



Bio-efficacy of insecticides against fall armyworm

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ABSTRACT

A field experiment was conducted in a randomized block design to find out the effective management of fall armyworm, *Spodoptera frugiperda* (J S Smith) in maize (*Zea mays* L.) through different insecticides and bio-pesticides during *kharif* 2019 and 2020 at Agronomy farm, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan. The three sprays of chlorantraniliprole 18.5 SC were found most effective treatment against *S. frugiperda* and gave the better results with maximum reduction of larval population, lowest plant damage (%), lowest leaf damage (%), lowest cob damage (%) and highest grain yield. It is followed by emamectin benzoate 5 SG and found at par at 5th day after each spray. The next effective treatments were spinosad 45 SC, thiodicarb 75 WP, *Beauveria bassiana*, *Metarhizium anisopliae* and azadirachtin 10000 ppm. The maximum Incremental Benefit Cost Ratio was obtained from the three sprays of emamectin benzoate 5 SG.

Keywords: Bio-efficacy, Bio-pesticides, Maize, Newer insecticides, *Spodoptera frugiperda*

Maize (*Zea mays* L.) is an important cereal crop next to rice and wheat grown over a wide range of geographical and environmental conditions in India as compared to other cereal crops (Anonymous 2013). It is a staple food of North India especially in the hilly and tribal belts of Rajasthan and Bihar. Among various biotic factors, insect pests take a heavy toll on the crop thus bringing down crop yields. As many as 141 insect pests cause varying degrees of damage to the crop right from sowing till the harvest (Reddy and Trivedi 2008). Recent introduction of invasive fall armyworm, *Spodoptera frugiperda* (J.E. Smith) is of serious concern for maize cultivation due to its notorious and polyphagous behaviour. The pest was first reported in West Africa in late 2016 (Goergen *et al.* 2016) by early 2017, the pest invaded sub-Saharan Africa. In India, it was reported for the first time on maize from Shivamogga district in Karnataka during May-June 2018 (Sharanabasappa *et al.* 2018). However, the presence of the pest has been reported from most growing regions of the country (Rakshit *et al.* 2019). To avoid the consequences of the persistence of insecticides, it becomes necessary to evaluate newer and more effective molecules that are safe for the ecosystem. Since the introduction of the pest, many pesticides have been evaluated for the management of *S. frugiperda* on maize (Kumar 2019, Mallapur *et al.* 2019, Sisay *et al.* 2019, Suthar *et al.* 2020

and Thumar *et al.* 2020). Considering the economic value of maize crops, the present investigation was conducted with newer and effective molecules against *S. frugiperda* on maize during *kharif* 2019 and 2020.

MATERIALS AND METHODS

The field experiment was conducted during *kharif* 2019 and 2020 at Agronomy farm, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan. In uniform sized plots of 4.8 m × 4.0 m in RBD with eight treatments and three replications. Maize variety Pratap Makka-3 was grown in the prepared field on 5 July 2019 and 2 July 2020 with row to row and plant to plant spacing of 60 cm × 25 cm, respectively. The treatments, viz. spinosad 45 SC, emamectin benzoate 5 SG, thiodicarb 75 WP, chlorantraniliprole 18.5 SC along with the biopesticides namely, azadirachtin 10000 ppm, *Metarhizium anisopliae*, *Beauveria bassiana* and untreated control was taken against *S. frugiperda*. The first spray was applied at appearance of *S. frugiperda* and the two subsequent sprays were given at 15 days interval. The observations on different parameters, viz. per cent plant infestation and the number of larvae per plant were recorded on 1 day before, 5 and 10 days after each spray. The total number of plants infested per plot was recorded in each treatment. The per cent plant infestation was worked out as:

$$\text{Per cent plant infestation} = \frac{\text{Number of infested plants/plot}}{\text{Total number of plants/plot}} \times 100$$

The total number of larvae on 10 randomly selected plants was recorded in each treatment and the mean was

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Table 1 Bio-efficacy of insecticides against larval population of *S. frugiperda* infesting maize during *kharif* 2019 and 2020

Treatment	Number of larvae per plant during <i>kharif</i> , 2019						Number of larvae per plant during <i>kharif</i> , 2020							
	PTP	First spray		Second spray		Third spray		PTP	First spray		Second spray		Third spray	
		5 DAS	10 DAS	5 DAS	10 DAS	5 DAS	10 DAS		5 DAS	10 DAS	5 DAS	10 DAS	5 DAS	10 DAS
Spinosad 45 SC	2.03 (1.59)*	0.40 (0.95)	0.73 (1.11)	0.37 (0.93)	0.57 (1.03)	0.30 (0.89)	0.33 (0.91)	2.80 (1.82)*	1.00 (1.22)	1.13 (1.28)	0.73 (1.11)	0.87 (1.17)	0.40 (0.95)	0.43 (0.97)
Emamectin benzoate 5 SG	1.97 (1.57)	0.23 (0.86)	0.70 (1.09)	0.20 (0.84)	0.53 (1.02)	0.17 (0.82)	0.30 (0.89)	2.93 (1.85)	0.73 (1.11)	1.00 (1.22)	0.57 (1.03)	0.80 (1.14)	0.23 (0.86)	0.40 (0.95)
Thiodicarb 75 WP	2.07 (1.60)	0.47 (0.98)	0.77 (1.12)	0.43 (0.97)	0.60 (1.05)	0.33 (0.91)	0.37 (0.93)	2.87 (1.83)	1.07 (1.25)	1.17 (1.29)	0.77 (1.13)	0.93 (1.20)	0.43 (0.96)	0.47 (0.98)
Chlorantraniliprole 18.5 SC	1.93 (1.56)	0.17 (0.82)	0.40 (0.94)	0.13 (0.80)	0.37 (0.93)	0.10 (0.77)	0.17 (0.82)	3.00 (1.87)	0.67 (1.08)	0.80 (1.14)	0.47 (0.98)	0.53 (1.02)	0.17 (0.82)	0.23 (0.86)
Azadirachtin 10000 PPM	2.03 (1.59)	1.00 (1.22)	1.07 (1.25)	0.83 (1.15)	1.00 (1.22)	0.53 (1.02)	0.83 (1.15)	2.93 (1.85)	1.47 (1.40)	1.67 (1.47)	1.27 (1.33)	1.37 (1.37)	0.70 (1.09)	0.97 (1.21)
<i>Metarhizium anisopliae</i>	2.00 (1.58)	1.10 (1.26)	1.00 (1.22)	0.70 (1.09)	0.93 (1.20)	0.50 (1.00)	0.53 (1.02)	2.97 (1.86)	1.60 (1.45)	1.57 (1.44)	1.20 (1.30)	1.30 (1.34)	0.63 (1.06)	0.73 (1.11)
<i>Beauveria bassiana</i>	1.97 (1.57)	1.03 (1.24)	0.97 (1.21)	0.60 (1.05)	0.87 (1.17)	0.47 (0.98)	0.50 (1.00)	3.00 (1.87)	1.53 (1.42)	1.47 (1.40)	1.17 (1.29)	1.23 (1.32)	0.60 (1.05)	0.67 (1.08)
Control	1.93 (1.56)	1.97 (1.57)	2.03 (1.59)	2.10 (1.61)	2.00 (1.58)	1.90 (1.55)	1.77 (1.51)	2.93 (1.85)	2.77 (1.81)	2.80 (1.82)	2.43 (1.71)	2.07 (1.60)	1.93 (1.56)	1.80 (1.52)
SEm±	0.032	0.023	0.027	0.017	0.026	0.018	0.020	0.024	0.029	0.024	0.023	0.020	0.023	0.025
CD (P=0.05)	NS	0.070	0.080	0.050	0.080	0.050	0.060	NS	0.090	0.070	0.070	0.060	0.070	0.080

PTP, Pre-treatment population; DAS, Days after spray; * Figures in parentheses are square root (x + 0.5) transformed value.

Table 2 Effect of insecticides on plant damage caused by *S. frugiperda* infesting maize during *kharif* 2019 and 2020

Treatment	Plant damage (%) during <i>kharif</i> , 2019									Plant damage (%) during <i>kharif</i> , 2020										
	PTI	First spray			Second spray			Third spray			PTI	First spray			Second spray			Third spray		
		5 DAS	10 DAS	5 DAS	10 DAS	5 DAS	10 DAS	5 DAS	10 DAS	5 DAS		10 DAS	5 DAS	10 DAS	5 DAS	10 DAS	5 DAS	10 DAS		
Spinosad 45 SC	5.88 (14.03)*	9.36 (17.80)	9.62 (18.06)	11.78 (20.05)	12.04 (20.29)	12.84 (20.99)	13.91 (21.89)	6.16 (14.37)*	6.16 (14.37)*	9.67 (18.11)	9.68 (18.13)	12.62 (20.79)	12.90 (21.05)	15.31 (23.03)	15.85 (23.44)					
Emamectin benzoate 5 SG	5.87 (14.00)	6.68 (14.98)	8.82 (17.26)	9.37 (17.81)	10.17 (18.59)	10.43 (18.84)	11.49 (19.81)	6.44 (14.68)	6.44 (14.68)	7.26 (15.62)	9.41 (17.86)	9.67 (18.11)	12.38 (20.58)	12.65 (20.80)	14.25 (22.17)					
Thiodicarb 75 WP	6.16 (14.36)	9.64 (18.07)	9.90 (18.33)	12.05 (20.30)	12.33 (20.51)	13.14 (21.18)	14.19 (22.11)	6.43 (14.67)	6.43 (14.67)	10.21 (18.64)	10.49 (18.89)	12.64 (20.81)	13.17 (21.28)	15.86 (23.45)	16.13 (23.67)					
Chlorantraniliprole 18.5 SC	5.89 (14.03)	6.43 (14.66)	6.69 (14.98)	7.48 (15.87)	7.75 (16.16)	8.29 (16.73)	8.82 (17.26)	6.70 (15.00)	6.70 (15.00)	6.99 (15.32)	7.26 (15.63)	7.79 (16.21)	8.86 (17.29)	10.21 (18.62)	10.74 (19.12)					
Azadirachtin 10000 PPM	6.14 (14.33)	12.83 (20.99)	13.11 (21.22)	15.52 (23.19)	16.06 (23.62)	17.39 (24.64)	18.99 (25.83)	6.71 (15.00)	6.71 (15.00)	12.91 (21.05)	13.99 (21.95)	15.59 (23.26)	16.95 (24.29)	19.90 (26.49)	20.17 (26.67)					
<i>Metarhizium anisopliae</i>	5.88 (14.03)	12.57 (20.74)	12.84 (20.99)	15.00 (22.75)	15.51 (23.19)	16.32 (23.82)	17.67 (24.84)	6.44 (14.70)	6.44 (14.70)	13.43 (21.50)	13.70 (21.71)	15.57 (23.22)	16.40 (23.88)	19.35 (26.09)	19.61 (26.28)					
<i>Beauveria bassiana</i>	6.13 (14.30)	12.32 (20.51)	12.58 (20.75)	14.72 (22.55)	14.97 (22.76)	16.05 (23.61)	17.39 (24.64)	6.18 (14.36)	6.18 (14.36)	13.17 (21.27)	13.44 (21.50)	15.31 (23.02)	16.13 (23.67)	19.09 (25.90)	19.35 (26.10)					
Control	6.16 (14.36)	18.17 (25.17)	24.66 (29.70)	30.56 (33.50)	37.50 (37.73)	45.53 (42.43)	51.14 (45.66)	6.43 (14.67)	6.43 (14.67)	20.17 (26.61)	26.52 (30.95)	31.19 (33.93)	38.97 (38.62)	48.37 (44.06)	53.78 (47.17)					
SEm±	0.499	0.672	0.714	0.705	0.666	0.699	0.724	0.475	0.475	0.743	0.660	0.661	0.694	0.725	0.679					
CD (P=0.05)	NS	2.04	2.16	2.14	2.02	2.12	2.20	NS	NS	2.25	2.00	2.00	2.10	2.20	2.06					

PTI, Pre-treatment infestation; DAS, Days after spray; * Figures in parentheses are retransformed per cent values.

expressed as larvae per plant. The number of damaged cobs by *S. frugiperda* was recorded at harvest from each plot and the cob damage was computed as:

$$\text{Per cent cob damage} = \frac{\text{Number of infested cob/plot}}{\text{Total number of cob/plot}} \times 100$$

The per cent cob damage was recorded at harvest. The grain yield in each plot was recorded separately and computed mean grain yield per ha of each treatment.

The economics of different treatments were calculated by taking into consideration the cost of different treatments and the prevailing market price of maize as.

$$\text{IBCR} = \frac{\text{Additional return (₹/ha)}}{\text{Cost of insecticide (₹/ha)}} \times 100$$

Under the statistical analysis, the per plant damage and per cob damage figures were transformed into arc sine values and subjected to analysis of variance. The larval population of *S. frugiperda* was transformed into square root values ($x + 0.5$) and subjected to analysis of variance.

RESULTS AND DISCUSSION

The results showed that (Table 1, 2) the spray of chlorantraniliprole 18.5 SC was found most effective against *S. frugiperda* with maximum reduction of the larval population of 0.17, 0.40; 0.13, 0.37; 0.10 and 0.17 larvae/plant; lowest plant damage of 6.43, 6.69; 7.48, 7.75; 8.29 and 8.82% at 5th and 10th days after first, second and third spray during 1st year, respectively whereas during 2nd year minimum larval population of 0.67, 0.80; 0.47, 0.53; 0.17 and 0.23 larvae/plant; lowest plant damage of 6.99, 7.26; 7.79, 8.86; 10.21 and 10.74% at 5th and 10th days after first, second and third spray, respectively. The minimum cob damage at harvest and maximum grain yield were 5.80 and 6.47%; 4078.00 and 3915.67 kg/ha during 2019 and 2020, respectively. The next effective treatment was emamectin benzoate 5 SG which was found at par with

chlorantraniliprole 18.5 SC at 5 days after each spray in both the year. The spray of spinosad 45 SC and thiodicarb 75 WP were found at par in each spray during both the year. The least effective treatments were *Beauveria bassiana*, *Metarhizium anisopliae* and azadirachtin 10000 ppm during both the year. The per cent cob damage in case of emamectin benzoate 5 SG, spinosad 45 SC, thiodicarb 75 WP, *Beauveria bassiana*, *Metarhizium anisopliae* and azadirachtin 10000 ppm were 6.03, 8.40; 7.87, 8.77; 7.93, 8.87; 10.10, 11.80; 10.20, 12.20 and 10.53, 13.15% during *kharif* 2019 and 2020, respectively. While cob damage in control was 38.56 and 46.82% during *kharif* 2019 and 2020, respectively.

Similarly, Kumar (2019) reported that spinetoram 11.7 SC, novaluron 10 EC, chlorantraniliprole 18.5 SC and spinosad 45 SC were found most effective against *S. frugiperda*. Mallapur *et al.* (2019) also observed that spinetoram, emamectin benzoate and spinosad 45 SC were significantly superior against *S. frugiperda*. Sisay *et al.* (2019) reported that 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. Wang *et al.* (2019) observed that chlorantraniliprole 0.4% granules were most effective against early instars and chlorantraniliprole 20% suspension against later instars larvae of *S. frugiperda*. Deshmukh *et al.* (2020) reported that the most effective insecticides were chlorantraniliprole 18.5 SC against *S. frugiperda*, followed by emamectin benzoate 5 SG, spinetoram 11.7 SC, flubendiamide 480 SC, indoxacarb 14.5 SC, lambda cyhalothrin 5 EC, and novaluron 10 EC. Suthar *et al.* (2020) observed that whorl application of chlorantraniliprole 0.4% GR and fipronil 0.6% GR @ 20 kg/ha, were found effective as it recorded lower larval population, plant damage and cob damage and incurred higher straw and grain yield. Thumar *et al.* (2020) reported that 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

Table 3 Economics of insecticides on maize during *kharif* 2019 and 2020

Treatment	Mean seed yield (kg/ha)		Additional yield over control (kg/ha)		Avoidable yield loss (%)		Additional returns (₹/ha)		Cost of insecticide (₹/ha)	Net returns (₹/ha)		IBCR	
	2019	2020	2019	2020	2019	2020	2019	2020		2019	2020	2019	2020
T ₁	4009.33	3806.67	1171.33	1088.67	29.22	28.60	20615.47	20140.33	10230	10385.47	9910.33	2.02	1.97
T ₂	4029.33	3842.67	1191.33	1124.67	29.57	29.27	20967.47	20806.33	3090	17877.47	17716.33	6.79	6.73
T ₃	3976.00	3785.00	1138.00	1067.00	28.62	28.19	20028.80	19739.50	8700	11328.80	11039.50	2.30	2.27
T ₄	4078.00	3915.67	1240.00	1197.67	30.41	30.59	21824.00	22156.83	6300	15524.00	15856.83	3.46	3.52
T ₅	3428.67	3256.67	590.67	538.67	17.23	16.54	10395.73	9965.33	9900	495.73	65.33	1.05	1.01
T ₆	3431.33	3270.00	593.33	552.00	17.29	16.88	10442.67	10212.00	2250	8192.67	7962.00	4.64	4.54
T ₇	3454.00	3283.33	616.00	565.33	17.83	17.22	10841.60	10458.67	2250	8591.60	8208.67	4.82	4.65
T ₈	2838.00	2718.00											

Spinosad = ₹ 3410/150 ml; Emamectin benzoate = ₹ 1030/200 g; Thiodicarb = ₹ 2900/kg; Chlorantraniliprole = ₹ 2100/150 ml; Azadirachtin = ₹ 3300/1500 ml; *Metarhizium anisopliae* = ₹ 750/2.5 kg; *Beauveria bassiana* = ₹ 750/2.5 kg; MSP of Maize during 2019 = ₹ 1760/q; MSP of maize during 2020 = ₹ 1850/q.

found more effective against *S. frugiperda* in checking the larval population, plant and cob damage in maize.

The economics of treatment (Table 3) revealed that the higher additional seed yield (1240.00 and 1197.67 kg/ha), avoidable yield loss (30.41 and 30.59%), additional return (₹ 21824/ha and ₹ 22156.83/ha) and maximum net return (₹ 15524 and ₹ 15856.83) over control (2838.0 and 2718.0 kg/ha) was obtained from three spray application of chlorantraniliprole 18.5 SC @ 150 ml/ha followed by emamectin benzoate 5 SG @ 200 g/ha, spinosad 45 SC @ 165 ml/ha and thiodicarb 75 WP @ 1000 g/ha during 2019 and 2020, respectively. Though, the maximum incremental benefit cost ratio was obtained from the three sprays of emamectin benzoate 5 SG @ 200 g/ha (6.79 and 6.73) in 2019 and 2020, respectively. Similar to present investigation Deshmukh *et al.* (2020) also reported higher grain yield (6233 kg/ha) in the case of chlorantraniliprole followed by emamectin benzoate (6180 kg/ha).

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REFERENCES

- Anonymous. 2013. Assessment of maize situation, outlook and investment opportunities in India. *Country report – regional assessment Asia*, NAARM, pp. 6.
- Deshmukh S, Pavithra H B, Kalleshwaraswamy C M, Shivanna B K, Maruthi M S and David Mota-Sanchez. 2020. Field efficacy of insecticides for management of invasive fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) on maize in India. *Florida Entomologist* **103**(2): 221–27.
- Goergen G, Lava Kumar P, Sankung B S, Togola A and Tamo M. 2016. First report of outbreaks of the fall armyworm *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera, Noctuidae), a new alien invasive pest in West and Central. *PLoS One* **11**(10): e0165632.
- Kumar D N T. 2019. 'Susceptibility of fall armyworm *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae) populations to insecticide molecules and its management' MSc Thesis, University of Agricultural sciences, Bangalore.
- Mallapur C P, Anjan K N, Sireesh Hagari, Praveen T and Manjunath Naik. 2019. Laboratory and field evaluation of new insecticide molecules against fall armyworm, *Spodoptera frugiperda* (J. E. Smith) on maize. *Journal of Entomology and Zoology Studies* **7**(5): 729–33.
- Rakshit S, Chandish R Ballal, Prasad Y G, Sekhar J C, Lakshmi S P, Suby S B, Jat S L, Siva Kumar G and Prasad J V. 2019. Fight against Fall armyworm, *Spodoptera frugiperda* (J.E. Smith). ICAR-Indian Institute of Maize Research, Ludhiana, Punjab, pp. 52.
- Reddy Y V R and Trivedi S. 2008. *Maize Production Technology*. Academic press, 0-192.
- Sharanabasappa, Kalleshwaraswamy C M, Asokan R, Mahadeva Swamy H M, Maruthi M S, Pavithra H B, Kavita H, Shivaray N, Prabhu S T and Georg G. 2018. 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* **24**(1): 23–29.
- Sisay B, Tadele T, Mulatu W, Gashawbeza A and Esayas Mendesil. 2019. The efficacy of selected synthetic insecticides and botanicals against fall armyworm, *Spodoptera frugiperda* in Maize. *Insects* **10**: 45.
- Suthar M, Zala M B, Varma H S, Minaxi Lunagariya, Patel M B, Patel B N and Borad P K. 2020. Bioefficacy of granular insecticides against fall armyworm, *Spodoptera frugiperda* (JE Smith) in maize. *International Journal of Chemical Studies* **8**(4): 174–79.
- Thumar R K, Zala M B, Varma H S, Dhobi C B, Patel B N, Patel M B and Borad P K. 2020. Evaluation of insecticides against fall armyworm, *Spodoptera frugiperda* (J. E. Smith) infesting maize. *International Journal of Chemical Studies* **8**(4): 100–04.
- Wang Y Q, Ma Q L, Tan Y T, Zheng Q, Yan W J, Yang S, Xu H and Zhang Z. 2019. The toxicity and field efficacy of Chlorantraniliprole against *Spodoptera frugiperda*. *Journal of Environmental Entomology* **41**(4): 782–88.