EFFICACY TESTING OF DIFFERENT MICROBIAL AND INSECTICIDES AGAINST ARMYWORM IN DHADING, NEPAL

Susmita lamichhane*, Prakriti Adhikari, Dristi Khanal, Saurav Bastakoti and Shiv Chandra Dhakal
Agriculture and Forestry University, Rampur, Chitwan, Nepal
*Corresponding author: lsusmita41@gmail.com

ABSTRACT

The fall armyworm was reported for the first time in Nepal in 2019 A.D. in Nawalpur district and FAW is widely distributed all over Nepal causing significant damage to maize. The present field experiment was conducted to estimate the "Efficacy of different microbial and insecticides against fall armyworm, *Spodoptera frugiperda* (J.E. Smith) on Maize in Nepal" under field conditions during the Kharif season of 2022 at the research field of Nilkantha municipality, Dhading, Nepal. The experiment was conducted to identify the effective biopesticide for the management of fall armyworm under a Randomized Complete Block Design with four replications of six treatments. The observations were recorded on the total number of live S. frugiperda larvae per plant, leaf damage rating one day before spray and five days, nine days and fourteen days after the spray. The treatments of different insecticides viz., Emamectin Benzoate 5SG, Bacillus thuringensis kurstaki 1% WG, Fipronil 0.6% GR, Poison baits (Spinosad 45% SC+Rice bran+ Jaggery), Azadiractin 1500ppm and control were evaluated against S. frugiperda and revealed that Poison baits (Spinosad 45% SC+Rice bran+ Jaggery) were found most effective treatment in reducing the population of S. frugiperda followed by Emamectin benzoate 5SG.

Keywords: Insect, management, feeding habit, leaf rating, damage, control

Introduction

Fall armyworm (FAW) *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) is a destructive pest native to the Americas (De Groote et al., 2020), recently invaded Nepal and presently causing economic damage to maize. *S. frugiperda* was previously thought to be a single species, but two morphologically indistinguishable host strains have been identified; one strain feeds primarily on maize and sorghum (corn strain), and the other strain feeds primarily on rice and bermudagrass (rice strain) (Clark et al., 2007).

The fall armyworm is active at a different time of year than the true armyworm, another species in the order Lepidoptera and family Noctuidae, but of the genus Mythimna. Outbreaks of the true armyworm usually occur during the early part of the summer; the fall armyworm does the most damage in the late summer in the southern part of the United States, and early fall in the northern regions (Bajracharya et al., 2019)

Larvae cause damage by consuming foliage. Young larvae initially consume leaf tissue from one side, leaving the opposite epidermal layer intact. By the second or third instar, larvae begin to make holes in leaves and eat from the edge of the leaves inward. Feeding in the whorl of corn often produces a characteristic row of perforations in the leaves and defoliation leaving only the ribs and stalk of the corn plant giving torn or ragged appearance. Larval densities are usually reduced to one to two per plant when larvae feed in close proximity to one another, due to cannibalistic behaviours. Older larvae cause extensive defoliation, often leaving only the ribs and stalks of corn plants, or a ragged, torn appearance. Typical symptoms of this pest are young larvae feeding on leaf tissue and making holes in them (Kandel & Poudel, 2020). Generally feeding on the young plant by fall armyworm through whorl may lead to a dead heart. At the reproductive stage of the maize plant, both tassels and maize cobs along with the silk are damaged by the larva of the fall armyworm (Bajracharya et al., 2020). The early whorl stage was found to be the least sensitive to injury, the mid-whorl stage to be intermediate, and the late whorl stage to be the most sensitive to injury. (Marenco et al.,1992) Also, mean densities of 0.2 to 0.8 larvae per plant during the late whorl stage could reduce yield by 5% to 20%. Larvae will also burrow into the growing point (bud, whorl, etc.), destroying the plant's growth potential or clipping the leaves. In corn, they will sometimes burrow into the ear and feed.

Helicoverpa Zea, the corn earworm, feeds on kernels in the same way. In contrast to corn earworm, which feeds down through the silk before attacking the kernels at the tip of the ear, Armyworms feed by burrowing into the husk on the side of the ear. During the reproductive stage of corn, corn ear tissue has a strong positive effect on fall armyworm larval feeding choice and survival, and the feeding site choice appears to be done by first instars. It implies that corn leaves are not appropriate for early instar development in reproductive stage corn. Silk and kernel tissues may also play a role in the survival and development of fall armyworm larvae. Silk appears to provide shelter and an ideal microclimate for early larval development, while kernels appear to have some nutritional value for larval development (Pannuti et al., 2015).

Control/management

Sensing Fall Armyworm infestation before it causes heavy damage is the key to their management and control. Its management should be done cautiously as it is a dangerous pest. Only one method is not sufficient for the control of this pest. The different systems should be integrated to control effectively**.**

Integrated Pest Management for Fall Armyworm. IPM is an integrated pest management strategy that aims to prevent pests and their damage through a combination of techniques such as chemical, biological, and new cropping systems, cultural practices modification, use of resistant varieties, and mechanical methods. Integrated Pest Management (IPM) is a set of practices for managing fall armyworms (FAW) in maize. Different modules have been developed for various maize crops, including grain corn, sweet corn, baby corn, fodder maize, and silage maize. Because FAW infests maize crops as early as the two-leaf stage, different measures are implemented as the crop grows. IPM focuses on growing a healthy crop with as little disruption to agroecosystems as possible in order to encourage natural control mechanisms (Sekhar et al., 2019). IPM emphasizes healthy crop growth with the least amount of disruption to agroecosystems and promotes natural pest control mechanisms. Farmers prefer chemical control over IPM because it is more effective and reduces pesticide use. FAW damage has wreaked havoc. In contrast to Nepal, the pest is in its early stages, so the IPM method of pest control will be the most effective.

Pest management using IPM includes a variety of pest control practices such as cultural, physical, and biological methods which are discussed on the following sections.

Cultural control. Cultural control is one of the methods for pest management using IPM. This is regarded as the best-applied method of crop management, however with no input costs. To practice this method, following procedures are applied;

- Apply enough fertilizer to have a healthy crop so that to stand the pest attack.
- Early plantation of maize is recommended as FAW infestation can get worse on late sowing crops.
- Proper field ploughing prior to maize crop plantation exposes FAW pupa in the soil to birds and predators, reducing the FAW population. By exposing the larvae and pupa during the winter season, they can also be killed. The larvae are unable to withstand freezing temperatures and thus perish.
- Clean cultivation and field sanitation by removing damaged and infested plant parts.

- Intercropping with other crops reduces the infestation of FAW, for example, pigeon
- pea, cassava, sweet potato, sweet pea, beans, pumpkin or green manure crops row by row. Intercropping with pigeon peas should be tested in certain areas.
- No tillage, crop residue retention, and crop rotation can promote the development of beneficial insects (spiders, beetles, ants, beneficial fungi, and bacteria), and these bio-control agents will aid in the control of FAW.
- FAW cannot be controlled by burning crop residues, as is commonly done for other insect pest control.
- Grow a variety of crops at the boundary/periphery of maize fields for biodiversification. This practice will also enhance the abundance of natural enemies to control FAW.
- Grow to increase the abundance of natural enemies. Grow sun hemp, lablab bean, and other pulses in open space to repel pests, reduce oviposition, and reduce FAW infestation.
- If there is a papery window on the leaves, a neem-based pesticide (Azadirachtin 1500 ppm) should be applied.
- Before making recommendations to maize growers, the push-pull strategy using Desmodium as a repellent or pushing the pest away crop and Napier grass as a pull crop should be field tested.
- Push-pull strategy is one of the most important strategies for controlling FAW infestations. In this method, maize is intercropped with pest-repellent Desmodium spp. (Push crop), which is surrounded by pest-attractive grasses Napier Grass, *Pennisetum purpureum* or *Bracharia spp* as pull crops (Neelima et al.,2020).

Mechanical control. Pest management is also made by applying mechanical control method. By applying this method, we can adopt the following procedures;

- Hand-picking egg masses and larvae is also effective but time-consuming.
- Collecting larvae and dropping them into hot water. Killing one caterpillar prevents immediate crop damage and reduces the appearance of over 1500-2000 new larvae in less than four weeks.
- Removing Grassy weeds in maize fields and nearby areas have also been found to be effective, as they harbor the pest.

Chemical control. Chemical pest control refers to the control of pests using chemical pesticides. Due to the high devastating damage of FAW farmers don't think twice to go for chemical application. In IPM, the use of insecticides is not considered good. However, the use of chemicals under the economic threshold does not harm human health excessively. An integrated approach with preventive measures together with biological treatments should be always considered if available. Thresholds for application of control measures may vary according to the area but are usually considered when: egg masses are present on 5 per cent of the plants or 25 per cent of the plant shows damage symptoms and live larvae are still present. Treatments must be applied before larvae burrow deep into the whorl or enter the ear of the mature plants. For the control of FAW pests, different pesticides and insecticides can be available e.g.: Indoxacarb, Emamectin benzoate, flubendiamide, Chlorantraniliprole, Spinosad, Spinetoram etc.

Damage ratings

Leaf damage can be visually rated on 10 randomly selected plants from each plot in the field on the following scale.

Table 1

Indicating leaf damage rating scale

Explanation/definition of damage	Ratings
No visible damage	0
Only pin-hole damage	1
Pin-hole and small circular hole damage to leaves	2
Pinholes, small circular lesions and a few small elongated (rectangular-shaped) lesions of up to 1.3 cm in length are present on whorl and furl leaves.	3
Several small to mid-sized 1.3 to 2.5 cm in length elongated lesions present on a few whorls and furl leaves	4
Several large elongated lesions greater than 2.5 cm in length present on a few whorls and furl leaves and/or a few small- to midsized uniform to irregular-shaped holes (basement membrane consumed) eaten from the whorl and/or furl leaves.	5
Several large elongated lesions are present on several whorls and furl leaves and/or several large uniforms to irregular-shaped holes eaten from furling and whorl leaves.	6
Many elongated lesions of all sizes are present on several whorls and furl leaves plus several large uniforms to irregularly shaped holes eaten from the whorl and furl leaves.	7
Many elongated lesions of all sizes are present on most whorl and furl leaves plus many mid- to large-sized uniform to irregular-shaped holes eaten from the whorl and furl leaves.	8
Whorl and furl leaves are almost totally destroyed	9

(Toepfer et al., 2021)

Materials and Methods

The study on "Efficacy of different microbial and insecticides against fall armyworm, Spodoptera frugiperda (J. E. Smith) on Maize in Nepal" was conducted under field condition during Kharif - 2022 at research field of Nilkantha municipality, Dhading, Nepal. The experiment was conducted in a randomized block design (RBD) with six treatments including untreated control with four replications using the Arun-2 variety of maize. The maize crop was sown on 20 March 2022 in a net plot of 3.6 m x 3 m. The row-to-row distance of 60 cm and plant-to-plant distance of 25 cm were maintained. The crop was grown under irrigated conditions with all recommended packages of practices recommended by Krishi Dairy, Lalitpur including the dose of fertilizer at the rate of 120 kg N, 60 kg P2O5 and 60 kg K2O per hectare, except plant protection. The treatments of different insecticides and microbial viz., Emamectin Benzoate 5SG, Bacillus thuringensis kurstaki 1% WG, Fipronil 0.6% GR, Poison baits (Spinosad 45% SC+Rice bran+ Jaggery), Azadiractin 1500ppm and control were evaluated against S. frugiperda and subsequent sprays were given at 15 days interval using Battery operated knapsack sprayer. The observations were recorded on the number of live larvae per plant, and leaf damage ratings on one day before spray and five days, Nine days and fourteen days after the spray. These observations of live larvae were taken based on the appearance of fresh excreta in leaf whorl and damage rating was done according to "Davis 0 to 9 whorl and furl damage scale." The data were analysed statistically for interpretation.

Results and discussion

S. frugiperda is one of the most intriguing variables affecting maize production today. It is well known for posing economic risks, causing yield losses, and incurring substantial management expenses (Sileshi et al.,2022). Worldwide, the bug posed a serious danger to stable food security, and prompt treatment of the insect was essential.

The research was conducted in Nilakantha Municipality, Dhading district. Various morphological, floral and metrical measurements were recorded and subjected to analysis using statistical tools like MS-Excel and R. The results obtained are discussed below.

Larval Population. The result shows that the average live larval population per plant was found to be highly influenced by the application of treatments on all days after spray.

First spray. On 5th day after the first spray, the lowest larval population was found with Spinosad (0.23) which was statistically at par with Emmamectin benzoate (0.43) and Bacillus Thuringensis (0.38). Azadirachtin (0.78) was also found effective in reducing the fall armyworm larval population while the largest larval population was found in control (3.30). Similar results were obtained at 9 days after first spray, with the lowest larval population by Spinosad (0.20) and Bacillus thuringensis (0.41) followed by Emamectin benzoate (0.45) and Azadiractin (0.68) while the highest larval population was found in control (3.40) followed by fipronil (1.15)

Similarly, Spinosad was found continuously superior at reducing the larval population at 9 days after the first spray with a 94.45% reduction rate which was followed by Bacillus thuringensis and Emamectin benzoate with a reduction rate of 88.50% and 86.65% respectively. Likewise, the population reduction of larva with fipronil (70.09%) was found to be the least among all treatments at 9 days after the first spray.

Table 1

Effect of different microbial and insecticides on larva population after the first spray

Treatment	Larva Population				
	1DBT	5DAT	PROC	9DAT	PROC
Emmamectin benzoate 5SG	3.60	0.43^{d}	86.94	0.45^{cd}	86.68
Bacillus Thuringensis kurstaki 1%WG	3.73	0.38^{d}	89.17	0.41^{de}	88.50
Fipronil 0.6% GR	4.00	1.13^{b}	71.19	1.15^{b}	70.09
Poison baits (Rice bran+jaggery+ Spinosad 45% SC)	3.40	0.23^{d}	93.17	0.20^{e}	94.45
Azadiractin 1500 PPM	3.68	0.78^{c}	78.03	0.68^{c}	80.63
Control	3.53	3.30^{a}		3.40^{a}	
$SE_m(\pm)$		0.03		0.03	
LSD(α=0.05)	NS	0.20		0.22	
F-test		***		***	
CV,%		13.21		14.44	
Grand Mean		1.040		1.047	

Note: DBT means Days Before Treatment, DAT means Days After first Treatment, CV: coefficient of variation; DAS: days after sowing; NS Non-significant; SE_m standard error of the mean; *-significance level at 5% probability level, **- significance level at 1% probability level, ***- significance level at 0.1% probability level; LSD (0.05): Least significant difference at 5% level of significance same letter indicates the similar effect.

Second spray. The result shows that the average live larval population per plant was found to be highly influenced by the application of treatments on all days after spray (Table 6).

At 5th day after the second spray, the lowest larval population was found with Spinosad (0.19) which was statistically at par with Emamectin benzoate (0.35) and Bacillus Thuringensis (0.35). Azadiractin (0.38) were also found equally effective in reducing fall armyworm larval population while the largest larval population was found in control (3.53). Similar results were obtained at 9 days after the second spray, with the lowest larval population by Spinosad (0.14) and Bacillus thuringensis (0.30) at par with Azadiractin (0.30) followed by Emamectin benzoate (0.39) while the highest larval population was found in control (3.55) followed by fipronil (0.79).

Similarly, Spinosad was found continuously superior at reducing the larval population at 9 days after the second spray with an 89.03% reduction rate which was followed by Bacillus thuringensis and Emamectin benzoate with a reduction rate of 80.65% and 73.87% respectively. Likewise, the population reduction of larva with fipronil (52.67%) was found to be the least among all treatments at 9 days after the second spray.

The effectiveness of Spinosad on larval mortality was found similar to Cruz et al.,2011 and Sharma et al.,2021. Similar studies testing the effectiveness of pesticides in field and laboratory circumstances to control FAW have been carried out all over the world, including in China, Africa, Brazil, and India, and they revealed that FAW is susceptible to synthetic pesticides. however, Spinosad and Emamectin benzoate cause the highest mortality compared to other synthetic pesticides (Idrees et al., 2022). According to Cook et al.,2004, Spinosad has been identified as the most effective pesticide with the maximum mortality of FAW larvae within a relatively short period of time.

Table 2

Effect of different microbial and insecticides on larva population after the second spray

Treatment	Larva Population				
	2DBT	5DAT$_2$	PROC	9DAT$_2$	PROC
Emmamectin benzoate 5SG	1.42^{bc}	0.35^{c}	77.03	0.39^{c}	73.87
Bacillus Thuringensis kurstaki 1%WG	1.44^{bc}	0.35^{c}	77.22	0.30^{cd}	80.65
Fipronil 0.6% GR	1.60^{b}	0.89^{b}	46.69	0.79^{b}	52.67
Poison baits (Rice bran+jaggery+ Spinosad 45% SC)	1.25^{c}	0.19^{d}	85.58	0.14^{d}	89.03
Azadiractin 1500 PPM	1.55^{bc}	0.38^{c}	76.96	0.30^{cd}	81.42
Control	3.33^{a}	3.53^{a}		3.55^{a}	
SE_m (±)	0.041	0.066		0.03	
LSD(α=0.05)	0.31	0.14		0.22	

F-test	***	***	***
CV	11.68	10.51	16.15
Grand Mean	1.76	0.94	0.90

Note: DBT means Days Before Treatment, DAT means Days After Treatment, DAT_2 means Days After Second Treatment; CV: coefficient of variation; DAS: days after sowing; NS Non-significant; SE_m standard error of mean; *-significance level at 5% probability level, **-significance level at 1% probability level, ***- significance level at 0.1% probability level; LSD (0.05): Least significant difference at 5% level of significance same letter indicates the similar effect.

Damage ratings. Leaf damage inflicted by FAW larva was found significantly different in the First and second rounds of spraying. The non-treated plants have an extensive injury as compared to the plots treated with insecticides and microbial.

First spray. After 5 days of the first spray, the Damage rating of the leaf was found least at the plot sprayed with Spinosad (2.2) which is statistically similar to Emamectin benzoate, BT and Azadiractin and the highest leaf rating was found in control (4.82). Similarly, after 9 days of the first spray, the least damage rating was found in the plot treated with Spinosad (2.32) which is statistically similar to Emamectin benzoate (2.225) and Bacillus thuringensis (2.225) followed by fipronil and azadiractin and highest damage rating was found in control (4.625).

Second spray. After 5 days of the second spray, the Damage rating of the leaf was found least at the plot sprayed with Spinosad (0.40) which is statistically similar to Bacillus thuringensis (0.75) and statistically par with Emamectin benzoate(0.80). Azadiractin(1.10) and fipronil(1.80) were also found effective and the highest leaf rating was found in control(2.92). Similarly, after 9 days of the second spray, the least damage rating was found in plots treated with Spinosad (0.25). Azadirachtin (0.65) was found statistically similar to Emamectin benzoate (0.55) and BT (0.525) followed by fipronil (1.45) and the highest damage rating was found in control (3.3). A similar result was also found in research conducted by Sisay et al.,2019.

Table 3

Effect of microbial and insecticide on damage ratings of leaf after first and second spray

Treatment	Damage Rating					
	1 DBT	5 DAT	9 DAT	$1DBT_2$	$5DAT_2$	$9DAT_2$
Emmamectin benzoate 5SG	3.875	2.2^{c}	2.225^{c}	1.275	0.80^{cd}	0.55^{c}
Bacillus Thuringensis kurstaki 1%WG	4	2.5^{c}	2.225^{c}	1.225	0.75^{d}	0.525^{c}
Fipronil 0.6% GR	4	2.8^{b}	2.575^{b}	2.25	1.80^{b}	1.45^{b}
Poison baits (Rice bran+jaggery+ Spinosad 45% SC)	3.8	2.2^{c}	2.325^{c}	0.625	0.40^{e}	0.25^{d}

Azadiractin 1500 PPM	3.75	2.55[c]	2.575[b]	1.775	1.10[c]	0.65[c]
Control	4.075	4.825[a]	4.625[a]	2.475	2.925[a]	3.3[a]
SE_m(±)	0.040	0.135	0.085	0.045	0.0439	0.026
LSD(α=0.05)	NS	1.002	0.200	0.332	0.324	0.195
F-test		***	***	***	***	***
CV	5.113	24.21	4.82	13.74	16.62	11.598
Grand Mean	3.91	2.74	2.75	1.60	1.29	1.12

Note: DBT means Days Before Treatment, DAT means Days After Treatment, DAT_2 means Days After Second Treatment; CV: coefficient of variation; DAS: days after sowing; NS Non-significant; SE_m standard error of mean; *-significance level at 5% probability level, **-significance level at 1% probability level, ***- significance level at 0.1% probability level; LSD (0.05): Least significant difference at 5% level of significance same letter indicates the similar effect.

Conclusions

Fall armyworm is the most serious threat to maize production in Dhading, Nepal. Farmers are found to use chemical pesticides haphazardly for their management which causes adverse effects on the plant, soil, human health and environment realizing this an experiment on the efficacy of different microbial and insecticides for the management of fall armyworms was conducted. From this experiment, it was observed that the maximum reduction of fall armyworm population over control as well as maximum increase in yield was found in Spinosad-treated plots. Bacillus thuringensis and Emamectin benzoate were effective next to Spinosad for both pest control and high yield. Azadirachtin was also significant in reducing pest population so can be recommended as an effective biological pesticide at a higher frequency of application. Spinosad proved to be the most cost-effective with a high population reduction over the control percentage followed by Bacillus thuringensis, Emamectin benzoate, and Azadiractin respectively. The present study concluded that among the six treatments, all the insecticide treatments were more effective than the control in reducing the fall armyworm, S. frugiperda. Where poison baits (Spinosad 40%SC+ Jaggery+ Rice bran) were found extremely effective for control of larval population on Maize.

References

Bajracharya, A. S. R., BhAt, B., Sharma, P., Shashank, P. R., Meshram, N. M., & Hashmi, T. R. (2019). First record of fall armyworm Spodoptera frugiperda (JE Smith) from Nepal. *Indian Journal of Entomology, 81*(4), 635-639.

CABI, (2019). Spodoptera frugiperda (fall armyworm). *Invasive Species Compendium.*

Clark, P. L., Molina-Ochoa, J., Martinelli, S., Skoda, S. R., Isenhour, D. J., Lee, D. J., ... & Foster, J. E. (2007). Population variation of the fall armyworm, Spodoptera frugiperda, in the Western Hemisphere. *Journal of Insect Science, 7*(1).

Cook, D. C., Gardiner, P. S., & Spafford, H. (2021). What will fall armyworm (Lepidoptera: Noctuidae) cost Western Australian agriculture, *Journal of Economic Entomology, 114*(4), 1613-1621.

Cruz, I., Figueiredo, M. D. L. C., Silva, R. B. D., Silva, I. F. D., Paula, C. D., & Foster, J. E. (2012). Using sex pheromone traps in the decision-making process for pesticide application against fall armyworm (Spodoptera frugiperda [Smith][Lepidoptera: Noctuidae]) larvae in maize. *International Journal of Pest Management, 58*(1), 83-90.

De Groote, Hugo & Kimenju, Simon & Munyua, Bernard & Palmas, Sebastian & Kassie, Menale & Bruce, Anani. (2020). Spread and impact of fall armyworm (Spodoptera frugiperda J.E. Smith) in maize production areas of Kenya. Agriculture Ecosystems & Environment. 292. 10.1016/j.agee.2019.106804.

Idrees, A., Qadir, Z. A., Afzal, A., Ranran, Q., & Li, J. (2022). Laboratory efficacy of selected synthetic insecticides against second instar invasive fall armyworm, Spodoptera frugiperda (Lepidoptera: Noctuidae) larvae. *Plos one, 17*(5), e0265265.

Kandel, S., & Poudel, R. (2020). Fall armyworm (Spodoptera Frugiperda) in maize: an emerging threat in Nepal and its management. *International Journal of Applied Sciences and Biotechnology, 8*(3), 305-309.

Marenco, R. J., Foster, R. E., & Sanchez, C. A. (1992). Sweet corn response to fall armyworm (Lepidoptera: Noctuidae) damage during vegetative growth. *Journal of Economic Entomology, 85*(4), 1285-1292.

Neelima, C., Nameirakam, L., Devi, Y. K., & Scholar, M. (2020). The invasive fall armyworm Spodoptera frugiperda (JE Smith)(Lepidoptera: Noctuidae) in Maize, status and infestation taken control under sustainable management: A Review. *Journal of Emerging Technologies and Innovation Research, 7*(12), 1459-1471.

Pannuti, L. E. R., Baldin, E. L. L., Hunt, T. E., & Paula-Moraes, S. V. (2016). On-plant larval movement and feeding behaviour of fall armyworm (Lepidoptera: Noctuidae) on reproductive corn stages. *Environmental Entomology, 45*(1), 192-200.

Sekhar, J. C., Soujanya, P. L., & Suby, S. B. (2019). Feed The Future India Triangular Training (FTF ITT) Program International Training Program on

"Integrated Management Strategies for Major Crop Pests & Diseases in Developing Countries"(With a special focus on Fall Army Worm).

Sileshi, A., Negeri, M., Selvaraj, T., & Abera, A. (2022). Determination of most effective insecticides against maize fall armyworm, Spodoptera frugiperda in South Western Ethiopia. *Cogent Food & Agriculture*, *8*(1), 2079210.

Sisay, B., Tefera, T., Wakgari, M., Ayalew, G., & Mendesil, E. (2019). The efficacy of selected synthetic insecticides and botanicals against fall armyworm, Spodoptera frugiperda, in maize. *Insects*, *10*(2), 45.

Toepfer, S., Fallet, P., Kajuga, J., Bazagwira, D., Mukundwa, I. P., Szalai, M., & Turlings, T. C. (2021). Streamlining leaf damage rating scales for the fall armyworm on maize. *Journal of Pest Science*, *94*(4), 1075-1089.