Content list available at http://epubs.icar.org.in, www.kiran.nic.in; ISSN: 0970-6429

Indian Journal of Hill Farming

December 2023, Volume 36, Issue 2, Pages 226-233

Eco-friendly management of Fall armyworm, *Spodoptera frugiperda* (J.E. Smith) on maize ecosystem in Meghalaya

Ansh Raj[1]* • Mahesh Pathak[2] • Bimal Kumar Sahoo[3] • Jyotim Gogoi[4] • Abhipsa Subhadarsini[5] • Ankit Alok[6] • Nawazish Ahmad[7] • Pramod Kumar Pandey[8] • Kennedy Ningthoujam[9] • T. Rajesh[10] • N.S.A Thakur[11]

[1,5]M.Sc. Scholar, [4]Ph.D. Scholar (Entomology), [6]Ph.D. Scholar (Plant Pathology) [2]Professor (Entomology), [9]Assistant Professor (Entomology), [10]Associate Professor (Plant Pathology), [11]Professor (Entomology), School of Crop Protection, College of Post Graduate Studies in Agricultural Sciences, CAU (Imphal), Umiam, Meghalaya -793 103.

[3]Ph.D. Scholar, Department of Agricultural Entomology, Centre for Plant Protection Studies, TNAU, Coimbatore.

[7]M.Sc. Scholar, Department of Entomology, Bihar Agricultural College, BAU Sabour, (Bhagalpur).

[8]Assistant Maize Breeder, (AICRP on Maize) CoA, CAU (I), Kyrdemkulai, Meghalaya

ARTICLE INFO

Article history:
Received: 14 September, 2023
Revision: 19 September, 2023
Accepted: 20 December, 2023

Key words: *Maize, Fall armyworm, Bacillus thuringiensis var. kurustaki, Emamectin benzoate, Metarhizium anisopliae, Beauveria bassiana, Lecinicilium lecenii*

DOI: 10.56678/iahf-2023.36.02.30

ABSTRACT

Maize (*Zea mays* L.) is the most versatile crop among cereals which belongs to the family Poaceae. Fall armyworm (FAW) is an important and destructive pest causing heavy damage to maize crops throughout the India and world. The extensive and indiscriminate use of conventional insecticides for pest management has led to several problem like resurgence of pests, reducing of beneficial organism, pesticides residues in corn. Hence, the present experiments were taken on "Eco-friendly management of Fall armyworm, *Spodoptera frugiperda* (J.E. Smith) on Maize ecosystem in Meghalaya*"* was conducted at CPGS-AS experimental Farm at CoA, Kyrdemkulai, CAU (I), Meghalaya during *Kharif* 2023. The experiment was carried out in randomized block design with seven treatments *viz*. *Bacillus thuringiensis* var. *kurustaki* @ 10ml/lit*, Beauveria bassiana* @ 5ml/lit, *Metarhizium anisopliae* @ 5ml/lit*, Lecinicilium lecenii* @ 5ml/lit*,* Neem oil 0.03%, Emamectin benzoate 5 SG @ 0.4g/lit and control replicated thrice. The evaluation of different biopesticides and chemical insecticide show that Emamectin benzoate 5% SG was found most effective against the *S. frugiperda* with highest yield (6.62 t/ha). Among the evaluated biopesticides, *Bacillus thuringiensis* var. *kurustaki* was found to be superior in reducing percent infestation of Fall armyworm and had significantly higher yield (5.20 t/ha) followed by Neem oil 0.03% (4.88 t/ha) and *Metarhizium robertsii* (4.71 t/ha) which can be safely used for management of fall armyworm in Maize ecosystem.

1. Introduction

Maize (*Zea mays* L.) is the most versatile crop among cereals which belongs to the family Poaceae. Maize, known as 'Queen of cereals', is the third most important cereal crop of the world and is cultivated in more than 170 countries spanning over the tropical and subtropical regions. Fall armyworm (FAW) *Spodoptera frugiperda* (J.E. Smith) is native to the America and it is a key pest of Maize (*Zea mays* L.). *S. frugiperda* has been reported for the first time in 2018 in Africa, in Nigeria, Sao Tome in Benin and Togo causing significant damages to Maize and it has great potential for further spread and economic damage. In maize, FAW mainly attacks on all the stages of the plant from seedling to tasseling and earing by causing defoliation and killing young plant, results in grain damage and subsequently reduce quantity and quality of yield. The occurrence of this new invasive pest FAW in Maize was reported for the first time in India from Shivamogga district in the state of Karnataka during May, 2018 (Sharanabasappa *et al.,* 2018) and subsequently spread to most parts of the Maize growing region of the subcontinent

*Corresponding author: anshraj949@gmail.com

(Ganiger *et al*., 2018). In Northeast India, this devastating pest appeared in large numbers during March-May 2019 in Mizoram, Tripura, Nagaland, Meghalaya, Manipur, Sikkim and Arunachal Pradesh (Firake *et al*., 2019). Neonate larvae mainly feed on leaf tissues whereas the second and third instars feed on the leaf making holes in leaves, typical damage symptoms of FAW. The FAW is a highly voracious polyphagous pest (Murúa *et al.,* 2009). FAW feeds on all growth stages of Maize but most frequently in the whorl of young plant up to 45 days old. Mostly, young larvae usually feed on leaves, creating a characteristic windowing effect. Larvae usually consume a large amount of foliage and sometimes destroy the growing point of the plant. The crop of maize serves as food for every larval instar. Larvae in their first instar phase skeletonize the leaf lamina by feeding on the tissues of leaves from one side. After creating holes in the leaves, the second and third instars feed on the edges of the leaves. Larvae in their fourth to sixth instars tunnel into the growing point, severing the whorl like to damage caused by rats. Yield reductions in Maize due to feeding of the *S. frugiperda* have been reported as high as 34%. (Deole and Paul, 2018). In India, 33-36% yield losses have been attributed to this pest as per the preliminary reports (Balla *et al*., 2019). This pest could result in maize yield reduction up to 70 % (Ayala *et al*., 2013; Hruska, 2019). Chemical pesticides have led to harm many beneficial insects and decline in their population as well as environment. Increasing use of biopesticides and reducing chemical pesticides application is safe to ecosystem. Bio-pesticide approaches are eco-friendly and safely used for management of fall armyworm in Maize ecosystem

2. Materials and Methods

The present study was carried out under Department of Entomology, School of Crop Protection, College of Post Graduate Studies in Agricultural Sciences, CAU (Imphal), Umiam, Meghalaya during *Kharif* season 2023 in a uniform sized plots of 3.0 m × 2.0 m in Randomized Block Design (RBD) with seven treatments and three replications. Maize variety "RCM 1-76" was grown in the prepared field with spacing of 60 cm × 20 cm. The experiment was conducted with the treatment of one entomopathogenic bacteria, three entomopathogenic fungi, one Botanical, one chemical insecticide and untreated control. were taken against *S. frugiperda*, Details of treatment are given in Table 1.

Application of the biopesticide and chemical insecticide

The biopesticide and chemical insecticide were sprayed three time using Knapsack sprayer at 15, 30 and 45 days after sowing, to compare the efficacy of biopesticides with chemical insecticides Emamectin benzoate (5% SG).

Observations

Pre-treatment observations were taken from 10 randomly selected plants per plot at one day before application of biopesticides and post-treatment observations were recorded at 1, 3, 7, 10 and 14 days after spraying. Pest infestation was calculated by given formula;

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

(Gowrish *et al*., 2015)

Yield

Mature Maize cobs were harvested from each plot separately and yield data were recorded.

Statistical Analysis

The statistical analysis of the field experiments involved the utilization of a Two-way Analysis of Variance (ANOVA) with a Randomized Complete Block Design

Table 1. Treatment details for the management of Fall armyworm on Maize

Treatment	Common name	Trade name	Dose
T1	*Bacillus thuringiensis* var. *kurustaki*	Green Larvicide	10 ml/l
T2	*Beauveria bassiana*	UmBir	5ml/l
T3	*Metarhizium robertsii*	UmMet	5 ml/l
T4	*Lecanicilium lecanii*	UmLec	5 ml/l
T5	Neem oil (0.03%)	Nimbecidine	3 ml/l
T6	Emamectin benzoate (5% SG)	Heraclaim	0.4 g/l
T7	Control	-	-

(RCBD). Tukey's HSD Test were applied to compare different treatments for their efficacy against fall armyworm. Significant or non-significant result of the variance due to treatment effect were determined by calculating the respective F values. Whenever, variance ratio (F) is significant CD is reported at 5% level. Tukey's HSD was applied to compare different treatments for their efficacy against Fall armyworm.

3. Results

Efficacy of different biopesticides on Percent infestation of Fall armyworm during *Kharif* season 2023

The efficacy of different biopesticides in controlling Fall armyworm infestation in Maize crop. The evaluation was based on the average percentage infestation observed on one day before of spraying and 1, 3, 7, 10 and 14 days after the spraying.

The data collected one day before the spraying revealed that the fall armyworm percent infestation was non significantly different and ranged from 70.00% to 73.33% infestation in all the treatments (Table 2). After first spray, the treatments Emamectin Benzoate 5% SG @ 0.4g/l was the most effective, with only 36.80%% followed by *Bacillus thuringiensis* var. *kurstaki* (46.40%), Neem oil 0.03% (44.67%) and *M. robertsii* (51.60%) which was at par with *B. bassiana* (48.00%). Similarly, after second spray Emamectin Benzoate 5% SG treatment registered lowest the infestation (22.27%), followed by *B. thuringiensis* var. *kurustaki* (35.87%), Neem oil 0.03% (40.80%) which was at par with *M. robertsii* (42.67%) and *B. bassiana* (44.67%) (Table 3). After the third spray, percent infestation due to FAW was recorded the least (10%) in plot treated with Emamectin Benzoate 5% SG (Table 4). *Bacillus thuringiensis* var. *kurstaki* (24.13% infestation) emerged as the next effective treatment followed by Neem oil 0.03% (29.07%) and *M. robertsii* (33.60%).

Yield of Maize

The maximum yield of the grains was found in T6 (6.62 t/ha) treated with Emamectin benzoate, followed by T1 (5.20 t/ha) treated with *B. thuringiensis* var. *kurustaki*, Neem oil 0.03% (4.88 t/ha) which was at par with *M. robertsii* (4.71 t/ha) However, the lowest grain yield was observed in the Control, where only 2.96 t/ha was obtained. (Table 5).

4. Discussion

The present results are similar with Wayal *et al*. (2021) who reported that *B. thuringiensis* 85% was most effective among the biopesticides for reduction of FAW infestation followed by *M. robertsii, B. bassiana*, *N. rileyi*, and Azadirachtin@1500ppm. Grijalba *et al.* (2018) reported 57% reduction in damage of plants which showed the potential of *M. rileyi* formulated as control for *S. frugiperda* in Maize. Dhobi *et al*. (2020) showed that minimum damage percent recorded on *M. rileyiI* (15.345) followed by *B. thuringiensis* (17.70%). Moreover, Ramanujam *et al*. (2020) revealed 70% and 60% reduction in FAW infestation by using *M. anisopliae* strain (ICAR - NBAIR Ma-35) and *B. bassiana* strain (ICAR - NBAIR Bb-45), respectively during 2019. Wale *et al*. (2022) reported that Chlorantaniliprole 18.5 SC @ 0.4 ml/l was found most effective with 5.00-24.17% infestation followed by Emamectin benzoate 5% SG @ 0.4 g/l water with 8.33-23.33% infestation as compared to 94.17-98.33% infestation in untreated control.

Yield of Maize

These results are similar to the work of Deshmukh *et al*. (2020) who reported highest acute toxicity of Emamectin benzoate against *S. frugiperda* and gave higher grain yields as compared to control followed by Chlorantraniliprole and Spinetoram. Similarly, Babendreier *et al*. (2020) concluded FAW larvae were controlled by the insecticide Emamectin benzoate and increases yield with reduction of crop damage. Likewize, Thumar *et al*. (2020) who reported Emamectin benzoate caused reduction of larval population, plant and cob damage in Maize crop and it was found more effective against *S. frugiperda*. Varshney *et al.* (2020) also found that yield of biocontrol based IPM field (32.3 q/acre) was higher than farmer's practice (22.7 q/acre) during *Kharif* season.

5. Conclusion

Based on the present findings, it can be concluded that the *Bacillus thuringiensis* var. *kurustaki* was most effective for controlling the FAW followed by Neem oil 0.03% and *M. robertsii*. with highest yield and BCR. Among the biopesticides, *Bacillus thuringiensis* var. *kurustaki* was superior for management of FAW, which can be safely used for management of fall armyworm in Maize ecosystem.

6. Acknowledgements

We gratefully acknowledge the guidelines, supports and facilities provided by Dean of CPGS-AS and CoA, CAU (I), Umiam, Meghalaya

Table 2. Effect of different bio-pesticides on Percent infestation of Fall armyworm during *Kharif* season 2023

	Treatments	Percentage infestation of Fall armyworm						
		First spray						
		1DBS	1 DAS	3 DAS	7 DAS	10 DAS	14 DAS	Mean
T_1	***Bacillus thuringiensis* var. *kurustaki***	72.00±1.15^{a} (58.05)	70.67±0.67^{ab} (57.21)	40.00±1.15^{d} (39.23)	35.33±0.67^{d} (36.47)	41.33±0.67^{e} (40.01)	44.67±0.67^{e} (41.94)	46.40
T_2	***Beauveria bassiana***	70.67±0.67^{a} (57.21)	70.00±0.00^{b} (56.79)	48.00±1.15^{c} (43.85)	44.67±0.67^{c} (41.94)	48.00±0.00^{c} (43.85)	51.33±0.67^{c} (45.76)	52.40
T_3	***Metarhizium robertsii***	72.67±0.67^{a} (58.480	72.00±0.00^{ab} (58.05)	46.67±0.67^{c} (43.09)	42.67±0.67^{c} (40.78)	46.67±0.67^{cd} (43.09)	50.00±1.15^{cd} (45.00)	51.60
T_4	***Lecanicilium lecanii***	73.33±0.67^{a} (58.91)	73.33±0.67^{a} (58.91)	55.33±1.76^{b} (48.06)	51.33±1.76^{b} (45.76)	59.33±0.67^{b} (50.38)	63.33±0.67^{b} (52.73)	60.53
T_5	**Neem oil (0.03%)**	71.33±0.67^{a} (57.63)	70.67±0.67^{ab} (57.21)	44.67±0.67^{cd} (41.94)	41.33±0.67^{c} (40.01)	44.00±0.00^{de} (41.55)	47.33±0.67^{de} (43.47)	49.60
T_6	**Emamectin benzoate 5% SG**	70.67±0.67^{a} (57.21)	58.67±0.67^{c} (49.99)	32.67±1.76^{e} (34.86)	26.67±1.76^{e} (31.09)	31.33±1.33^{f} (34.04)	34.67±0.67^{f} (36.07)	36.80
T_7	**Control**	71.33±0.67^{a} (57.63)	71.33±0.67^{ab} (57.63)	72.00±0.00^{a} (58.05)	72.67±0.67^{a} (58.48)	72.67±0.67^{a} (58.48)	73.33±0.67^{a} (58.91)	72.40
	F stat	**Nsig**	**Sig**	**Sig**	**Sig**	**Sig**	**Sig**	
	CD @ 5 %	1.44	1.12	1.75	1.99	1.13	1.36	
	SE(m) ±	0.47	0.36	0.57	0.64	0.37	0.44	

Data represented by alphabet are calculated by Tukey's HDS

Data followed by same alphabets are statistically at par

DBS- Days before spray DAS- Days after spray

Data in parenthesis are Arcsine transformed values

Table 3. Effect of different bio-pesticides on Percent infestation of Fall armyworm during *Kharif* season 2023

	Treatments	Second spray					
		Percentage infestation of Fall armyworm					
		1 DAS	3 DAS	7 DAS	10 DAS	14 DAS	Mean
T_1	***Bacillus thuringiensis* var. *kurustaki***	43.33±0.67^{d} (41.17)	36.00±0.00^{e} (36.87)	31.33±0.67^{e} (34.04)	33.33±0.67^{e} (35.26)	35.33±0.67^{e} (36.47)	35.87
T_2	***Beauveria bassiana***	50.67±0.67^{c} (45.38)	44.67±0.67^{c} (41.94)	42.00±1.15^{c} (40.40)	45.33±1.76^{c} (42.32)	47.33±0.67^{c} (43.47)	46.00
T_3	***Metarhizium robertsii***	49.33±0.67^{c} (44.62)	42.67±0.67^{cd} (40.78)	38.67±0.67^{cd} (38.45)	41.33±0.67^{cd} (40.01)	43.33±0.67^{d} (41.17)	43.07
T_4	***Lecanicilium lecanii***	62.67±0.67^{b} (52.34)	52.67±0.67^{b} (46.53)	49.33±0.67^{b} (44.62)	53.33±0.67^{b} (46.91)	55.33±0.67^{b} (48.06)	54.67
T_5	**Neem oil (0.03%)**	46.00±0.00^{d} (42.71)	40.67±0.67^{d} (39.62)	36.67±0.67^{d} (37.27)	39.33±0.67^{d} (38.84)	41.33±0.67^{d} (40.01)	40.80
T_6	**Emamectin benzoate 5% SG**	28.67±0.67^{e} (32.37)	21.33±0.67^{f} (27.51)	18.00±1.15^{f} (25.10)	20.67±0.67^{f} (27.04)	22.67±0.67^{f} (28.43)	22.27
T_7	**Control**	73.33±0.67^{a} (58.91)	75.33±0.67^{a} (60.22)	76.67±0.67^{a} (61.12)	74.00±0.00^{a} (59.34)	73.33±0.67^{a} (58.91)	74.53
	F stat	Sig	Sig	Sig	Sig	Sig	
	CD @ 5 %	1.12	1.15	1.57	1.48	1.14	
	SE(m) ±	0.36	0.37	0.51	0.48	0.37	

Data represented by alphabet are calculated by Tukey's HDS

Data followed by same alphabets are statistically at par

DBS- Days before spray DAS- Days after spray

Data in parenthesis are Arcsine transformed values

Table 4. Effect of different bio-pesticides on Percent infestation of Fall armyworm during *Kharif* season 2023

	Treatments	Percentage infestation of Fall armyworm					
		Third spray					
		1 DAS	3 DAS	7 DAS	10 DAS	14 DAS	Mean
T_1	***Bacillus thuringiensis* var. *kurustaki***	32.00±1.15^{e} (34.45)	26.67±0.67^{e} (31.09)	22.67±0.67^{e} (28.43)	19.33±0.67^{d} (26.08)	20.00±1.15^{e} (26.57)	24.13
T_2	***Beauveria bassiana***	46.00±1.15^{c} (42.71)	42.00±1.15^{c} (40.40)	36.67±0.67^{c} (37.27)	32.67±0.67^{e} (34.86)	33.33±0.67^{c} (35.26)	38.13
T_3	***Metarhizium robertsii***	41.33±0.67^{d} (40.01)	37.33±0.67^{cd} (37.66)	32.67±1.33^{cd} (34.86)	28.00±1.15^{e} (31.95)	28.67±0.67^{d} (32.37)	33.60
T_4	***Lecanicilium lecanii***	54.00±1.15^{b} (47.29)	50.00±1.15^{b} (45.00)	46.67±0.67^{b} (43.09)	43.33±0.67^{b} (41.17)	44.00±0.00^{b} (41.55)	47.60
T_5	**Neem oil (0.03%)**	38.67±0.67^{d} (38.45)	34.00±1.15^{d} (35.67)	28.00±1.15^{d} (31.95)	22.00±1.15^{d} (27.97)	22.67±0.67^{e} (28.43)	29.07
T_6	**Emamectin benzoate 5% SG**	18.67±0.67^{f} (25.60)	13.33±0.67^{f} (21.42)	8.67±0.67^{f} (17.12)	4.67±0.67^{e} (12.48)	5.33±0.67^{f} (13.35)	10.13
T_7	**Control**	72.00±0.00^{a} (58.05)	70.67±0.67^{a} (57.21)	69.33±0.67^{a} (56.37)	68.67±0.67^{a} (55.96)	68.00±0.00^{a} (55.55)	69.73
	F stat	Sig	Sig	Sig	Sig	Sig	
	CD @ 5 %	1.66	1.82	1.87	1.82	1.54	
	SE(m) ±	0.54	0.59	0.61	0.59	0.50	

Data represented by alphabet are calculated by Tukey's HDS

Data followed by same alphabets are statistically at par

DBS- Days before spray DAS- Days after spray

Data in parenthesis are Arcsine transformed values

Table 5. Effect of different bio-pesticides on Percent infestation of Fall armyworm during *Kharif* season 2023

	Treatments	Effect of treatments against per cent infestation of Fall armyworm				Yield (t/ha)
		First spray	Second spray	Third spray	Overall Mean	
T_1	***Bacillus thuringiensis* var. *kurustaki***	46.40	35.87	24.13	35.47	5.20±0.12[b]
T_2	***Beauveria bassiana***	52.40	46.00	38.13	45.51	4.36±0.03[d]
T_3	***Metarhizium robertsii***	51.60	43.07	33.60	42.76	4.71±0.03[c]
T_4	***Lecanicilium lecanii***	60.53	54.67	47.60	54.27	3.58±0.04[e]
T_5	**Neem oil (0.03%)**	49.60	40.80	29.07	39.82	4.88±0.04[c]
T_6	**Emamectin benzoate 5% SG**	36.80	22.27	10.13	23.07	6.62±0.04[a]
T_7	**Control**	72.40	74.53	69.73	72.22	2.96±0.03[f]
	CD @ 5 %					0.06
	SE(m) ±					0.18

Data represented by alphabet are calculated by Tukey's HDS

Data followed by same alphabets are statistically at par

DBS- Days before spray DAS- Days after spray

Data in parenthesis are Arcsine transformed values

7. References

Ayala, OR, Navarro F, and EG Virla (2013) Evaluation of the attack rates and level of damages by the fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae), affecting corn-crops in the northeast of Argentina. Revista De La Facultad De Ciencias Agrarias 45(2): 1-12

Babendreier D, Koku Agboyi, L, Beseh P, Osae M, Nboyine J, Ofori SE and M Kenis (2020) The efficacy of alternative environmentally friendly plant protection measures for control of Fall armyworm *Spodoptera frugiperda*, in Maize. Insect 11(4): 240

Balla A, Bhasker M, Bagade P, and N Rawal (2019) Yield losses in Maize (*Zea mays*) due to Fall armyworm infestation and potential IoT-based interventions for its control. Journal of Entomology & Zoology Studies 7(5), 920-927

Deole S and N Paul (2018) First report of fall army worm, *Spodoptera frugiperda* (JE Smith), their nature of damage and biology on Maize crop at Raipur, Chhattisgarh. Journal of Entomology and Zoology Studies 6(6): 219-221

Deshmukh S, Pavithra HB, Kalleshwaraswamy CM, Shivanna BK, Maruthi MS, and D Mota-Sanchez (2020) Field efficacy of insecticides for management of invasive Fall armyworm, *Spodoptera frugiperda* (JE Smith) (Lepidoptera Noctuidae) on Maize in India. Florida Entomologist103(2): 221-227

Dhobi CB, Zala MB, Verma HS, Sisodiya, DB, Thumar RK, Patel MB, Patel JK, and PK Borad (2020) Evaluation of Bio-Pesticides against Fall armyworm, *Spodoptera frugiperda* (JE Smith) in Maize. International Journal of Current Microbiology and Applied Sciences 9(8): 1150-1160

Firake DM, Behere GT, Babu S, and N Prakash (2019) Fall armyworm: Diagnosis and Management (An extension pocket-book). ICAR Research Complex for NEH Region, Umiam, Meghalaya. P. 48

Ganiger PC, Yeshwanth HM, Muralimohan K, Vinay N, Kumar ARV, and K Chandrashekara (2018) Occurrence of the new invasive pest, Fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), in the Maize fields of Karnataka, India. Current Science 115(4): 621-623

Gowrish KR, Ramesha B, and R Ushakumari (2015) Biorational management of major insect pests of brinjal. Indian Journal of Entomology 77(1): 51-55

Hruska AJ (2019) Fall armyworm (*Spodoptera frugiperda*) management by smallholders. CAB Reviews 14(043): 1-11

Mallapur CP, Naik AK, Hagari S, Prabhu ST, and RK Patil (2018) Status of alien pest Fall armyworm, *Spodoptera frugiperda* (JE Smith) on Maize in Northern Karnataka. Journal of Entomology and Zoology Studies 6(6): 432-436

Murúa MG, Juárez ML, Prieto S, Gastaminza G, and E Willink (2009) Distribución temporal y espacial de Poblaciones Larvarias de *Spodoptera frugiperda* (Smith) (Lep.: Noctuidae) en diferentes hospederos en provincias del norte de la Argentina. Revista IndustrialS Agrícola De Tucumán 86(1): 25-36

Ramanujam B, Poornesha B, and AN Shylesha (2020) Effect of entomopathogenic fungi against invasive pest *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae) in Maize. Egyptian Journal of biological Pest control 30(1): 1-5

Sharanabasappa, Kalleshwaraswamy CM, Asokan R, Swamv HM, Maruthi MS, Pavithra HB, Hegde K, Navi S, Prabhu ST, and G Goergen (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

Thumar RK, Zala MB, Varma HS, Dhobi CB, Patel BN, Patel MB, and PK Borad (2020) Evaluation of insecticides against fall armyworm, *Spodoptera frugiperda* (J.E Smith) infesting maize. International Journal of Chemical Studies 8(4): 100-104

Varshney R, Poornesha B, Raghavendra A, Lalitha Y, Apoorva V, Ramanujam B, and V Pandit (2020) Biocontrol-based management of Fall armyworm, *Spodoptera frugiperda* (J.E.Smith) (Lepidoptera: Noctuidae) on Indian Maize. Journal of Plant Diseases and Protection 128(1): 87-95

Wale SD, Mahadik SS, and UB Hole (2022) Biointensive management of Fall armyworm, *Spodoptera frugiperda*, infesting Maize. Annals of Plant Protection Sciences 30(1): 73-77

Wayal A, Unidirwadwade D, Jawanjal K, and G. Chopade (2022) Biorational management of *Spodoptera frugiperda* (J.E Smith) on Maize. Indian Journal of Entomology doi: https://doi.org/10.55446/IJE.2021.352.