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Evaluation of chemical insecticides against Fall Armyworm, *Spodoptera frugiperda* (J. E. Smith) in maize

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ABSTRACT

Fall armyworm, *Spodoptera frugiperda* is an invasive insect pest of maize in plains and hills of Nepal causing serious damage in summer as well as winter maize production. Field experiments were conducted in Randomized Complete Block Design (RCBD) to evaluate five chemical insecticides against *S. frugiperda* at National Entomology Research Center, Khumaltar, Lalitpur during 2021 and 2022. On the basis of percent plant with live larvae infestation, damage symptoms and damage score, Spinosad 45% SC, Spinetoram 11.7% SC and Chlorantraniliprole 18.5% SC were found consistently superior among the treatments. Average percent plant infestation with live larvae was recorded 0 to 3.81 percent whereas, percent plant with FAW damage symptoms was recorded 0 to 5.72 percent on Spinosad, Spinetoram and Chlorantraniliprole treated plots. Statistically, cocktail insecticide Chlorpyrifos 50% + Cypermethrin 5% EC was also found effective in comparison to control and average percent plant with live larvae and damage symptoms were recorded 14.82 to 31.48 percent and 4.74 to 46.29 percent, respectively. Statistically, Azadirachtin 0.15% was also found effective as compared to control, however, percent plant infestation was recorded as high as 91.57 percent. Spinosad, Spinetoram and Chlorantraniliprole can be judiciously utilized for chemical management of fall armyworm in Nepal.

Keywords: Azadirachtin, Chlorantraniliprole, invasive insect, Spinosad.

सारांश

नेपालको पहाड तथा तराईमा खेति गरिने वर्षे तथा हिउँदे मकै वालीमा अमेरिकन फौजी कीरा एक प्रमुख शत्रु जीव हो । यस कीराको रासायनिक व्यवस्थापनका लागि राष्ट्रिय कीट विज्ञान अनुसन्धान केन्द्र, खुमलटार, ललितपुरमा सन् २०२१ तथा २०२२ मा विभिन्न कीटनाशक विषादीहरुको प्रभावकारिता परिक्षण गरिएको थियो । मकैमा कीराले गरेको क्षति र विषादीको प्रयोग पछि जिवित कीराहरुको तथ्याङ्को आधारमा स्पाइनोस्याड ४५% एस सी, स्पाइनोटोराम ११.७% एस सी तथा क्लोरएण्ट्रानिलिप्रोल १८.५% एस सी नामक कीटनाशक विषादीहरु दुबै सालमा उत्कृष्ट पाइएका थिए । उक्त विषादीहरु प्रयोग गर्दा जिवित कीरा भएका विरुवाहरु ३.८१% तथा कीराको क्षति ५.७२% वा सो भन्दा कम भएको पाइयो । त्यस्तै क्लोरोपाइरिफोस ५०% + साइपरमेथ्रिन ५% को समिश्रण भएको विषादी प्रयोग गर्दा कीराको क्षति १४.८२ देखि ३१.४८ प्रतिशत तथा ४.७४ देखि ४६.२९ प्रतिशत विरुवामा जिउँदो कीरा भेटियो । त्यस्तै निमजन्य विषादी एजाडिराक्टिन ०.१५% प्रयोग गर्दा ९१.७५ प्रतिशत विरुवामा कीरा नमरेको भेटियो । यस अध्ययनबाट स्पाइनोस्याड, स्पाइनोटोराम तथा क्लोरएण्ट्रानिप्रोल नामक कीटनाशक विषादीहरु अमेरिकन फौजी कीराको व्यवस्थापनको लागि विवेकपूर्ण तरिकाबाट प्रयोग गर्न सकिने देखिएको छ ।

INTRODUCTION

Fall armyworm (FAW) *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) is an invasive insect pest of maize in Nepal. The *Spodoptera frugiperda* had been reported for the first time in Nepal from Gaindakot of Nawalpur district (N 27º42'16.67", E 084º22'50.61") in May 2019 (Bajracharya et al 2019). Since then the FAW had spread into maize growing regions of entire Nepal and winter temperature in terai and inner terai regions of Nepal was found suitable for survival of the insect (Bajracharya et al 2020). *S.*

frugiperda has very wide host range and 353 plant species has been recorded as larval host belonging to 76 plant families including major hosts from Poacaea, Asteraceae and Fabaceae (Debora 2018). Apart from maize FAW can cause major damage to sorghum, rice, wheat, finger millet, sugarcane, cabbage, beet, groundnut, soybean, onion, cotton, tomato, potato and many fodder grasses (Prasanna et al 2018). Fall armyworm larvae feed on leaf, whorl, tassel and cob of maize plants. FAW is strong flier and has migratory and localized dispersal habit. Maize yield losses caused by *S. furgipeda* larvae were estimated, 20.15 percent in African countries (Abraham et al 2017) and 34 percent in Brazil (Cruz et al, 1999).

The mean incubation, larval and pupal periods of *S. frugiperda* were found 2.79, 14.04 and 9.49 days, respectively, while studying biology of the insect at laboratory conditions in Nepal (Bhat and Bajracharya 2022). Similarly, the adult longevity of male and female moths was recorded 15.39 days and 16.16 days and fecundity was recorded 1712 eggs per gravid female. Female moth of fall armyworm lays eggs in multiple clusters covered with abdominal hairs on maize leaves. New born larvae aggregate near egg masses; however, after some time larvae aggressively disperse from hatching site. Young larvae feed on green tissue from lower surface of maize leaves leaving upper epidermis resulting into elongated papery window like symptoms. Grown larvae start to feed inside the whorl of maize plant and deposit faecal matter in the whorl. Both tassels and maize cobs along with silk are found damaged by *S. frugiperda* larvae at reproductive stage of maize plants.

S. frugiperda is a destructive insect pest of maize and new to Nepalese agriculture. Integrated pest management of *S. frugiperda* being developed by Nepal Agriculture Research Council and other institutes involved in FAW research. Insecticide management is also an important tool of IPM of fall armyworm management. Maize farmers in Nepal are using various inappropriate insecticides in higher doses and frequency against FAW on recommendation of pesticide traders. Even using various cocktail formulations which were readily available in local market under various trade names. Considering all these facts some selected chemical insecticides which are available in local markets in Nepal were evaluated against *S. frugiperda* in the fields of National Entomology Research Center. This paper highlights the findings of insecticide evaluation against fall armyworm in Nepal.

MATERIALS AND METHODS

Field experiments were conducted to evaluate various chemical insecticides against *S. frugiperda*. in the screen houses of National Entomology Research Center, Khumaltar, Lalitpur. The experiments were conducted with six treatments in Randomized Complete Bolck Design (RCBD) with three replications The experiment was replicated two years during June to August, 2021 and March to June, 2022. The details of the treatments with their common names, formulations, doses and trade names are given in **Table** 1. The maize variety "Rampur composite" was planted with spacing of 75cm X 25cm following recommended package of practices of maize cultivation in Nepal. A plot size of 3m X 2.25m was used for each treatment. There was a total of four rows of maize plants with nine plants in a row in each treatment. Three screen houses were used for three different replications of the experiment.

Table 1. List of treatments with their common names, formulations, doses and trade names

SN	Chemical name	Formulation	Dose	Trade name
1	Spinosad	45 % SC	0.3 ml/liter of water	Tracer
2	Spinetoram	11.7% SC	0.5 ml/liter of water	Delegate
3	Chlorantraniliprole	18.5 % SC	0.4 g/liter of water	Coragen
4	Azadirachtin	0.15 % EC	5 ml/liter of water	Niconeem
5	Chlorpyrifos + Cypermethrin	50% + 5% EC	2ml/liter of water	Fighter 505
6	Non-treated control			

The treatments were applied on the maize plants one month after sowing of maize seeds. The insecticides were sprayed with the help of knapsack sprayer. The insecticides were applied three times in 15-day interval and drifting of insecticide solution during spray was checked by black polythene (**Figure** 1a). About 500 ml to 1000 ml of each insecticide solution was used for spraying one plot of each treatment depending upon stage of the plant. Each plant was inoculated with five early instar (first to second instar) FAW larvae with the help of camel hair brush after 24 hours of insecticide spray (**Figure** 1b). 25 pairs of three days old adult FAW were released in each cage to increase the pest population in the cage.

A b

Figure 1. (a) Insecticide spray in experiment with partition of black polythene to check insecticide drifting (b) inoculation of early instar FAW larvae on maize plants in experimental plots

Observations on different parameters were recorded three times i.e., seven days after each insecticide application. Data was recorded from all 18 maize plants of central two rows from each treatment. The plants were observed for presence or absence of live larvae of FAW. The presence or absence of foliar damage on upper four new leaves and maize whorl was recorded from each plant. The damage scoring was performed from observed plants with the help of foliar damage scoring scale given by Davis and Williams (1992) and modified by Bajracharya et al (2020a). The details of scoring scale are presented in **Table** 2. The data collected were entered in Microsoft Excel computer application and "percent plants infested with live larvae" and "percent plants with whorl damage symptoms" were calculated. The Analysis of Variance (ANOVA) was performed in Genstat Discovery (Edition 4) computer software after arcsine transformation of the percent data.

Table 2. Scoring scale (0-5) for assessment of foliar damage due to fall armyworm

Score	Damage symptoms/description
0	No visible feeding symptoms on upper leaves and whorl.
1	Papery window damage symptoms on upper leaves and whorl.
2	Few small holes on upper leaves and whorl.
3	Ragged holes on upper leaves and partially whorl damaged.
4	Whorl and upper leaves extensively damaged.
5	Whorl completely destroyed and plant drying due to extreme defoliation

RESULTS

The percent plants infested with live larvae after first, second and third sprays of various chemical insecticides during 2021 is given in **Table** 3. The infestation of live larvae was found significantly lower in insecticide treated plots compared to control (p<0.001). Spinosad, Spinetoram and Chlorantraniliprole treated plots showed less than 6 percent infestation in maize plants, whereas control plots recorded 96-100 percent plants infested with FAW larvae. Maize plant infestation in Chlorpyrifos + Cypermethrin treated

plots ranged between 16-27 percent. Although, Azadirachtin treatment had significant effective compared to control, plant infestation was found very high recording up to 68 percent.

Table 3. Percentage of plants infested with fall armyworm larvae after insecticides treatments during 2021.

Treatments	Percent Plants infested with live larvae.		
	AFS*	ASS*	ATS*
Spinosad	0.00(0.57)[#]	5.77(11.45)	0.00(0.57)
Spinetoram	0.00 (0.57)	1.85(4.94)	1.85(4.94)
Chlorantraniliprole	1.85(4.94)	1.96(5.07)	3.81(9.44)
Azadirachtin	55.56(48.20)	67.97(55.59)	46.29(42.85)
Chlorpyrifos + Cypermethrin	27.78(31.72)	31.48(33.98)	16.67(23.90)
Non-treated control	100(89.19)	98.15(84.90)	96.29(80.60)
P value	<0.001	<0.001	<0.001
L.S.D.	6.49	13.40	10.81
CV (%)	12.20	22.60	22.00

*AFT: After first spray, AST: After second spray, ATS after third spray. [#]Value within parentheses are arcsine transformed.

The percent plant infested with live fall armyworm larvae after application of various insecticides during 2022 are presented in **Table** 4. All the insecticides except Azadirachtin had shown consistently significant effect is reducing larval population during 2022 (p<0.001). Similar to first year result, insecticides Spinosad, Spinetoram and Chlorantraniliprole were found superior in reducing FAW larval infestation recording less than 4 percent of infested maize plants after all three sprays. Chlorpyrifos and Cypermethrin mixed insecticide recorded less than 30 percent of infested maize plant. Azadirachtin had significantl effective after first and second spray, but was not effective after third spray, recording 92 percent plant infestation. 93-98 percent of the plants in control plots were infested with live FAW larvae.

Table 4. Percentage of plants infested with fall armyworm larvae after insecticides treatments during 2022.

Treatments	Percent Plants infested with live larvae.		
	AFS*	ASS*	ATS*
Spinosad	3.71(9.32) [#]	2.38(5.53)	1.85(4.94)
Spinetoram	0.00(0.57)	0.00(0.57)	1.75(4.94)
Chlorantraniliprole	1.85(4.94)	0.00(0.57)	1.85(4.94)
Azadirachtin	24.07(29.35)	17.32(24.63)	91.53(75.84)
Chlorpyrifos + Cypermethrin	14.82(22.57)	11.99(19.75)	30.08(33.58)
Non-treated control	92.59(76.76)	97.92(84.65)	97.92(84.65)
P value	<0.001	<0.001	<0.001
L.S.D.	12.27	9.44	11.70
CV (%)	28.20	22.90	16.10

*AFT: After first spray, AST: After second spray, ATS after third spray. [#]Value within parentheses are arcsine transformed.

Percent plant with fall armyworm damage symptoms in whorl and average damage score after insecticide sprays during 2021 are presented in **Table** 5. The percent plant with whorl damage symptoms were significantly lower in various insecticide sprayed plots compared to control (p<0.001). Treatments, Spinosad, Spinetoram and Chlorantraniliprole were found equally effective in reducing fall armyworm damage on maize whorl. Although Chloropyrifos + Cypermethrine and Azadirachtin were found statistically effective in reducing FAW larval damage, the damage percentage was higher up to 72. Nearly all plants in control plots damaged by fall armyworm larvae Was recorded 98-100 percent. The initial damage symptoms with papery window type of damage on upper leaves were found on Spinosad,

Spinetoram and Chlorantraniliprole treated plants. The damage symptoms with ragged holes with partial world damage was seen on Azadirachtin treated plants. The damage symptoms in Chlorpyrifos + Cypermethrin treated plants were inconsistent, some plants with papery window damage, some with small holes and few with large holes with partial whorl damage. Nearly all plants in control treatment were found with big holes on leaves and partially damaged whorl.

Table 5. Percentage of plant with fall armyworm larvae damage symptoms in whorl and upper leaves with their average foliar damage score during 2021

Insecticides	Percent plant with whorl damage symptoms.			Average foliar damage score		
	AFS*	ASS*	ATS*	AFS	ASS	ATS
Spinosad	5.56(11.24)[#]	5.67(13.81)	0.00(0.57)	0	0	0
Spinetoram	1.85(4.94)	3.70(6.87)	3.70(9.32)	0	0	0-1
Chlorantraniliprole	3.7(6.87)	5.56(13.69)	5.77(11.45)	1	0-1	0-1
Azadirachtin	68.52(56.02)	71.68(57.94)	50.00(45.00)	3	3	2-3
Chlorpyrifos + Cypermethrin	4.74(39.65)	46.29(44.82)	18.52(25.45)	1	2-3	2
Non-treated control	100(89.19)	98.15(84.90)	98.15(84.90)	3	3	3
P value	<0.001	<0.001	<0.001			
L.S.D.	11.24	9.63	11.93			
CV (%)	17.80	14.30	22.30			

*AFT: After first spray, AST: After second spray, ATS after third spray. [#]Value within parentheses are arcsine transformed.

Percent plant with fall armyworm damage symptoms in whorl and average damage score after insecticides spray during 2021 are presented in **Table** 6. Percent whorl damage symptoms in different treatment applied maize plants were significantly differed (p<0.001). Spinosad, Spinetoram and Chlorantraniliprole were statistically at par and found superior among treated insecticides with few papery window type damage symptoms on upper maize leaves. Similar to previous year experiment Azadirachtin and Chlorpyrifos + Cypermethrine were also found effective statistically but with higher percentage of whorl damage which ranged between 16-90 percent. Whorls and upper leaves of maize plant in control plots were found extensively damaged (4 average foliar damage score). Nearly all plants (96-98%) of control plots were found damaged by fall armyworm larvae.

Table 6. Percentage of plant with fall armyworm larvae damage symptoms in whorl and upper leaves with their average foliar damage score during 2021

Insecticides	Percent plant with whorl damage symptoms.			Average foliar damage score		
	AFS*	ASS*	ATS*	AFS	ASS	ATS
Spinosad	3.71(9.36)[#]	2.38(5.53)	1.85(4.98)	0	0	0-1
Spinetoram	0.00(0.57)	0.00(0.57)	1.75(4.98)	0	0	0-1
Chlorantraniliprole	1.85(4.98)	0.00(0.57)	1.85(4.98)	0	0	0-1
Azadirachtin	25.92(30.58)	23.09(28.61)	89.28(74.15)	3	1	3
Chlorpyrifos + Cypermethrin	16.67(24.12)	14.36(21.53)	31.27(43.11)	1	1	2
Non-treated control	96.29(82.97)	97.92(84.65)	97.92(82.65)	4	4	4
P value	<0.001	<0.001	<0.001			
L.S.D.	12.41	9.37	13.27			
CV (%)	26.80	21.80	17.50			

*AFT: After first spray, AST: After second spray, ATS after third spray. [#]Value within parentheses are arcsine transformed.

DISCUSSION

Insecticides, Spinosad, Spinetoram and Chlorantraniliprole were consistently found superior on the basis of percent plant infestation with live larvae, percent plant with whorl damage symptom and average foliar damage score. Similar finding was reported by Bajracharya et al (2020) with superior effect of Chlorantraniliprole and Spinetoram in reducing fall armyworm infestation while conducting action research at hot spots of Nawalpur district in 2019 immediately after introduction of fall armyworm in Nepal. Spinetoram, Emamectin benzoate and Chlorantraniliprole were found the most effective in checking larval population and plant and cob damage in India while evaluating various insecticides against the fall armyworm in the field condition (Thakur et al 2020). Nonci et al (2021) reported the most effective insecticide to control fall army were Spinetoram, Emamectin benzoate and Chlorantraniliprole in Indonesia. Chlorantraniliprole and Spinetoram showed acute toxicity against fall armyworm larvae in field and laboratory bioassay in India (Sharanbasappa et al 2024). Similarly, Khanal et al (2024) reported the highest efficacy of Spinetoram followed by Spinosad, while conducting leaf dip laboratory bioassay on third instar of fall armyworm larvae.

In present study also, authors found the Chlorpyrifos + Cypermethrin and Azadirachtin effective against the fall armyworm larvae as compared to control but recorded higher percentage of larval infestation and damage on maize whorl as well as inconsistent effect on the insect. Chlorpyrifos alone was not found effective against fall armyworm larvae but when mixed with the Cypermethrin, additive effect was found against day old fall armyworm larvae (Chandler 2012). Ravikumar et al (2022) reported the maize infestation with fall armyworm persisted even the dose of the Chlorpyrifos 50% + Cypermethrin 5% increased to level of 2500 g active ingredient per hectare from 750 g active ingredient per hectare. Frequent application of insecticides could result in resistance development in fall armyworm (Su et al 2023). The inconsistent result of Chlorpyrifos + Cypermethrin in present study could be due to development of resistance in fall armyworm larvae in Nepal. Yu (1991) reported a strain of fall armyworm from North Florida showed resistance to pyrethroids from 2 to 216 fold and organophosphorus insecticides from 12 to 271 fold and indicated that broad spectrum insecticide resistance observed in fall armyworm in the field level. The higher infestation FAL armyoworm on Azadirachtin treated maize plants in field was also reported in previous finding in Nepal (Bajracharya et al 2020, Sharma et al 2023). Foliar application of Azadirachtin lowers the efficacy of controlling target insect owing to photo-degradation (Acharya et al. 2023).

Fall armyworm is a devastating invasive pest of maize in Nepal. Control strategies could include preventive methods like, monitoring, scouting, installation of traps, cultural control and mechanical controls whereas, curative methods could be biological control and chemical control. Breeding for host plant resistance is an another avenue of fall armyworm management in long term strategy. Various bio-control agents of fall armyworm being reported from Nepal including egg parasitoids *Trichogramma chilonis* and *Telenomus remus* (Elibariki et al 2020). Although mass production technologies for these egg parasitoids are developed by National Entomology Research Center of Nepal Agricultural Research Council, the regional and local mass production laboratories and distribution system of bio-control agents still need to be developed in Nepal (NERC 2023). The chemical management will be an option for a time being to manage the invasive fall armyworm in maize crop in Nepal. The present findings insecticides Spinosad, Spinetoram and Chlorantraniliprole could be judiciously used for curative management of fall armyworm. Spinosad and Spinetoram are insecticides containing spinosyns developed from soil bacterium *Saccharaopolyspora spinosa* with unique mode of action and acts upon nicotinic acetyl choline receptor of insect. Chlorantraniliprole is a anthranilic diamide insecticide which affects the ryanodine receptor of insect muscle system. These unique modes of action of the insecticides makes them different from traditional insecticides like organophosphates, carbamates and synthetic pyrethroids, which will help in delaying resistance development in the insect. These insecticides are not free from resistance development. Moreno et al (2018) reported resistance by fall armyworm against Chlorantraniliprole (160 fold), Spinetoram (14

fold) and Spinosad (8 fold). Thus these insecticides need to be used alternately and judiciously in order resistance development in the fall armyworm.

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REFERENCES

Abrahams P, T Beale, M Cock, N Corniani, R Day, J Godwin, S Murphy, G Richards and J Vos. 2017. Fall armyworm status. Impact and control option in Africa: Preliminary Evidence note. Uk Aid, CABI.

Acharya R, SS Sharma, AK Burman, SM Kim and KY Lperdaee. 2023. Control efficacy of azadirachtin on the fall armyworm, *Spodoptera frugiperda* (J. E. Smith) by soil drenching. Ins. Biochem, Physiology. **113(3)**:Article e22020. **DOI**: https://doi.org/10.1002/arch.22020.

Bajracharya ASR, B Bhat and PN Sharma. 2020. Field efficacy of selected insecticides against fall armyworm, *Spodoptera frugiperda* (J. E. Smith) in Nepal. J. Plant Proct. Soc. **6**:127-133.

Bajracharya ASR, B Bhat and PN Sharma. 2020. Spatial and seasonal distribution of fall armyworm *Spodoptera frugiperda* (J. E. Smith) in Nepal. J. Plant Proct. Soc. **6**:192-201.

Bajracharya ASR, B Bhat, PN Sharma, PR Shashank PR, NM Meshram and TR Hashmi. 2019. First record of fall armyworm *Spodoptera frugiperda* (J. E. Smith) from Nepal. Ind. J. Ent. **81(3)**: 635-639.

Bhat B and ASR Bajracharya. 2022. Biology and life table of fall armyworm *Spodoptera frugiperda* (J.E Smith) on maize. Nep. J Sci. Tech. **21(2)**: 1-8.

Chandeler LD, JL Robertson and HK Preisler. 2012. Effects of combinations of chlorpyrifos and cypermethrin on mortality of corn earworm and fall armyworm (Lepidoptera: Noctuidae) larvae. The Can. Entomologist. **127(1)**: 25-32.

Cruz E, MLA Figueiredo, AC Oliveira and AV Carlos. 1999. Damage of *Spodoptera frugiperda* (Smith) in different maize genotypes cultivated in soil in three different levels aluminum saturation. Int. J. Pest Manage. **45(4)**: 293-296.

Debora M. 2018. Host plant of *Spodoptera furgiperda* (Lepidoptera: Noctuidae) in the Americas. Afr. Ent.. **26(2)**: 286-300.

Elibariki, N, ASRBajrachareya, B Bhat, T Tefera, JL Mottern, G Evans, R Muniappan, Y GC, B Pallangyo, and P Likhayo. 2020. Candidates for augmentative biological control of *Spodoptera frugiperda* (J. E. Smith) in Kenya, Tanzania and Nepal. Ind. J. Ent. **82(4)**:606-608. **DOI**: https://doi.org/doi.org/10.5958/0974-8172.2020.00088.7.

Khanal D, D Subedi, G Banjade, M Lamichhane, S Shrestha and P Chaudhary. 2024. Efficacy of different pesticides against fall armyworm (*Spodoptera frugiperda* (J.E. Smith) Lepidoptera: Noctuidae) under laboratory condition in Rupandehi, Nepal. Int. J. Agron. **2024**:1-9. **DOI**: https://doi.org/10.1155/2024/7140258.

Moreno RG, DM Sanchez, CA Blanco, ME Whalon, HT Santofimio, JC Rodriguez-Maciel and C DiFonzo. 2018. Field-evolved resistance of th fall armyworm (Lepidoptera: Noctuidae) to synthetic insecticides in Puerto Rico and Mexico. J. Econ. Ent. **20(10)**: 1–11.

NERC. 2023. Stock maintenance, methodology development and mass production of bio-control agents. **In**: Annual Report 2022/23. National Entomology Research Center (NERC), Nepal Agricultural Research Council, Khumaltar, Lalitpur, Nepal.**pp**.24-27.

Nonci N, S Pakki and A Muis. 2021. Field efficacy of synthetic insecticides on fall armyworm (*Spodoptera frugiperda* J. E. Smith) in corn plant. **In**: IPO Conf. Series: Earth and Environmental Science. **911**(2021)012059. **DOI**: https://doi.org/10/1088/1755-1315/911/1/012059.

Prasanna BM, JE Huesing, R Eddy and VM Peschke. 2018. Fall armyworm in Africa: A guide for integrated pest management, First edition, CIMMYT, Mexico.

Ravikumar A, VA Kumar and K Basavaraj. 2022. Field bio-efficacey of chloropyrifos 50% + cypermethrin 5% EC against fall armyworm, stem borer and on natural enemy maize during 2021-22 kharif season. Env. Ecol. **40(2A)**: 554-559.

Sharanabasappa D, HB Pavithra, CM Kalleshwaraswamy, BK Shivanna, MS Maruthi and DM Sanchez. 2024. Field efficacy of insecticides for management of invasive fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) on maize in India. Flo. Ent.**103(2)**: 221-227. **DOI**: https://doi.org/10.1653/024.103.0211.

Sharma S, RB Thapa, S Pokhrel, S Neupane, S Tiwari and C Adhikari, 2023. Evaluation on the efficacy of synthetic insecticides for the management of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (lepidoptera: noctuidae) in maize. J. Plant Prot. Soc. **8**:14-21.

Su XN, CY Li and YP Zhang. 2023. Chlorpyrifos and chlorfenapyr resistance in *Spodoptera frugiperda* (Lepidoptera: Noctuidae) relies on UDP-glucuronosyltrnsferases. J. Econ. Ento. **116(4)**:1329-1343. **DOI**: https://doi.org/10.1093/jee/toad088

Thakur RK, MB Zala, HS Varama, CB Dhobi, BN Patel, MB Patel and PK Board. 2020. Evaluation of insecticides against fall armyworm *Spodoptera frugiperda* (J. E. Smith) infesting maize. Int. J. Chem. Studies. **SP8(4)**:100-104.

Yu SJ 1991. Insecticide resistance in the fall armyworm, *Spodoptera frugiperda* (J. E. Smith). Pesticide Biochem. Physiol. **39**: 84-91. **DOI**: https://doi.org/10.1016/0048-3575(91)90216-9.

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