %) followed by chloranraniliprole 18.5 SC (5.55 %). The highest (24.59 %) plant damage recorded in the treatment of chlorpyriphos 20 EC and proved the least effective.

Overall, the data on pooled over periods, sprays and locations revealed that the lowest (3.47 %) plant damage was noticed in the treatment of spinetoram 11.7 SC which was at par with emamectin benzoate 5 SG (6.01 %) followed by chlorantraniliprole (10.15 %) and thiodicarb 75 WP (15.43 %).

Cob damage (%)

The data on cob damage pooled over at all the three locations (Table 4) showed significant difference among the various insecticides tested. Spinetoram 11.7 SC recorded the lowest (3.26 %) cob damage and it was at par with emamectin benzoate 5 SG (5.29 %), chlorantraniliprole 18.5 SC (9.80 %) and thiodicarb 75 WP (12.81 %). The treatment of flubendiamide 48 SC, chlorpyriphos 50% + cypermethrin 5% and thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC were found mediocre in preventing the cob damage. The highest (25.93 %) cob damage recorded in the treatment of chlorpyriphos 20 EC and proved the least effective in controlling the FAW in maize.

Table 1: Evaluation of insecticides against larval population of fall armyworm, *S. frugiperda* infesting maize (Pooled over periods, sprays and locations)

Tr. No.	Treatments	No. of larva(e)/10 plants days after spray													Pooled over sprays
		Before spray	First						Second						
			1	3	5	10	15	Pooled	1	3	5	10	15	Pooled	
1	Chlorantraniliprole 18.5 SC, 0.006 %	2.03^{a} (3.62)	1.39^{ab} (1.43)	1.25^{ab} (1.06)	1.05^{ab} (0.60)	0.99^{abc} (0.48)	1.44^{ab} (1.57)	1.22^{ab} (0.99)	1.28^{ab} (1.14)	1.12^{abc} (0.75)	1.03^{ab} (0.56)	0.97^{abc} (0.44)	0.93^{ab} (0.36)	1.07^{ab} (0.64)	1.15^{ab} (0.82)
2	Emamectin benzoate 5 SG, 0.0025 %	2.14^{a} (4.08)	1.32^{a} (1.24)	1.09^{a} (0.69)	0.94^{ab} (0.38)	0.94^{ab} (0.38)	1.32^{a} (1.24)	1.12^{ab} (0.75)	1.13^{a} (0.78)	0.99^{ab} (0.48)	0.82^{a} (0.17)	0.82^{ab} (0.17)	0.88^{ab} (0.27)	0.93^{a} (0.36)	1.02^{a} (0.54)
3	Flubendiamide 48 SC, 0.015 %	2.03^{a} (3.62)	1.69^{abc} (2.36)	1.48^{abc} (1.69)	1.38^{bcd} (1.40)	1.39^{bcd} (1.43)	1.94^{bcd} (3.26)	1.57^{bcd} (1.96)	1.78^{bcd} (2.67)	1.55^{bcde} (1.90)	1.52^{bcd} (1.81)	1.36^{bcd} (1.35)	1.34^{bcd} (1.30)	1.51^{bcd} (1.78)	1.54^{bcd} (1.87)
4	Spinetoram 11.7 SC, 0.0117 %	2.13^{a} (4.04)	1.26^{a} (1.09)	0.99^{a} (0.48)	0.76^{a} (0.08)	0.76^{a} (0.08)	1.23^{a} (1.01)	1.00^{a} (0.50)	1.03^{a} (0.56)	0.88^{a} (0.27)	0.82^{a} (0.17)	0.76^{a} (0.08)	0.76^{a} (0.08)	0.85^{a} (0.22)	0.93^{a} (0.36)
5	Spinosad 45 SC, 0.014 %	2.15^{a} (4.12)	1.86^{cd} (2.96)	1.74^{bc} (2.53)	1.59^{cd} (2.03)	1.58^{cd} (2.00)	2.07^{cd} (3.78)	1.77^{cd} (2.63)	1.95^{cd} (3.30)	1.84^{de} (2.89)	1.73^{cd} (2.49)	1.55^{cd} (1.90)	1.51^{cd} (1.78)	1.71^{cd} (2.42)	1.74^{cd} (2.55)
6	Chlorpyriphos 20 EC, 0.04 %	2.03^{a} (3.62)	1.94^{cd} (3.26)	1.84^{c} (2.89)	1.73^{d} (2.49)	1.65^{b} (2.22)	2.30^{d} (4.79)	1.89^{d} (3.07)	2.28^{d} (4.70)	2.15^{e} (4.12)	2.03^{d} (3.62)	1.86^{d} (2.96)	1.80^{d} (2.74)	2.02^{d} (3.58)	1.96^{d} (3.34)
7	Chlorpyriphos 50% + cypermethrin 5% EC, 0.11 %	2.08^{a} (3.83)	1.83^{bcd} (2.85)	1.69^{bc} (2.36)	1.63^{cd} (2.16)	1.58^{cd} (2.00)	2.26^{d} (4.61)	1.80^{cd} (2.74)	2.13^{d} (4.04)	1.98^{e} (3.42)	1.91^{d} (3.15)	1.77^{d} (2.63)	1.76^{d} (2.60)	1.91^{d} (3.15)	1.86^{d} (2.96)
8	Thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC, 0.01 %	2.02^{a} (3.58)	1.80^{bcd} (2.74)	1.68^{bc} (2.32)	1.62^{cd} (2.12)	1.57^{cd} (1.96)	1.92^{bcd} (3.19)	1.72 ^{cd} (2.46)	1.78^{bcd} (2.67)	1.70^{cde} (2.39)	1.68^{cd} (2.35)	1.52^{cd} (1.81)	1.47^{cd} (1.66)	1.63^{bcd} (2.16)	1.68^{cd} (2.32)
9	Thiodicarb 75 WP, 0.11 %	2.21^{a} (4.38)	1.53^{abc} (1.84)	1.34^{abc} (1.30)	1.20^{abc} (0.94)	1.11^{abcd} (0.73)	1.60^{abc} (2.06)	1.35^{abc} (1.32)	1.53^{abc} (1.84)	1.30^{abcd} (1.19)	1.27^{abc} (1.11)	1.12^{abc} (0.75)	1.16^{abc} (0.85)	1.27^{abc} (1.11)	1.32^{ab} (1.24)
10	Control (Water spray)	2.10^{a} (3.91)	2.26^{d} (4.61)	2.45^{d} (5.50)	2.60^{e} (6.26)	2.80^{e} (7.34)	3.11^{e} (9.17)	2.64^{e} (6.47)	3.16^{e} (9.49)	3.23^{f} (9.93)	3.32^{e} (10.52)	3.41^{e} (11.13)	3.51^{e} (11.82)	3.33^{e} (10.59)	2.99^{e} (8.44)
S. Em.± Treatment (T)		0.08	0.14	0.16	0.16	0.19	0.18	0.15	0.18	0.19	0.19	0.18	0.16	0.18	0.16
Location (L)		0.04	0.04	0.04	0.04	0.03	0.04	0.02	0.04	0.03	0.04	0.04	0.04	0.02	0.01
T x L		0.12	0.12	0.12	0.12	0.12	0.14	0.06	0.13	0.12	0.14	0.13	0.12	0.06	0.04
C. V. %		10.31	12.38	13.15	14.53	14.29	13.08	13.61	12.04	12.89	15.06	15.14	13.86	13.87	13.79

Note: 1. Figures in parenthesis are retransformed values, those outside are $\sqrt{x+0.5}$ transformed values
2. Treatment means with the letter(s) in common are not significant by DNMRT at 5% level of significance
3. Significant parameters and its interactions: T, L, T x P, T x S, P x S, T x L, S x L, P x L, T x S x L and P x S x L, where P=Period and S=Spray

Table 2: Evaluation of insecticides against plant damage caused by fall armyworm, *S. frugiperda* infesting maize (Pooled over periods, sprays and locations)

Tr. No.	Treatments	Plant damage (%) days after spray													Pooled over spray
		Before spray	First						Second						
			1	3	5	10	15	Pooled	1	3	5	10	15	Pooled	
1	Chlorantraniliprole 18.5 SC, 0.006 %	33.06^{a} (29.76)	29.51^{ab} (24.26)	25.15^{ab} (18.06)	21.13^{bc} (12.99)	17.28^{bc} (8.82)	24.58^{abc} (17.30)	23.53^{bc} (15.94)	22.04^{abc} (14.08)	19.33^{bc} (10.96)	14.33^{bc} (6.13)	8.19^{ab} (2.03)	8.36^{a} (2.11)	13.63^{bc} (5.55)	18.58^{bc} (10.15)
2	Emamectin benzoate 5 SG, 0.0025 %	32.13^{a} (28.29)	28.77^{a} (23.16)	21.46^{a} (13.38)	16.13^{ab} (7.72)	10.23^{ab} (3.15)	21.13^{ab} (12.99)	19.55^{ab} (11.20)	19.33^{ab} (10.96)	10.24^{ab} (3.16)	8.19^{ab} (2.03)	2.16^{a} (0.14)	4.26^{a} (0.55)	8.83^{ab} (2.36)	14.19^{ab} (6.01)
3	Flubendiamide 48 SC, 0.015 %	32.87^{a} (29.46)	31.56^{ab} (27.39)	28.87^{bc} (23.31)	26.06^{cd} (19.30)	22.77^{cd} (14.98)	30.58^{cde} (25.88)	27.97^{cde} (22.00)	27.56^{bcde} (21.41)	24.58^{c} (17.30)	22.03^{cd} (14.07)	19.33^{bc} (10.96)	19.33^{b} (10.96)	22.56^{de} (14.72)	25.27^{cde} (18.22)
4	Spinetoram 11.7 SC, 0.0117 %	32.39^{a} (28.70)	28.77^{a} (23.16)	20.89^{a} (12.71)	11.14^{a} (3.73)	4.51^{a} (0.62)	17.28^{a} (8.82)	16.45^{a} (8.02)	14.33^{a} (6.13)	6.19^{a} (1.16)	2.16^{a} (0.14)	0.17^{a} (0.00)	2.21^{a} (0.15)	5.01^{a} (0.76)	10.73^{a} (3.47)
5	Spinosad 45 SC, 0.014 %	33.77^{a} (30.90)	33.10^{b} (29.82)	31.08^{c} (26.65)	31.08^{d} (26.65)	26.49^{d} (19.90)	34.17^{de} (31.55)	31.18^{e} (26.80)	30.98^{cde} (26.50)	30.35^{c} (25.53)	27.39^{d} (21.16)	24.25^{c} (16.87)	24.74^{bc} (17.51)	27.37^{de} (21.14)	29.27^{de} (23.90)
6	Chlorpyriphos 20 EC, 0.04 %	31.49^{a} (27.28)	30.99^{ab} (26.51)	30.98^{c} (26.50)	29.61^{cd} (24.41)	30.61^{d} (25.93)	36.38^{e} (35.18)	31.72^{e} (27.64)	33.27^{de} (30.09)	29.44^{c} (24.16)	28.96^{d} (23.44)	27.63^{c} (21.51)	29.34^{c} (24.01)	29.73^{e} (24.59)	30.72^{e} (26.10)
7	Chlorpyriphos 50% + cypermethrin 5% EC, 0.11 %	32.39^{a} (28.70)	32.62^{ab} (29.06)	30.61^{c} (25.93)	30.17^{cd} (25.26)	29.50^{d} (24.25)	37.78^{e} (37.53)	32.14^{e} (28.30)	34.29^{e} (31.74)	30.84^{c} (26.28)	28.76^{d} (23.15)	25.48^{c} (18.51)	28.94^{c} (23.42)	29.67^{e} (24.50)	30.90^{e} (26.37)
8	Thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC, 0.01 %	32.87^{a} (29.46)	29.98^{ab} (24.97)	29.92^{bc} (24.88)	28.70^{cd} (23.06)	26.90^{d} (20.47)	32.43^{cde} (28.76)	29.59^{de} (24.38)	29.98^{cde} (24.97)	26.63^{c} (20.29)	23.30^{cd} (15.65)	20.59^{c} (12.37)	22.03^{bc} (14.07)	24.51^{de} (17.21)	27.05^{de} (20.68)
9	Thiodicarb 75 WP, 0.11 %	31.46^{a} (27.24)	31.49^{ab} (27.28)	25.32^{ab} (18.29)	22.77^{bcd} (14.98)	22.94^{cd} (15.19)	27.18^{bcd} (20.87)	25.93^{cd} (19.12)	23.68^{abcd} (16.13)	21.13^{c} (12.99)	19.33^{cd} (10.96)	16.38^{bc} (7.95)	21.13^{bc} (12.99)	20.33^{cd} (12.07)	23.13^{cd} (15.43)
10	Control (Water spray)	30.92^{a} (26.40)	38.26^{c} (38.34)	41.72^{d} (44.29)	45.62^{e} (51.08)	49.49^{e} (57.80)	52.75^{f} (63.36)	45.57^{f} (50.99)	55.49^{f} (67.90)	57.57^{d} (71.24)	60.45^{e} (75.68)	62.83^{d} (79.15)	63.90^{d} (80.65)	60.23^{f} (75.35)	52.90^{f} (63.61)
S. Em.± Treatment (T)		1.42	1.24	1.56	1.99	2.50	2.61	1.74	3.07	3.52	3.21	3.59	2.57	2.79	2.18
Location (L)		0.86	0.69	0.81	0.77	0.80	0.84	0.35	0.83	0.87	0.88	0.82	0.69	0.37	0.26
T x L		2.72	2.19	2.57	2.43	2.54	2.67	1.11	2.63	2.74	2.78	2.58	2.18	1.18	0.82
C. V. %		14.55	12.08	15.59	16.04	18.29	14.73	15.16	15.66	18.55	20.51	21.66	16.90	19.02	17.16

Note: 1. Figures in parenthesis are retransformed values, those outside are arc sine transformed values
2. Treatment means with the letter(s) in common are not significant by DNMRT at 5% level of significance
3. Significant parameters and its interactions: T, P, L, T x P, T x S, T x L, S x L, P x L, T x S x L and P x S x L, where P=Period and S=Spray

Table 3: Evaluation of insecticides against plant damage caused by fall armyworm, *S. frugiperda* infesting maize (Pooled over locations)

Tr. No.	Treatment	No. of larva(e)/10 plants				Plant damage (%)			
		Godhra	Anand	Sansoli	Pooled	Godhra	Anand	Sansoli	Pooled
1	Chlorantraniliprole 18.5 SC, 0.006 %	1.08^{b} (0.67)*	1.32^{a} (1.24)	1.03^{b} (0.56)	1.15^{ab} (0.82)	17.84^{b} (9.39)**	22.08^{b} (14.13)	15.83^{c} (7.44)	18.58^{bc} (10.15)
2	Emamectin benzoate 5 SG, 0.0025 %	0.96^{b} (0.42)	1.25^{a} (1.06)	0.86^{a} (0.24)	1.02^{a} (0.54)	13.73^{a} (5.63)	19.63^{b} (11.29)	9.29^{b} (2.61)	14.19^{ab} (6.01)
3	Flubendiamide 48 SC, 0.015 %	1.38^{cd} (1.40)	1.85^{b} (2.92)	1.39^{c} (1.43)	1.54^{bcd} (1.87)	23.82^{b} (16.31)	31.12^{d} (26.71)	20.87^{e} (12.69)	25.27^{cde} (18.22)
4	Spinetoram 11.7 SC, 0.0117 %	0.84^{a} (0.21)	1.30^{a} (1.19)	0.81^{a} (0.16)	0.93^{a} (0.36)	10.17^{a} (3.12)	15.88^{a} (7.49)	6.26^{a} (1.19)	10.73^{a} (3.47)
5	Spinosad 45 SC, 0.014 %	1.25^{c} (1.06)	2.48^{d} (5.65)	1.49^{c} (1.72)	1.74^{cd} (2.55)	24.80^{b} (17.59)	39.06^{e} (39.71)	23.97^{f} (16.50)	29.27^{de} (23.90)
6	Chlorpyriphos 20 EC, 0.04 %	1.56^{e} (1.93)	2.57^{de} (6.10)	1.74^{d} (2.53)	1.96^{d} (3.34)	26.75^{c} (20.26)	39.80^{e} (40.97)	25.62^{f} (18.70)	30.72^{e} (26.10)
7	Chlorpyriphos 50% + cypermethrin 5% EC, 0.11%	1.70^{f} (2.39)	1.98^{c} (3.42)	1.88^{e} (3.03)	1.86^{d} (2.96)	29.37^{d} (24.05)	32.18^{d} (28.36)	31.16^{g} (26.77)	30.90^{e} (26.37)
8	Thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC, 0.01 %	1.31^{c} (1.22)	2.62^{e} (6.36)	1.10^{b} (0.71)	1.68^{cd} (2.32)	22.93^{c} (15.18)	40.55^{e} (42.26)	17.68^{cd} (9.22)	27.05^{de} (20.68)
9	Thiodicarb 75 WP, 0.11 %	1.48^{de} (1.69)	1.33^{a} (1.27)	1.14^{b} (0.80)	1.32^{ab} (1.24)	24.71^{c} (17.47)	25.52^{c} (18.56)	19.17^{de} (10.78)	23.13^{cd} (15.43)
10	Control (Water spray)	2.76^{g} (7.12)	3.25^{f} (10.06)	2.94^{f} (8.14)	2.99^{e} (8.44)	55.39^{c} (67.74)	53.21^{f} (64.13)	50.11^{h} (58.87)	52.90^{f} (63.61)
S. Em.± Treatment (T)		0.04	0.04	0.04	0.16	0.75	0.89	0.91	2.18
Location (L)		-	-	-	0.01	-	-	-	0.26
T x L		-	-	-	0.04	-	-	-	0.82
C. V. %		16.16	11.44	14.63	13.79	16.61	13.71	22.61	17.16

Note: 1. *Figures in parenthesis are retransformed values; those outside are $\sqrt{x+0.5}$ transformed values
2. **Figures in parenthesis are retransformed values; those outside are arc sine transformed values
2. Treatment mean(s) with the letter(s) in common are not significant by DNMRT at 5% level of significance
3. Significant parameters and its interactions: T, L, T x P, T x S, P x S, T x L, S x L, P x L, T x S x L and P x S x L, where P=Period and S=Spray (for No. of larva(e)/plants
4. Significant parameters and its interactions: T, L, T x P, T x S, P x S, T x L, S x L, P x L, T x S x L and P x S x L (for plant damage (%))

Table 4: Evaluation of insecticides on cob damage caused by fall armyworm, *S. frugiperda* in maize (Pooled over locations)

Tr. No.	Treatment	Cob damage (%)			
		Anand	Sansoli	Godhra	Pooled
1	Chlorantraniliprole 18.5 SC, 0.006 %	12.46^{bc} (4.66)	18.43^{ab} (9.99)	23.84^{ab} (16.34)	18.24^{abc} (9.80)
2	Emamectin benzoate 5 SG, 0.0025 %	6.48^{ab} (1.27)	12.28^{a} (4.52)	21.13^{ab} (12.99)	13.30^{ab} (5.29)
3	Flubendiamide 48 SC, 0.015 %	26.55^{de} (19.98)	21.14^{ab} (13.01)	23.84^{ab} (16.34)	23.85^{bc} (16.35)
4	Spinetoram 11.7 SC, 0.0117 %	0.51^{a} (0.01)	12.28^{a} (4.52)	18.42^{a} (9.98)	10.41^{a} (3.26)
5	Spinosad 45 SC, 0.014 %	33.20^{ef} (29.98)	13.84^{b} (5.72)	23.84^{ab} (16.34)	26.96^{c} (20.55)
6	Chlorpyriphos 20 EC, 0.04 %	39.22^{f} (39.98)	26.55^{b} (19.96)	26.06^{ab} (19.30)	30.61^{c} (25.93)
7	Chlorpyriphos 50% + cypermethrin 5% EC, 0.11 %	28.77^{d} (23.16)	28.77^{b} (23.16)	28.76^{b} (23.15)	28.77^{c} (23.16)
8	Thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC, 0.01 %	41.14^{f} (43.28)	21.14^{ab} (13.01)	28.76^{b} (23.15)	30.35^{c} (25.53)
9	Thiodicarb 75 WP, 0.11 %	18.43^{cd} (9.99)	18.43^{ab} (9.99)	26.06^{ab} (19.30)	20.97^{abc} (12.81)
10	Control (Water spray)	66.12^{g} (83.61)	41.14^{c} (43.28)	41.13^{c} (43.27)	49.47^{d} (57.77)
S. Em.± Treatment (T)		2.57	3.23	2.49	4.41
Location (L)		-	-	-	0.88
T x L		-	-	-	2.78
C. V. %		16.34	25.00	16.45	19.07

Note: 1. Figures in parenthesis are retransformed values; those outside are arc sine transformed values
2. Treatment mean(s) with the letter(s) in common are not significant by DNMRT at 5% level of significance

Yield (kg/ha)

Grain yield (kg/ha)

Of the tested insecticides, the highest (2914 kg/ha) grain yield (Table 5) was recorded in the treatment of spinetoram 11.7 SC which was at par emamectin benzoate 5 SG (2792 kg/ha), chlorantraniliprole 18.5 SC (2732 kg/ha) and thiodicarb 75 WP (2677 kg/ha) at all the three locations. Chlorpyriphos 50% + cypermethrin 5% recorded the lowest (2108 kg/ha) grain yield followed by chlorpyriphos 20 EC (2126 kg/ha).

Fodder yield (kg/ha)

The highest (3713 kg/ha) fodder yield (Table 5) was recorded in treatment of spinetoram followed by emamectin benzoate 5 SG (3599 kg/ha), chlorantraniliprole 18.5 SC (3493 kg/ha), thiodicarb 75 WP (3452 kg/ha) and flubendiamide 48 SC (3180 kg/ha) at all the three locations. Chlorpyriphos 50% + cypermethrin 5% recorded the lowest (2754 kg/ha) fodder yield followed by chlorpyriphos 20 EC (2795 kg/ha).

Chlorantraniliprole 200 SC, spinetoram 120 SC, spinosad 480 SC and chlorantraniliprole + lambda cyhalothrin 150 SC were found effective and significantly increased larval mortality, reduced leaf damage and increased biomass in maize compared to untreated control (Sisay *et al.*, 2019) [8]. According to Song *et al.* (2020) [10] chlorfenpyr-chlorantraniliprole-lufenuron proved to be most effective bringing about significant reduction (94.86 %) in the population of *S. frugiperda* in sugarcane and it was followed by abamectin–chlorantraniliprole (80%). FAW was also

effectively controlled by application of chlorantraniliprole 0.4 % granules as well as 20 % SC spray as reported by Wang *et al.* (2019) [12].

Conclusion

It can be deduced from the present investigation, that application of spinetoram 11.7 SC, 0.117, emamectin benzoate 5 SG, 0.0025 %, chlorantraniliprole 18.5 EC, 0.006 % and thiodicarb 75 WP, 0.11 % were found more effective in managing the population and damage in maize which also reflected on yield of grain and fodder as well.

Table 5: Effect of insecticides on grain and fodder yield of maize (Pooled over locations)

Tr. No.	Treatment	Grain yield (kg/ha)				Fodder yield (kg/ha)			
		Godhara	Anand	Sansoli	Pooled	Godhara	Anand	Sansoli	Pooled
1	Chlorantraniliprole 18.5 SC, 0.006 %	2536^{b}	2628^{a}	3032^{ab}	2732^{abc}	2800^{bc}	3423^{ab}	4256^{ab}	3493^{abc}
2	Emamectin benzoate 5 SG, 0.0025 %	2620^{ab}	2671^{a}	3086^{a}	2792^{ab}	2946^{ab}	3533^{ab}	4317^{a}	3599^{ab}
3	Flubendiamide 48 SC, 0.015 %	2556^{b}	2024^{bc}	2646^{bcd}	2409^{bcd}	2853^{ab}	2980^{bc}	3705^{bcd}	3180^{abc}
4	Spinetoram 11.7 SC, 0.0117 %	2836^{a}	2795^{a}	3110^{a}	2914^{a}	3050^{a}	3746^{a}	4342^{a}	3713^{a}
5	Spinosad 45 SC, 0.014 %	2610^{ab}	1832^{c}	2584^{cd}	2342^{cd}	2876^{ab}	2524^{cd}	3613^{cd}	3004^{bc}
6	Chlorpyriphos 20 EC, 0.04 %	2286^{c}	1787^{c}	2306de	2126^{d}	2626^{cd}	2521^{cd}	3238de	2795^{c}
7	Chlorpyriphos 50% + cypermethrin 5% EC, 0.11 %	2270^{c}	1922^{bc}	2131^{e}	2108^{d}	2553^{d}	2720^{cd}	2987^{e}	2754^{c}
8	Thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC, 0.01 %	2520^{b}	1654^{c}	2897^{abc}	2357^{cd}	2870^{ab}	2323^{d}	4056^{abc}	3083^{bc}
9	Thiodicarb 75 WP, @ 0.11 %	2603^{ab}	2510^{ab}	2917^{abc}	2677^{abc}	2906^{ab}	3368^{ab}	4080^{abc}	3452^{ab}
10	Control (Water spray)	1793^{d}	1513^{c}	1560^{f}	1622^{e}	2100^{d}	1751^{e}	2182^{f}	2011^{d}
S. Em.± Treatment (T)		71.04	177.40	123.62	126.57	68.48	191.24	171.74	177.97
Location (L)		-	-	-	41.55	-	-	-	48.56
T x L		-	-	-	131.40	-	-	-	153.57
C. V. %		5.00	14.40	8.15	9.45	6.15	11.47	8.09	8.56

Note: Treatment mean(s) with the letter(s) in common are not significant by DNMRT at 5% level of significance

References

1. Anonymous. Annual report 2017-18. Department of agriculture, cooperation & farmers welfare, Ministry of agriculture & farmers welfare, Government of India, New Delhi, 2018a. Retrieved from http://www.agricoop.nic.in
2. Anonymous. Crop wise fourth advance estimate of area, production and yield of food grains, oilseeds and other crops for 2017-18 of Gujarat state, Directorate of Agriculture, Agriculture Co-operation Department, Government of Gujarat, 2018b. Retrieved from https://dag.gujarat.gov.in/index.htm
3. Atwal AS, Dhaliwal GS. Agricultural Pests of South Asia and Their Management. Kalyani Publishers, Ludhiana, 2002, pp. 189-192.
4. Dileep Kumar NT. Susceptibility of fall armyworm *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae) populations to insecticide molecules and its management, A Masters thesis submitted University of Agricultural sciences, GKVK, Bangalore, 2019.
5. Early R, Gonzales-moreno P, Murphy ST, Day R. Forecasting the global of invasion of the cereal pest *Spodoptera frugiperda*, the fall armyworm. *Neobiota*. 2018; 40:25-50.
6. Lima MS, Oliveira OF, Silva PSL, Silva KMB. Corn yield response to weed & fall armyworm controls. *Planta Daninha*. 2009; 28(1):103-111.
7. Sharanabasappa D, Kalleshwaraswamy CM, Asokan R, Mahadevaswamy HM, Marutid MS, Pavithra HB *et al*. First report of the fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae), an alien invasive pest on maize in India. Pest Management in Horticultural Ecosystems. 2018; 24(1):23-29.
8. Sisay B, Tefera T, Wakgari M, Ayalew G, Mendesil E. The efficacy of selected synthetic insecticides and botanicles against fall armyworm, *Spodoptera frugiperda*, in maize. Insects. 2019; 10(2):45-58.
9. Sisodiya DB, Raghunandan BL, Bhatt NA, Verma HS, Shewale CP, Timbadiya BG *et al*. The fall armyworm, *Spodoptera frugiperda* (JE. Smith) (Lepidoptera: Noctuidae); first report of new invasive pest in maize fields of Gujarat, India. Journal of Entomology & Zoology Studies. 2018; 6(5):2089-2091.
10. Song XP, Yong JL, Jian MW. Intrusion of fall armyworm (*Spodoptera frugiperda*) in sugarcane and its control by drone in China. Sugar Tech, 2020, DOI: 10.1007/s12355-020-00799-x
11. Steel RGD, Torrie JH. Principles and procedures of statistics. Publ. McGraw Hill Book Company, New York, 1980, pp. 137.
12. Wang YQ, Ma QL, Tan YT, Zheng Q, Yan WJ, Yang S *et al*. The toxicity and field efficacy of Chlorantraniliprole against *Spodoptera frugiperda.* Journal of Environmental Entomology. 2019; 41(4):782-788.
13. Wiseman BR, Painter RH, Wasson CE. Detecting corn seedling differences in the greenhouse by visual classification of damage by the fall armyworm. Journal of Economic Entomology. 1966; 59:1211-1214.
14. Worku M, Ebabuye Y. Evaluation of efficacy of insecticides against the fall army worm *Spodoptera frugiperda.* Indian Journal of Entomology. 2019; 81(1):13-15.