

Field Efficacy and Economics Certain Chemicals and Botanical against Fall Armyworm, [(*Spodoptera frugiperda* (J.E. smith.)] on Maize (*Zea mays*)

ABSTRACT

The present investigation was carried out in a Randomized Block Design having 3 replications and 8 treatments (seven insecticides and one control) during ~~Khari~~ ~~season~~ 2023 conducted at the (CRF) Central Research Farm, Sam Higginbottom University of Agriculture, Technology and ~~Sciences~~, Prayagraj Sciences, Prayagraj, (U.P.) to evaluate the field efficacy of certain chemicals and botanicals against fall armyworm [(*Spodoptera frugiperda*)] on maize [(*zea mays* Linn.)]. The order of effectiveness was observed in Chlorantraniliprole 18.5% SC (3.25) > Spinosad 45 SC (3.46) > ~~is found to be the next best treatment followed by~~ Lambda-cyhalothrin 5% EC + Chlorantraniliprole 18.5% SC (3.99) > ~~followed~~ ~~followed~~ Emamectin benzoate 5% SG (4.16) > Lambda-cyhalothrin 5% EC (4.44) > followed by Flubendiamide 39.35% SC (4.87) > Neem oil 1500 ppm (5.18) ~~is found to be least effective but comparatively superior over the control.~~ Among all the treatments the most economical treatment and highest ~~Benefit-Cost~~ ~~Benefit-Cost~~ ratio was recorded in Chlorantraniliprole 18.5% SC with of (1:2.96) followed by Spinosad 45 SC (1:2.82), Lambda-cyhalothrin 5% EC + Chlorantraniliprole 18.5% SC (1:2.60), Emamectin benzoate 5% SG (1:2.53), Lambda-cyhalothrin 5% EC (1:2.36), Flubendiamide 39.35% SC (1:1.81), Neem oil 1500 ppm (1:1.74) respectively as compared to untreated ~~Control~~ ~~control~~ plot (1:1.52).

Keywords: *Spodoptera frugiperda*; chlorantraniliprole; spinosad; neem oils.

1. INTRODUCTION

Maize (*Zea mays* L.) is an important cereal crop grown ~~all over the world~~ ~~worldwide~~ as food for human consumption, animal feed, fodder, and an industrial product. It has the highest genetic yield potential among cereals. Among the cereal crops, due to its highest genetic yield potential globally, Maize is also known as the "queen of cereals". It is also known as the "Miracle Crop" because of its high solar use efficiency and immense potential for increased production. (Panigrahi *et al.*, 2023).

Globally India ranks sixth in global maize production and fifteenth position in its productivity in the world, contributing to 2.4 ~~per cent~~ ~~percent~~ of world production with almost a 5 ~~per cent~~ ~~percent~~ share in world harvested area. It is cultivated on nearly 150 million hectares in about 160 countries having wider diversity of soil, climate, biodiversity, and management practices. It contributes 36% (782 MT) in the global grain production. (Sangle *et al.*, 2020). "India produced 31.51 million tonnes in an area of 9.9 million hectares in 2020-21, whereas in ~~khari~~ ~~khari~~ 2021-22, maize production was 21.24 million tonnes (1st advance estimates) in ~~an area of~~ 8.15 million hectares". (Panigrahi *et al.*, 2023).

The area of cultivation under maize in ~~india~~ ~~India~~ is 9.47 million hectares with production of 28.72 million tonnes and with average productivity of 3032 kg per hectare during 2017-18 (Bharadwaj *et al.*, 2020). A general view of the pest problem in maize in ~~india~~ ~~India~~ reveals that this crop is attacked ~~several~~ ~~by~~ ~~several~~ ~~number~~ ~~of~~ pests stem borers, armyworm (*Mythimna separata*) and *Helicoverpa armigera*. Out of these pests, the maize fall armyworm, *Spodoptera frugiperda* is considered to be the most destructive and has become a great threat ~~for~~ ~~to~~ maize cultivation.

~~Maize is affected by as many as 141 insect pests. Among these, only a few are~~

Comment [SS1]: RCBD

Comment [SS2]: Family and order

Comment [SS3]: Followed by

Comment [SS4]: by

Comment [SS5]: by

Comment [SS6]: ,

Comment [SS7]: and

Comment [SS8]: please provide a concluding statement of the summary

Formatted: Font: Bold, Not Italic

Formatted: Font: Not Italic

Formatted: Strikethrough

considered as major pests in India viz., shoot fly flies, stem borers, armyworm armyworms (*Mythimna separata*) and *Helicoverpa armigera*. However, the recent invasion of the fall armyworm, *Spodoptera frugiperda* (Noctuidae: Lepidoptera) has become a great threat to maize cultivation.

Formatted: Strikethrough

Formatted: Strikethrough

The fast and wide spread of this pest is mainly attributed to its strong flying ability, higher fecundity, and polyphagous nature having an ample number of alternate hosts coupled with the availability of host crops throughout the year (Mallapur *et al.*, 2019).

It is also reported to cause major damage to economically important crops. Damage due to this pest attack can reduce corn grain yield by up to 34 percent in Brazil, 20 to 50 percent in Africa has the potential to cause maize yield losses in a range from 8.3 to 20.6 m tonnes per annum, in the absence of any control methods (Day *et al.*, 2017).

The bio-pesticides play an important role in insect pest management by their various inhibitory actions on insect physiology and behavior. They are the best alternative to chemical insecticides against Fall armyworm on maize. They are locally available, relatively cheap, biodegradable, and easy to handle. They are bringing about the balance back to the ecosystem. As the agriculture shifts toward organic farming, they have much better scope in the management tactics. (Warghat *et al.*, 2019).

Comment [SS9]: mention the objectives you are going to find.

2. MATERIALS AND METHODS

The present investigation was conducted at the experimental research plot of the Department of Entomology, Central Research Farm, Sam Higginbottom University of Agriculture, Technology and Sciences, during the Kharif season of 2023, in a Randomized Block Design (RBD) with eight treatments and three replications using variety Komal seeds in a plot size of 2m x 1m at a spacing of 60 cm x 20 cm with the recommended package of practices excluding plant protection. The soil of the experimental site was well-drained and medium-high.

The pest population was estimated by observing five plants selected randomly from each treatment for the presence of larvae at one day prior to before insecticide application and at on the 3rd, 7th, and 14th days after each application. The larval population over control against fall armyworm was calculated by considering the mean of three observations recorded at on the 3rd, 7th, and 14th days after first and second spraying.

Comment [SS10]: Methodology references if any.

2.1 Data Collection

2.1.1 Larval population

The observation of maize fall armyworm larval population and damaged plants was recorded 1 day before spraying and on the 3rd, 7th, and 14th days after insecticidal application. The observation will be recorded on randomly selected 5 plants in each plot. At harvest, the grain yield per plot was recorded and converted into Q/ha for comparison.

Comment [SS11]: Methodology references

The results obtained are converted into percent plant damage ~~work-out~~ using the following formula.

$$\text{Mean larval population} = \frac{\text{Number of larvae}}{5 \text{ randomly plant selected}}$$

2.2 Cost-Benefit Ratio

Based on the yield data, the gross returns and net returns were calculated for each treatment. Gross returns were calculated by multiplying the total yield with the market price of the produce. The ratio of gross return and cost of cultivation will be ~~work-worked~~ for each treatment and was used as a benefit: cost ratio (BCR) to compare the performance of different treatments. ~~Benefit~~ The benefit-cost ratio was calculated by using the following equation.

$$\text{Gross return} = \text{Marketable yield} \times \text{Market price}$$

Net return = Gross return - Total cost

$$B:C \text{ Ratio} = \frac{\text{Gross returns}}{\text{Total Cost}}$$

(Thuppukonda and Kumar 2022)

Where, BCR = Benefit Cost Ratio

3. RESULTS

The data on the mean (3rd, 7th and 14th DAS) population of *Spodoptera frugiperda* after the first spray revealed that all the treatments except untreated control are effective. Among all the treatments, the lowest population was recorded in Chlorantraniliprole @ 18.5% EC (4.4). Spinosad 45 SC (4.63) was found to be the next best treatment followed by Lambda cyhalothrin @ 2.5% EC + Chlorantraniliprole @ 18.5% EC (4.95), Emamectin benzoate @ 5% SG (5.1), Lambda cyhalothrin @ 2.5% EC (5.23), Flubendiamide 39.35% EC (5.23) and Neemoil 1500 ppm (5.8) was found to be least effective but comparatively superior over the control.

The data on the population of *Spodoptera frugiperda* on the second spray revealed that all the treatments were significantly superior over the control. Among all the treatments, in Chlorantraniliprole @ 18.5% EC (2.09). Spinosad 45 SC (2.29) was found to be the next best treatment followed by Lambda cyhalothrin @ 2.5% EC + Chlorantraniliprole @ 18.5% EC (3.02), Emamectin benzoate @ 5% SG (3.22), Lambda cyhalothrin @ 2.5% EC (3.64), Flubendiamide 39.35% EC (4.27) and Neemoil 1500 ppm (4.55) was found to be least effective but comparatively superior over the control.

The yields among the different treatments were significant. The highest yield was recorded in Chlorantraniliprole @ 18.5% EC (51.52 q/ha). Spinosad 45 SC (45.40 q/ha) was found to be the next best treatment followed by Lambda cyhalothrin @ 2.5% EC + Chlorantraniliprole @ 18.5% EC (46 q/ha), Emamectin benzoate @ 5% SG (40 q/ha), Lambda cyhalothrin @ 2.5% EC (37 q/ha), Flubendiamide 39.35% EC (35.18 q/ha) and Neemoil 1500 ppm (28.82 q/ha) as compared to control plot (22.26 q/ha).

When the cost-benefit ratio was worked out, an interesting result was achieved. Among the treatments studied, the best and most economical treatment was Chlorantraniliprole @ 18.5% EC (1:2.96). Spinosad 45 SC (1:2.82) was found to be the next best treatment followed by Lambda cyhalothrin @ 2.5% EC + Chlorantraniliprole @ 18.5% EC (1:2.60), Emamectin benzoate @ 5% SG (1:2.53), Lambda cyhalothrin @ 2.5% EC (1:2.36), Flubendiamide 39.35% EC (1:1.81) and Neem oil 1500 ppm (1:1.74) as compared to control plot (1:1.52). (Table 3).

Comment [SS12]: Mention the table and figure no. in the text.

Table 1.
Efficacy of certain chemicals and biopesticides against larval population of *Spodoptera frugiperda* on maize after (1st spray)

Number of larva-larvae <i>Spodoptera frugiperda</i> / five plants						
Treatments no.	Treatments	1 st DBS	3 rd DAS	7 th DAS	14 th DAS	Overall mean
T1	Spinosad 45 SC	5.93	4.6	3.8	4.2	4.63
T2	Chlorantraniliprole 18.5% SC	5.86	4.26	3.46	4	4.40
T3	Emamectin benzoate 5% SG	6.33	5.06	4.33	4.66	5.10

T4	Lambda-cyhalothrin5%EC +Chlorantraniliprole 18.5%SC	5.8	4.8	4.73	4.46	4.95
T5	Flubendiamide 39.35%SC	5.8	5.6	5.13	5.33	5.47
T6	Lambda- cyhalothrin5%EC	6.13	5.26	4.53	5	5.23
T7	Neemoil 1500ppm	5.93	6.2	5.4	5.66	5.80
T ₀	Control	6	6.26	6.6	5.77	6.16
F-test		NS	S	S	S	S
S.Ed(±)			0.22	0.18	0.16	0.21
C.D.(P=0.05)			0.46	0.390	0.347	0.367

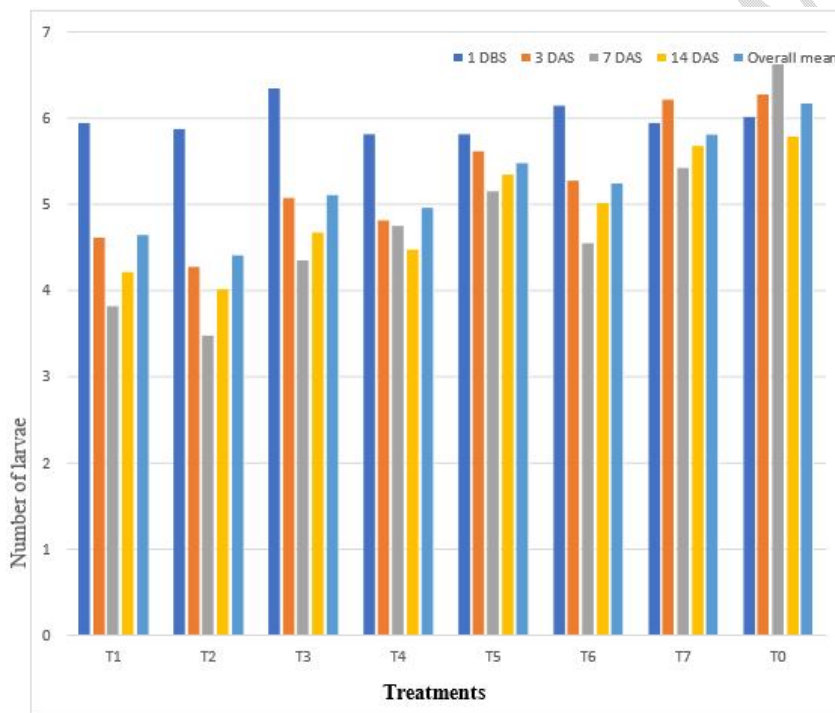


Fig.1. Effect of different **treatment treatments** on maize fallarmyworm, *Spodoptera frugiperda* after first spray (Larval population)

Table2. Efficacy of certain chemicals and biopesticides against larval population of *Spodoptera frugiperda* on maize after (2nd spray)

No.of.	Treatments	3 rd DAS	7 th DAS	14 th DAS	Overall mean
T1	Spinosad45SC	2.86	1.8	2.2	2.29
T2	Chlorantraniliprole 18.5%SC	2.8	1.6	1.86	2.09
T3	Emamectinbenzoate 5%SG	3.73	2.73	3.2	3.22
T4	Lambda-cyhalothrin 5%EC +Chlorantraniliprole 18.5%SC	3.53	2.53	3	3.02

T5	Flubendiamide 39.35%SC	4.6	4	4.2	4.27
T6	Lambda-cyhalothrin 5%EC	4.13	3.26	3.53	3.64
T7	Neemoil 1500ppm	4.93	4.26	4.46	4.55
T0	Control	7	7.13	7.33	7.15
F-test		S	S	S	S
S.Ed(±)		1.03	1.22	0.19	1.17
C.D.(P=0.05)		0.398	0.366	0.413	0.406

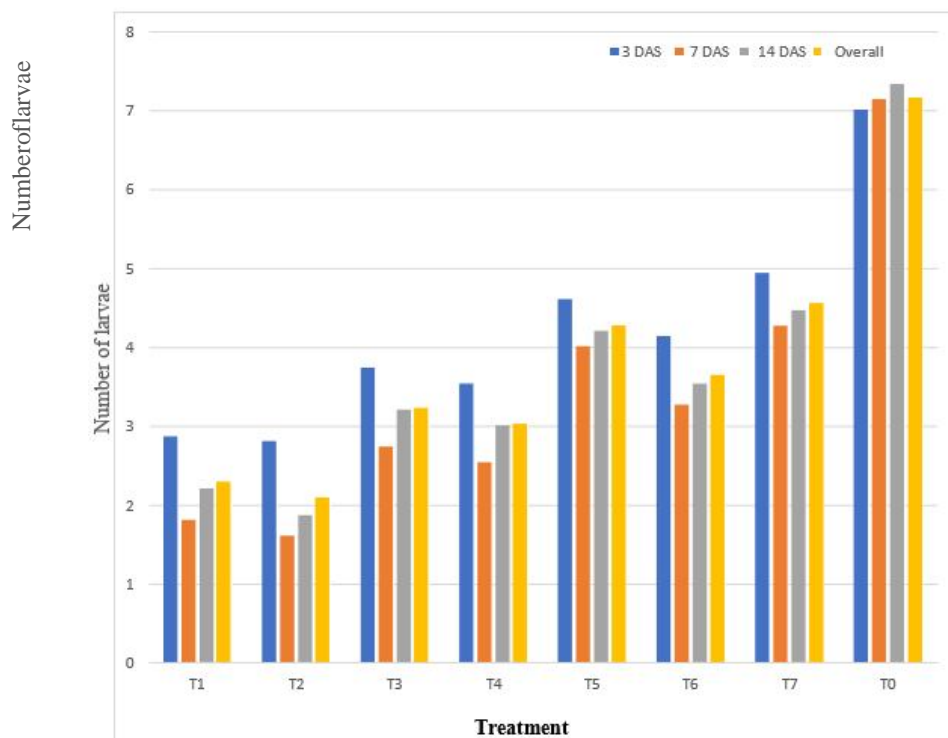


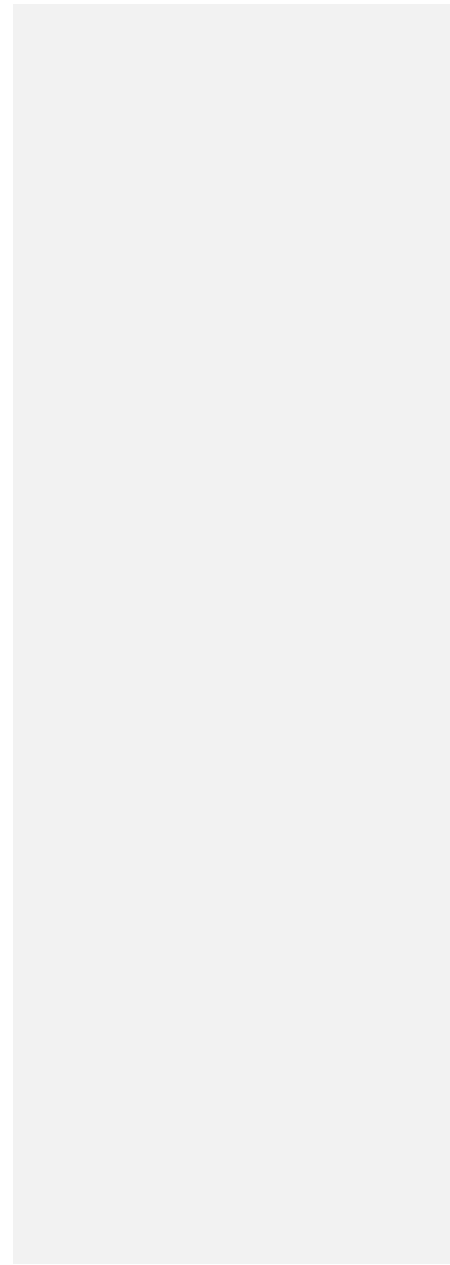
Fig.2. Effect of different treatment-treatments on maize fall armyworm, *Spodoptera frugiperda* after second spray (Larval population)

Table3.Economicsofcultivation

S.N.S.N	Treatments	Yield (q/ha)	Costof yield / (₹)	Total cost of yield(₹)	Common cost (₹)	Treatment cost (₹)	Net Return (₹)	Total cost (₹)	C:B:Cratio
T1	Spinosad45 SC	45.40	1800	81720	26222	2737	52761	28959	1:2.82
T2	Chlorantraniliprole 18.5%SC	51.52	1800	92736	26222	5040	61474	31262	1:2.96
T3	Emamectin benzoate 5%SG	40	1800	72000	26222	2236	43542	28458	1:2.53
T4	Lambda-cyhalothrin 5%EC + Chlorantraniliprole 18.5%SC	46	1800	82800	26222	5525	51053	31747	1:2.60
T5	Flubendiamide 39.35%SC	35.18	1800	63324	26222	8645	28457	34867	1:1.81
T6	Lambda- cyhalothrin 5%EC	37	1800	66600	26222	1885	38493	28107	1:2.36
T7	Neem oil 1500ppm	28.82	1800	51876	26222	3500	22154	29722	1:1.74
T0	Control	22.26	1800	40068	26222	—	13846	26222	1:1.52

UNDER PEER REVIEW

UNDER PEER REVIEW



4. DISCUSSION

In the present research work, the lowest percent of maize fall armyworm population was recorded in T₂ Chlorantraniliprole @ 18.5% EC (3.25%) Similar findings were made by Baurtetet *et al.*, (2017), Triboniet *et al.*, (2019) and Viteri *et al.*, (2019) who reported that T₂ Chlorantraniliprole @ 18.5% EC was the most effective treatment indicating recorded lowest population of fall armyworm (*Spodoptera frugiperda*). Followed by T₁ Spinosad 45% SC (3.46) was the most effective treatment in reducing the population of *S. frugiperda* which is in line with the findings of Belay *et al.*, (2012), Sharma *et al.*, (2018) and Rebeca *et al.*, (2018).

In the present research work, lowest percent of maize fall armyworm population was recorded in T₂ Chlorantraniliprole @ 18.5% EC (51.50 q/ha) these findings were supported by Bharadwaj *et al.*, (2020), Dileep *et al.*, (2020) and Jayarajan *et al.*, (2021) followed by T₁ Spinosad 45% SC (45.50 q/ha) these findings were supported by Siddhartha *et al.*, (2019) and Sharma *et al.*, (2018), T₄ Lambda cyhalothrin @ 2.5% EC + Chlorantraniliprole @ 18.5% EC (46 q/ha.) and T₃ Emamectin benzoate @ 5% SG (40 q/ha) these findings were supported by Mallapur *et al.*, (2019) and Rebeca *et al.*, (2018). The next best treatment was T₆ Lambda cyhalothrin @ 2.5% EC (37 q/ha) which is in line with the similar findings of Ingavale (2021) and Nboyineet *et al.*, (2020). T₅ Flubendiamide @ 39.35 SC (35.18 q/ha) which is in line with the similar findings of Sangle *et al.*, (2020), Deshmukh *et al.*, (2018) and Ramesh and Tayde (2022).

When the cost-benefit ratio was worked out, an interesting result was achieved. Among the treatments studied, the best and most economical treatment was T₂ Chlorantraniliprole @ 18.5% EC (1:2.96). T₁ Spinosad 45 SC (1:2.82) was found to be the next best treatment followed by T₄ Lambda cyhalothrin @ 2.5% EC + Chlorantraniliprole @ 18.5% EC (1:2.60), T₃ Emamectin benzoate @ 5% SG (1:2.53), T₆ Lambda cyhalothrin @ 2.5% EC (1:2.36), T₅ Flubendiamide 39.35% EC (1:1.81) and T₇ Neem oil 1500 ppm (1:1.74) as compared to control plot (1:1.52).

Comment [SS14]: (Please mention the limitations of the findings, as the chemical treatment will vary from one researcher to another).

5. CONCLUSION

From the analysis of the present findings of the field efficacy of certain chemicals and botanicals against fall armyworm [(*Spodoptera frugiperda*)] on maize *zea mays* (Linn.): it can be concluded that T₂ Chlorantraniliprole @ 18.5% EC is more effective in controlling the population of maize fall armyworm followed by T₁ Spinosad 45% SC, T₄ Lambda cyhalothrin @ 2.5% EC + Chlorantraniliprole @ 18.5% EC, T₃ Emamectin benzoate @ 5% SG, T₆ Lambda cyhalothrin @ 2.5% EC, T₅ Flubendiamide @ 48% SC and T₇ Neem oil 1500 ppm managing *Spodoptera frugiperda*.

Comment [SS15]: Found to be

Comment [SS16]: Don't mention the treatment numbers in the conclusion.

Among the treatments studied was T₂ Chlorantraniliprole @ 18.5% EC (1:2.96 and 51.52 q/ha.). T₁ Spinosad 45 SC (1:2.82 and 45.40 q/ha.) was found to be the next best treatment followed by T₄ Lambda cyhalothrin @ 2.5% EC + Chlorantraniliprole @ 18.5% EC (1:2.60 and 46 q/ha.), T₃ Emamectin benzoate @ 5% SG (1:2.53 and 40 q/ha.), T₆ Lambda cyhalothrin @ 2.5% EC (1:2.36 and 37 q/ha.), T₅ Flubendiamide 39.35% EC (1:1.81 and 35.18 q/ha) and T₇ Neem oil 1500 ppm (1:1.74 and 28.82 q/ha.) as compared to control plot (1:1.52 and 22.26 q/ha.) as such more trials are required in future to validate the findings.

Comment [SS17]: Please mention a list of any future line of works for subsequent researchers

REFERENCES

- Bharadwaj, G. S., Mutkule, D. S., Thakre, B.A. and Jadhav, A. S. (2020). Bio-efficacy of different insecticides against fall armyworm, *Spodoptera frugiperda* (J.E. Smith) on Maize. *Journal of Pharmacognosy and Phytochemistry*, 9(5): 603-607.
- Chandar, A. S., and Tayde, A. R. (2023). Field Efficacy of Insecticides against Fall Army Worm, *Spodoptera frugiperda* (J.E. Smith) on Maize (*Zea mays* L.). *International Journal of Environment and Climate Change*, 13(11), 3010-3020.
- Divya, J., Kalleshwaraswamy, C. M., Deshmukh, S., Ambarish, S. and Sunil, C. (2021). Evaluation of whorl application of insecticides mixed with sand against fall army worm *Spodoptera frugiperda* in maize. *Indian Journal of Entomology*, 84(3): 617-621.
- Deshmukh, S., Pavithr, A.H.B., Kalleshwaraswamy, C.M., Shivanna, B.K. and Maruth, M. S. (2018). Field efficacy of insecticides for management of invasive fall armyworm, *Spodoptera*

frugiperda(J.E.Smith) (Lepidoptera: Noctuidae) on maize in India. *Florida Entomological Society*, 103(2): 221-227.

- Dileep, N. T., Murali K., Prabhu C., Ganiger. and Mahesh, H. M. (2020). Safe and ~~cost-effective~~
effective management of the fall armyworm, *Spodoptera frugiperda*(Lepidoptera: Noctuidae)usinggreeninsecticidebaits. *InternationalJournalofChemicalStudies*,8(5): 106-110.
- Ingavale, D. (2021). Control of Fall Armyworm (*Spodoptera frugiperda*) by Using Some SelectiveChemicalInsecticides. *InternationalJournalofInnovativeScienceandResearch Technology*, 6(2): 2456-2165.
- Kachave, S. B. and Tayde,A. R. (2023). Efficacy and economics of selected chemicals and biopesticides against fall armyworm, *Spodoptera frugiperda*(JE Smith) on maize (*Zea mays* L.). *Journal of Experimental Zoology India*, 26(2).
- Kalleshwaraswamy, C. M.,Asokan, R., Swamy, H. M., Maruthi, M. S., Pavithra, H. B., Kavita, H. and Goergen, G. (2018). First report of the fall armyworm, *Spodoptera frugiperda*(JE Smith)(Lepidoptera: Noctuidae), an alien invasive pest on maize inIndia. *Pest Management in Horticultural Ecosystems*, 24(1), 23-29.
- Mallapur,C.P.,Naik,A.K.S.,Hagari,T.,Praveen.andNaik,M.(2019).Laboratoryandfield evaluationofnewinsecticidemoleculesagainstfallarmyworm,*Spodopterafrugiperda*(J. E.Smith)onmaize. *JournalofEntomologyandZoologyStudies*,7(5):729-733.
- Nagesh, C. and Tayde, A. R (2023). Efficacy of different Chemicals and Neem Products against Fall ~~Army-worm~~Armyworm, [*Spodoptera frugiperda*(JE Smith)] in Maize (*Zea mays* L.) *Biological Forum – An International Journal* 15(6): 432-436.
- Panigrahi, C. K., Yadav, U. and Sarangi, D. (2023). Field Efficacy of Certain Insecticides againstFallArmyworm,*Spodopterafrugiperda*(JESmith)onMaize(*Zeamays*L.)under PrayagrajRegionofIndia. *InternationalJournalofEnvironmentandClimate Change*, 13(9), 1207-1215.
- Patidar, S., Das, S. B., Vishwakarma, R., Kumari, P., Mohanta, S. and Paradkar, V. K. (2022).Field evaluationofinsecticides against fall armyworminfestingmaize. *The Pharma Innovation Journal*, 11(4): 892-895.
- Ramesh, M. and Tayde, A. R. (2022). Comparative efficacy of selected chemicals and biopesticidesagainstfallarmyworm,*Spodopterafrugiperda*(J.E.Smith)onmaize(*Zea mays*L.). *InternationalJournalofPlantandSoilScience*,34(23):466-470.
- SangleSingle. S. V., Jayewar, N. E. and Kadam, D. R. (2020). Efficacy of insecticides on larval populationoffallarmyworm,*Spodopterafrugiperda*onmaize. *JournalofEntomologyand Zoology Studies*, 8(6): 1831-1834.
- Suthar, M., Zala, M. B., Varma, H. S., Lunagariya, M., Patel, M. B. and Borad, B. P. P. (2020).Bioefficacyofgranularinsecticidesagainstfallarmyworm,*Spodopterafrugiperda*(JESmith)inm aize. *InternationalJournalof ChemicalStudies*,8(4):174-179.
- Viteri, D. M., Linares,A. M., Cabrera, L. and Sarmiento, L. (2019). Presence of corn earworm and fall armyworm (Lepidoptera: Noctuidae) populations in sweet corn and their susceptibilitytoinsecticidesinpuertoicoPuerto Rico. *FloridaEntomology*,102(2):451-454.
- Zhao,Y.X.,JingMei,Huang,Huan,Ni,GuoD.I.,Feng,Yang,Xin,WangShun,FanWu. and Cong, Fen Gao. (2020). Susceptibility of fall armyworm, *Spodoptera frugiperda*(J.E. Smith),to eight insecticides in China, with special referenceto lambda-cyhalothrin. *National Center for Biotechnogical BiotechnologicalInformation*, 168:104-623.