Available online freely at www.isisn.org

Bioscience Research

Print ISSN: 1811-9506 Online ISSN: 2218-3973

Journal by Innovative Scientific Information & Services Network

RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2024 21(3):571-584. **OPEN ACCESS**

Field efficacy of some new chemistry insecticides for management of Invasive Fall armyworm, Spodoptera Frugiperda (*Lepidoptera: noctuidae*) on Maize Crop

Shehroz Mehmood Ali Butt[1], Wajeeha Altaf[2], Muhammad Mahboob Haider[3], Zaid Rasheed[4], Irslan Ali[5], Hasil Khan[6], Talib Hussain[7], Muhammad Jamshed Iqbal[8], Sartaj Aziz[9], Muhammad Rashid[1]and Muhammad Usman[1]

[1]Department of Entomology, University of Agriculture Faisalabad, **Pakistan**
[2]Department of Zoology, Wildlife and Fisheries, University of Agriculture Faisalabad, **Pakistan**
[3]Institute of Agronomy, Bahaudin Zakariya University Multan, Punjab, **Pakistan**
[4]Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, **Pakistan**
[5]Scientific officer Floriculture Program, Horticultural Research Institute, National Agriculture Research Centre, Islamabad, **Pakistan**
[6]PARC- Mountain Agricultural Research Centre Gilgit, **Pakistan**
[7]Department of Entomology, PMAS Arid Agriculture University Rawalpindi, **Pakistan**
[8]Department, Agricultural Engineering, University, Khwaja Fareed University of Engineering and Information Technology Rahim Yar Khan Punjab, **Pakistan**
[9]Department of Agronomy, University of Agriculture Faisalabad, **Pakistan**

***Correspondence:** usman6053@gmail.com **Received: July 22, 2024, Revised: August 14, 2024, Accepted: August 20, 2024 e-Published: August 26, 2024**

Maize is 3rd main cereal crop in Pakistan, after wheat and rice. The *Spodoptera frugiperda* (J.E. Smith) (fall armyworm) deteriorates the crop as well as plays a role in the reduction of the crop. The study was performed in the Entomological Research Area, Department of Entomology, University of Agriculture Faisalabad, to determine the comparative toxicity of different formulations of new chemistry insecticides against maize fall armyworm. All the treatments were replicated three times under a Randomized Complete Block Design (RCBD). Results showed that Radiant 120 SC (Spinetoram 80ml/acre) gives 46.66.73.33, 80 and 86,66% mortality after 3, 7, 14 and 21 days of treatment application. Results of Ferterra 0.4% G (Chlorantraniliprole, 6kg/Acre) give 53.33, 60, 60 and 66.66% mortality after 3, 7, 14 and 21 days of treatment application. Results of Virtako 40 WG (Thiamethoxum+Chlorantraniliprole, 60gm/Acre) gives 40.46.66, 60 and 66.66% mortality after 3, 7, 14and 21 days of treatment application Results also showed that Coragen (Chlorantraniliprole,100 ml/Acre) gives80, 80, 86.66 and 86.66% mortality after 3, 7, 14 and 21 days of treatment application. Results of Volium flexi 300 *SC* (Thiamethoxam+ Chlorantraniliprole 80 ml/ Acre) give 53.33, 60, 73.33 and 80% mortality after 3, 7, 14 and 21 days of treatment application. Results of Match 5% EC (Lufenuron, 240 ml/Acre) 73.33, 80, 80 and 93.33% mortality after 3, 7, 14 and 21 days of treatment application and results of Xtall 43.6% *EC* (Triazophos + Indoxacarb + Lufenuron, 400 ml/Acre) gives 40, 53.33, 60 and 66.66% mortality after 3, 7, 14 and 21 days of treatment application. Results of Amplio 150 ZC (Lambda-cyhalothrin+ Chlorantraniliprole120ml/Acre*)* showed the highest mortality 86.66% after21 days of treatment application. Results of Radiant showed that the highest mortality was 86.66% after 21 days of treatment application and results of Feterra showed the highest mortality was 93.33% after 21 days of treatment application. The percent infested plant results showed Virtako 53.33%, Volium Floxi 66.66%, Proclaim 73.33%, Match 60%, Xtall 80% and Ampligo 46.66% respectively. It is concluded that *S. frugiperda* can be controlled in the field conditions and helpful in increasing of GDP of Pakistan as well as also contribute to the maize industry by providing good quality maize.

Keywords: New Chemistry, Invasive Fall Armyworm, Maize Crop, Field Efficacy

INTRODUCTION

Maize is one of the most widely grown grain crops because of its great value. Therefore, steady food and its seeds are used for animal feed, fuel, and also used for construction purposes. In terms of calorie consumption maize is a very significant staple crop in Asian rural households (Abebe and Feyisa, 2017). After wheat and rice, maize is the third-most significant grain crop in Pakistan. It adds 2.9 % to agricultural value. On maize in the field, more than 40 different insect species have been identified. Long-recognized significant insect pests include the maize stalk borer (Busscolafusca), spotted stalk borer, shoot fly (*Chilo partellus*), and numerous termite species (*Macrolermes and Microtermes spp*.), but a more recent invasive species, *Spodoptera frugiperda*, also known as fall armyworm, is now the major insect pest causing significant yield losses of maize (Tula and Ketema, 2016).

The FAW is therefore a nomadic and polyphagous insect pest that if allowed to spread may devastate a huge spectrum of crop kinds (Meagher *et al*., 2013). It takes roughly 30 days to finish its development throughout the summer, but 60 days during the Autumn, Spring, , and 80 to 90 days in the winter (Capincra, 2000). The *Spodoptera frugiperda* is the invasive pest of maize crop. It belongs to order of Lepidoptera. The life cycle lasts approximately 35 days, in the spring and fall, 62 days, and in the winter, 81 to 92 days. The number of generations that exist in a certain area change according to the appearance of the dispersed adults. This species is incapable of going into diapause. (John and Capinera, 2017).

In insects like *Spodoptera littoralis* multiple researchers suggest that methoxy fenoride was successfully adopted to understand the toxicity of certain insecticides (Spinosad, Abamectin, and Cypermethrin) (Pineda *et al*., 2006). To find out the most effective and suitable new chemistry insecticides for the control of fall armyworm, we used Spinetoram, Neonicotinoids, *Chlorantraniliprole,* Fipronil, Abamectin, Thiamethoxam, and Flubendiamide. In this experiment, we used to find the most effective and suitable new chemistry insecticides for the control of fall armyworms and to evaluate the impact of insecticides on biological control agents in maize crops.

MATERIALS AND METHODS

The current study was carried out in the field at the University of Agriculture Faisalabad's Entomological Research Area. The research study was conducted from September 2021 to March 2022, to evaluate the toxicity of different formulations of new chemistry insecticides against *Spodoptera frugiperda.*A maize hybrid variety was sown in September under Randomized Complete Block Design (RCBD) with 7 inches plant-to-plant distance and 30-inch row-to-row distance. Standard cultural practices were adopted to maintain crop. Nine insecticides with field-recommended doses were evaluated for their efficacy, as shown below:

Nine new chemistry insecticides were used singly under field conditions. These insecticides were purchased from the local market of Faisalabad. Each insecticide treatment was replicated three times. Pre-treatment data was recorded before the application of insecticides in respective plots. Reduction in infestation data was observed0,1.3,7,14 and 21 days after treatment. Plants were randomly selected from each replication and observed on the top, middle and bottom leaf respectively. In control treatment, no insecticide was applied.

The plants from each replication plot were randomly selected from the middle rows. Fall armyworm-infested plants were observed randomly from plants in a row.

Table 1: Layout of the Research

Treatments	Formulations	Active ingredients	Dose /acre
T1	Ferterra 0.4% *G*	Chlorantraniliprole	6 kg
T2	Virtako 40 *WG*	Thiamethoxum+ Chlorantraniliprole	60gm
T3	Coragen 20% *SC*	Chlorantraniliprole	100ml
T4	Match 5% *EC*	Lufeneron	240ml
T5	Radiant 120 *SC*	Spintoram	80ml
T6	Proclaim 1.9 *EC*	Emamectin benzoate	240ml
T7	Xtall 43.6 *EC*	Triazophos + Indoxacarb + Lufenuron	500ml
T8	Volium flexi 300 *SC*	Thiamethoxum+ Chlorantraniliprole	80ml
T9	Ampligo 150 ZC	Lambda -cyhalothrin+ Chlorantraniliprole	120ml
T10	Control		

The number of infested whorls were observed for larval infestation and percent mortality was calculated with the following formula.

Formula:

$$(\%) \text{ Population reduction formula } = \frac{\text{No. of dead larvae}}{\text{Total larvae}} \times 100$$

Impact of insecticides on biological control agents:

For observation of insecticides impact on biological control agent's population, maize field inspection was started after treatment of insecticides, and five plants were randomly selected from each plot and number of biological control agents (C*hrysoperlacarnea, Coccinellaseptempuntata*, etc) was counted at 3,7,14 and 21 days intervals.

Data analysis:

Mortality data was analysed by using statistical software for the analysis of Variance

(ANOVA). Tukey's HSD at α = 5% significant level was used to compare the treatment means.

RESULTS AND DISCUSSION

Population reduction of *S. frugiperda* against Ferterra (6kg/Acre) after 0,1,3,7,14 and 21 days

The results indicated that besides untreated checks which cosidered as zero highest population of larvae rate was seen in treatment 1 Ferterra (6kg/acre) after three days 90.66%. The larval population decreased by Ferterra and gave 22.51% after 7 days,19.88% after 14 days and 17.21% after 21 days. The result also showed that the lowest larval population was recorded after 14 and 21 days, 19.88%, 17.21%, significantly different from all other treatments.

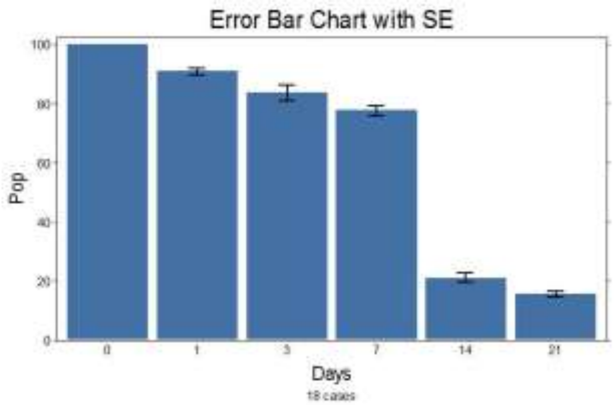

Figure 1: Mean comparisons of larval population reduction of *S. frugiperda* against ferterra (6kg/acre) after 0,3,7,14 and 21 days. bars with different time intervals show significant differences at α:0.05(Tuckey's HSD test).

Population reduction of *S. frugiperda* against virtako (60gm/Acre) after 0,1,3,7,14 and 21 days

The results indicated that besides untreated checks which considered as zero highest population of larvae rate was seen in treatment 2 virtako (60gm/Acre)after three days 90.21%. The larval population decreased by virtako and gave 43.51% after 7 days,21.16% after 14 days and 20.41% after 21 days. Results also showed that the lowest larval population was recorded after 14 and 21 days 29.88% 17.21%, significantly different from all other treatments.

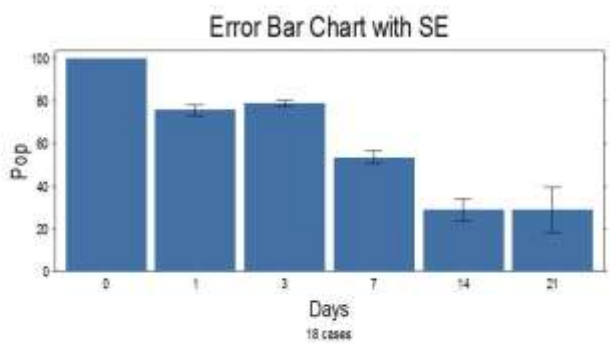

Figure 2: Mean comparisons of larval population reduction of *S. frugiperda* against virtako (60gm/acre) after 0,3,7,14 and 21 days. bars with different time intervals show significant differences AT α:0.05(Tuckey's HSD test).

Population reduction of *S. frugiperda* against coragen (240ml/Acre) after 0,1,3,7,14 and 21 days

The results indicated that besides untreated checks which considered zero highest population of larvae rate was seen in treatment 3 coragen (240ml/Acre)after 14 and 21 days 44.21% and 42.54%, The larval population decreased by coragen and gave 25.73% after 3 days,21.16% after 7 days.Result also showed that lowest larval population was recorded after 3 and 7 days 20.73% 19.16% that was significantly different from all other treatments.

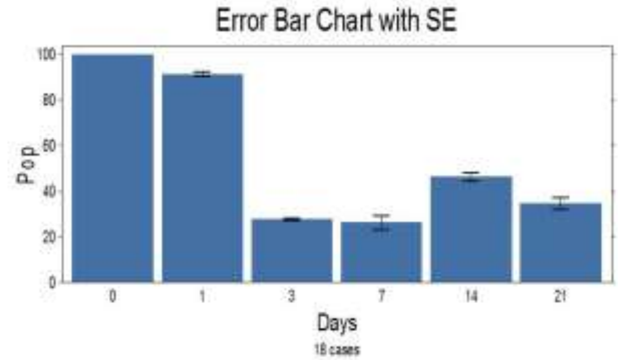

Figure 3: Mean comparisons of larval population reduction of *S. frugiperda* against coragen (240ml/Acre) after 0,3,7,14 and 21 days. bars with different time intervals show a significant difference at α:0.05(Tuckey's HSD test).

Population reduction of *S. frugiperda* against Match (240ml/Acre) after 0,3,7,14 and 21 days

The results indicated that besides untreated checks which are cosidered as zero highest population of larvae rate was seen in treatment 4 match (240ml/Acre)after 14 and 21 days 49.31% and 42.54%. The larval population decreased by coragen and gave 25.73% after 3 days,21.16% after 7 days. Results also showed that the lowest larval population was recorded after 3 and 7 days 29.73% 25.16%, significantly different from all other treatments.

Figure 4: Mean comparisons of larval population reduction of *S. frugiperda* against Match (240ml/Acre) after 0,3,7,14 and 21 days.

Population reduction of *S. frugiperda* against Proclaim (240ml/Acre) after 0,1,3,7,14 and 21 days

The results indicated that besides untreated checks which considered as zero highest population of larvae rate was seen in treatment 5 proclaim (240ml/Acre)after 14 and 21 days 39.21% and 44.54% . The larval population decreased by proclaim and gave 25.73% after 3 days,21.16% after 7 days.Result also showed that the lowest larval population was recorded after 3 and 7 days 23.43% 20.77% that was significantly different from all other treatments.

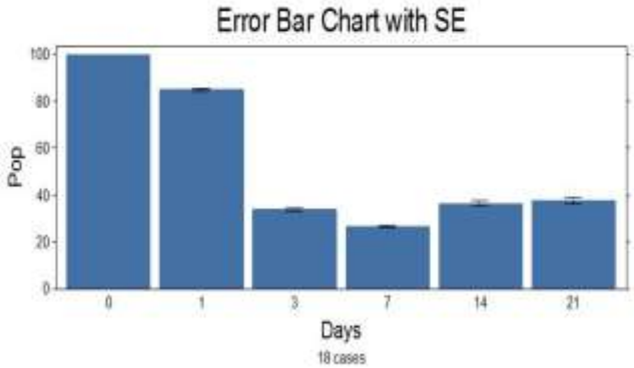

Figure 5: Mean comparisons of larval population reduction of *S. frugiperda* against Proclaim (240ml/Acre) after 0,3,7,14 and 21 days.

Population reduction of *S. frugiperda* against Radient (80ml/Acre) after 0,1,3,7,14 and 21 days

The results indicated that besides untreated checks which considered as zero highest population of larvae rate was seen in treatment 6 radiant (80ml/Acre)after 14 and 21 days 43.71% and 45.54%. The larval population decreased by radiant and gave 25.73% after 3 days,21.16% after 7 days. Result also showed that lowest larval population was recorded after 3 and 7 days 10.22% 8.41% that was significantly different from all other treatments.

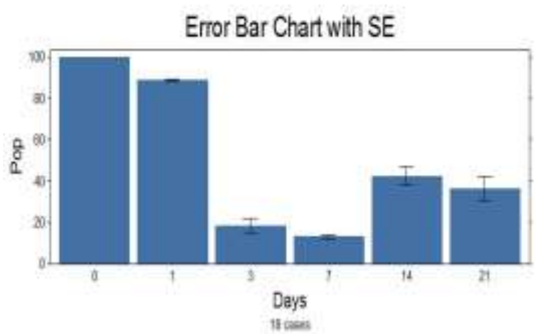

Figure 6: Mean comparisons of larval population reduction of *S. frugiperda* against Radient (80ml/Acre) after 0,1,3,7,14 and 21 days.

Population reduction of *S. frugiperda* against Volium flexi (80ml/Acre) after 0,1,3,7,14 and 21 days

The results indicated that besides untreated checks which cosidered as zero highest population of larvae rate was seen in treatment 7 volium flexi (80ml/Acre)after 14 and 21 days 44.21% and 42.54% . The larval population decreased by volium flexi and gave 25.73% after 3 days,21.16% after 7 days.Result also showed that lowest larval population was recorded after 3 and 7 days 31.37% 25.16% that was significantly different from all other treatments.

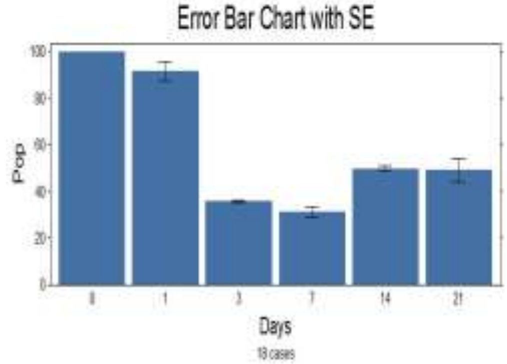

Figure 7: Mean comparisons of larval population reduction of *S. frugiperda* against Volium flexi (80ml/Acre) after 0,3,7,14 and 21 days.

Population reduction of *S. frugiperda* against Xtall (500ml/Acre) after 0,1,3,7,14 and 21 days

The results indicated that besides untreated checks which cosidered as zero highest population of larvae rate was seen in treatment 8 xtall (500ml/Acre)after 14 and 21 days 43.22% and 46.54% . The larval population decreased by coragen and gave 25.73% after 3 days,21.16% after 7 days. Results also showed that the lowest larval population was recorded after 3 and 7 days 35.44% 26.49%, significantly different from all other treatments.

Figure 8: Mean comparisons of larval population reduction of *S. frugiperda* against Xtall (500ml/Acre) after 0,1,3,7,14 and 21 days.

Population reduction of *S. frugiperda* against Ampligo (120ml/Acre) after 0,1,3,7,14 and 21 days

The results indicated that besides untreated checks which are cosidered as zero highest population of larvae rate was seen in treatment 9 Ampligo (240ml/Acre)after

14 and 21 days 47.21% and 62.54% . The larval population decreased by coragen and gave 25.73% after 3 days,21.16% after 7 days.Result also showed that the lowest larval population was recorded after 3 and 7 days 29.41% 25.76% that was significantly different from all other treatments.

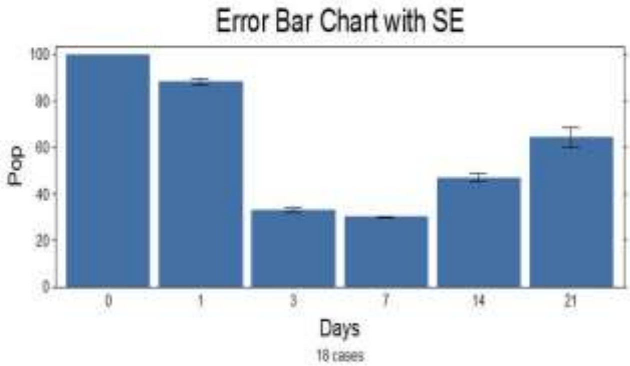

Figure 9: Mean comparisons of larval population reduction of *S. frugiperda* against Ampligo (120ml/Acre) after 0,3,7,14 and 21 days.

Alive (%) of biological control against ferterra after 3, 7, 14 and 21 days

The results showed that besides untreated check minimum Alive percentage was seen in treatment (ferterra) after 3 days 66.66%. The alive percentage increase of ferterrawas 73.33% after 7 days, 73.33% after 14 days and 80% after 21 days.Results also showed that maximum alive percentage was recorded after 14 days 73.33% and 21 days 80% that was significantly different from all other treatments.

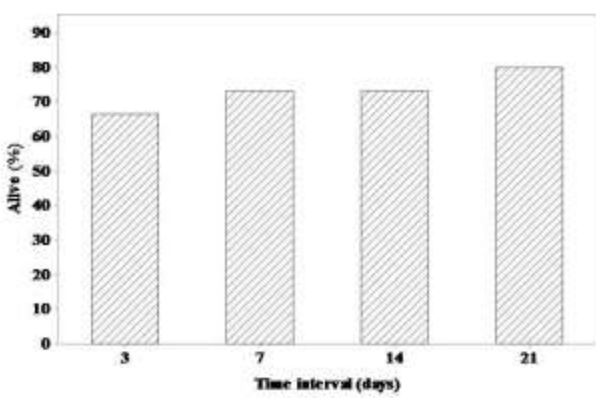

Figure 10: Mean comparisons of alive (%) of biological control agents against ferterra after 3, 7, 14 and 21 days.

Alive (%) of biological control agents against Volium Floxi 300 SC after 3, 7, 14 and 21 days

The results showed that besides untreated check minimum alive percentage was seen in treatment (Volium Floxi) after 3 days 60%. The alive percentage increase of Volium Floxi gave 66.66% after 7 days, 66.66% after 14 days and 80% after 21 days.Results also showed that maximum alive percentage was recorded after 21 days 80% which was significantly different from all other treatments.

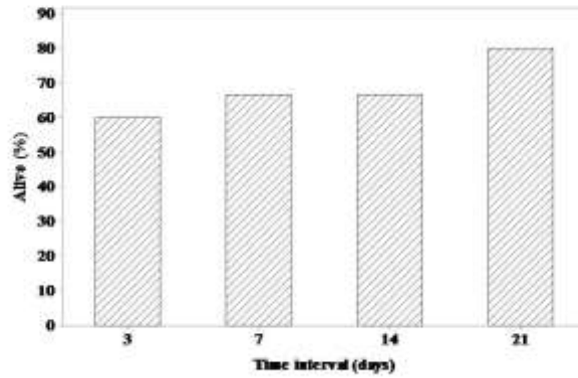

Figure 11: Mean comparisons of alive (%) of biological control agents against Volium Floxi after 3, 7, 14 and 21 days.

Alive (%) of biological control agentsagainst Coragen 200 SC after 3, 7, 14 and 21 days

The results showed that besides untreated check minimum Alive percentage was seen in treatment (Coragen) after 3 days 46.66%. The alive percentage increase of Coragen gave 60% after 7 days, 73.33% after 14 days and 86.66% after 21 days.Results also showed that maximum alive percentage was recorded after 14 days 73.33% and 21 days 86.66% which was significantly different from all other treatments.

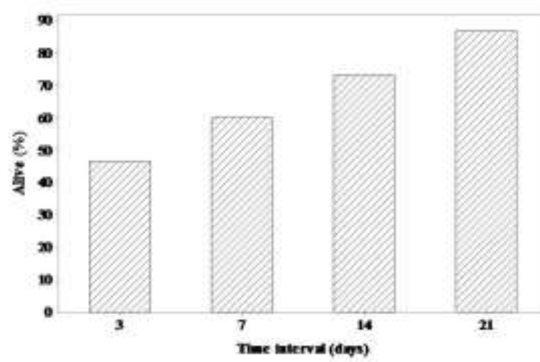

Figure 12: Mean comparisons of alive (%) of biological control agents against Coragen after 0,1,3, 7, 14 and 21 days.

Alive (%) of biological control agents against Proclaim 1.9 EC after 3, 7, 14 and 21 days

The results showed that besides untreated check minimum Alive percentage was seen in treatment (Proclaim) after 3 days 53.33%. The alive percentage increase of Proclaim gave 60% after 7 days, 66.66% after 14 days and 73.33% after 21 days.Results also showed that maximum alive percentage was recorded after 14 days 66.66% and 21 days 73.33% that was significantly different from all other treatments.

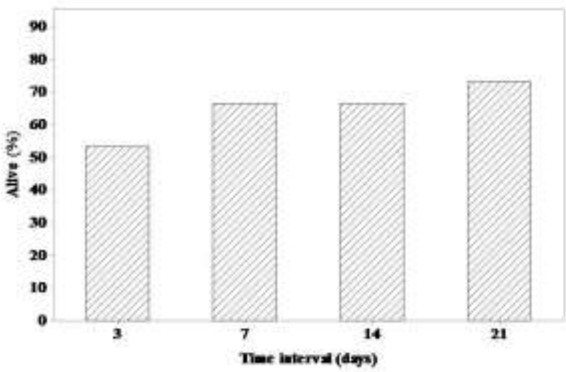

Figure 13: Mean comparisons of alive (%) of biological control agents against Proclaim after 3, 7, 14 and 21 days.

Alive (%) of biological control agentsagainst Radiant after 3, 7, 14 and 21 days

The results showed that besides untreated check minimum Alive percentage was seen in treatment (Radiant) after 3 days 53.33%. The alive percentage increase of Radiant gave 60% after 7 days, 73.33% after 14 days and 80% after 21 days.Results also showed that maximum alive percentage was recorded after 14 days 73.33% and 21 days 70% that was significantly different from all other treatments.

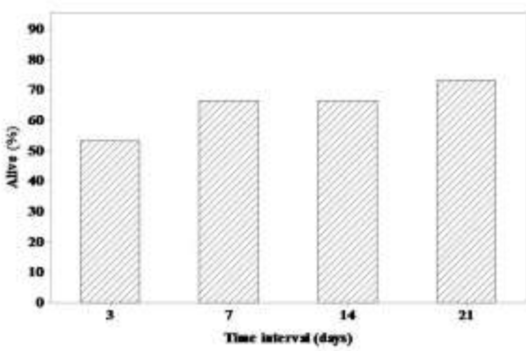

Figure 14: Mean comparisons of alive (%) of biological control agents against Radiant after 3, 7, 14 and 21 days.

Alive (%) of biological control against Ampligo after 3, 7, 14 and 21 days

The results showed that besides untreated check minimum Alive percentage was seen in treatment (Ampligo**)** after 3 days 60%. The alive percentage increase of Belt gave 80% after 7 days, 93.33% after 14 days and 100% after 21 days.Results also showed that maximum alive percentage was recorded after 14 days 93.33% and 21 days 100% that was significantly different from all other treatments.

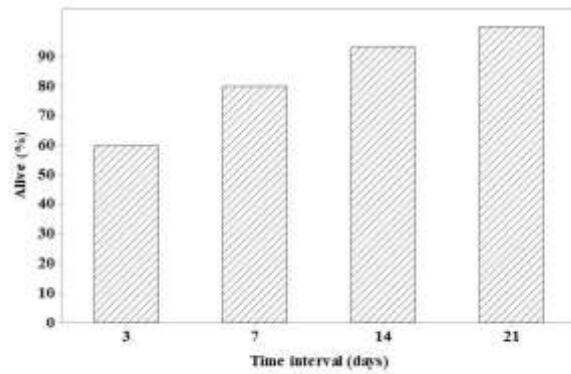

Figure 15: Mean comparisons of alive (%) of biological control agents against Ampligo after 3, 7, 14 and 21 days.

Alive (%) of biological control agentsagainst Match after 3, 7, 14 and 21 days

The results showed that besides untreated check lowest alive percentage was seen in treatment (Sega Pest Clear) after 3 days 40%. The alive percentage increase of Match gave 46.66% after 7 days, 53.33% after 14 days and 60% after 21 days.Results also showed that maximum alive percentage was recorded after 14 days 53.33% and 21 days 60% that was significantly different from all other treatments.

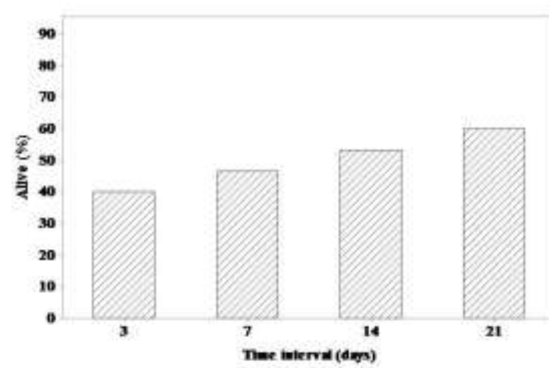

Figure 16: Mean comparisons of alive (%) of biological control agents against Match Clear after 3, 7, 14 and 21 days.

Alive (%) of biological control agents against Virtako after 3, 7, 14 and 21 days

The results showed that besides untreated check minimum Alive percentage was seen in treatment (Virtako) after 3 days 60%. The alive percentage increase of Belt gave 80% after 7 days, 93.33% after 14 days and 100% after 21 days.Results also showed that maximum alive percentage was recorded after 14 days 93.33% and 21 days 100% that was significantly different from all other treatments.

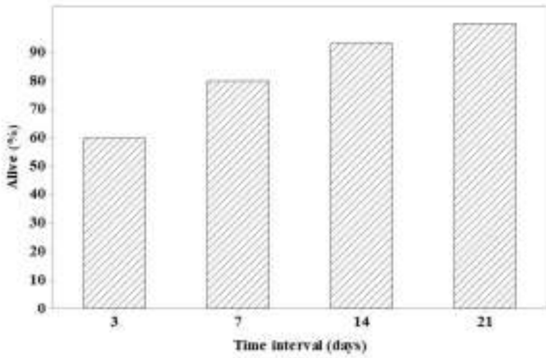

Figure 17: Mean comparisons of alive (%) of biological control agents against Virtako after 3, 7, 14 and 21 days.

Alive (%) of biological control agentsagainst Xtall after 3, 7, 14 and 21 days

The results showed that besides untreated check lowest Alive percentage was seen in treatment (Xtall) after 3 days 40%. The alive percentage increase of Sega Pest Clear gave 46.66% after 7 days, 53.33% after 14 days and 60% after 21 days. Results also showed that maximum alive percentage was recorded after 14 days 53.33% and 21 days 60% that was significantly different from all other treatments.

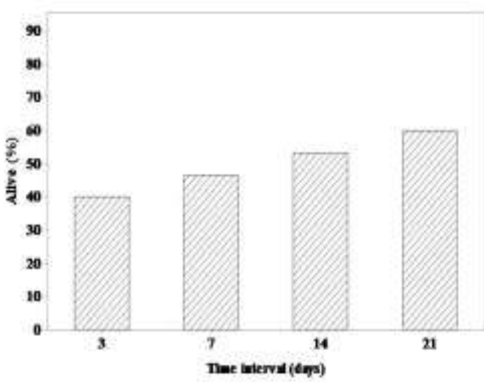

Figure 18: Mean comparisons of alive (%) of biological control agents against Xtall Clear after 3, 7, 14 and 21 days.

Mean comparison of mortality (%) of *S. Frugiperda* against ferterra and Virtako after 3, 7, 14 and 21 days

The results showed that besides untreated check highest mortality was seen in treatment 1 (Ferterra) 29.33%, 33%, 80 and 81.66% after 3, 7, 14 and 21 days respectively. The maximum mortality (%) was seen in treatment 1 (ferterra) 36.42%, 40.33%, 76% and 78.32% after 3, 7, 14 and 21 days respectively.Results also showed that maximum mortality (%) was recorded of Feterra 80 and 81.66% after 14 and 21 days. But minimum mortality (%) was recorded of Virtako 76% and 78.66% after 14 and 21 days as compared to Ferterra.

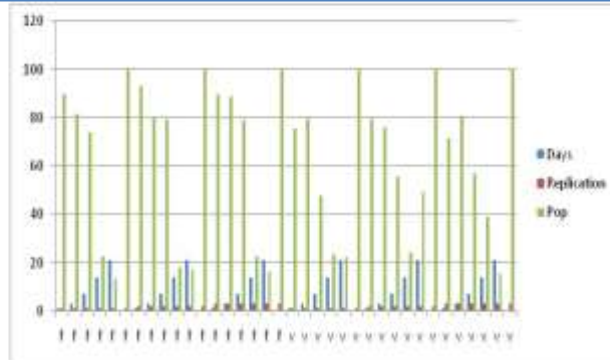

Figure 19: Mean comparison of population reduction against Ferterra (f) and Virtako (v) after 3,7,14 and 21 days.

Mean comparison of mortality (%) of *S. frugiperda*against Radiant and coragen after 3, 7, 14 and 21 days

The results showed that besides untreated check highest mortality was seen in treatment 1 (Radiant) 83.33%, 82.41%, 36.42% and 40.66% after 3, 7, 14 and 21 days respectively. The maximum mortality (%) was seen in treatment 1 (Radiant) 83.33%, 82.41%, 36.42% and 40.66% after 3, 7, 14 and 21 days respectively. Results also showed that maximum mortality (%) was recorded of Radiant 83.33% and 82.41% after 3 and 7 days. But minimum mortality (%) was recorded of coragen 79% and 78.66% after 3 and 7 days as compared to Radiant.

Comparisons of analysis of variance of population reduction (%) of *S. frugiperda* against Ferterra and Virtako after 3,7,14, and 21 days of treatment application

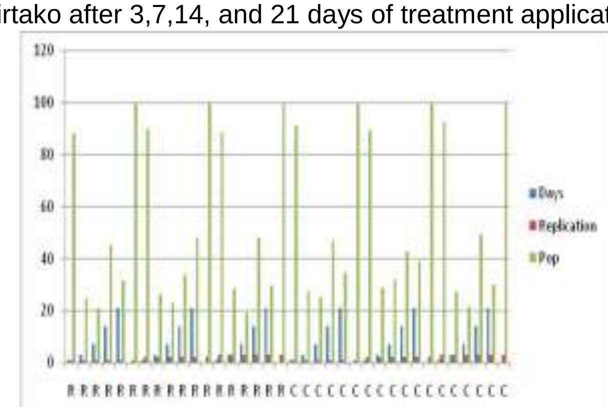

Figure 20: Mean comparisons of population reduction against Radiant (R) and Coragen (C) after 3,7,14 and 21 days.

Mean comparison of mortality (%) of *S. frugiperda*against Match (M) and Volium flexi (VF) after 3, 7, 14 and 21 days

The results showed that besides the untreated check highest mortality was seen in treatment 1 (Volium flexi) 79.33%, 75%, 35.67% and 43.66% after 3, 7, 14 and 21 days respectively. The maximum mortality (%)

was seen in treatment 1 (volium flexi) 79.33%, 75%, 35.67% and 43.66% after 3, 7, 14 and 21 days respectively. Results also showed that maximum mortality (%) was recorded of volium flexi 79.33% and 75% after 3 and 7 days. But minimum mortality (%) was recorded of match 75% and 76.66% after 3 and 7 days as compared to Ferterra.

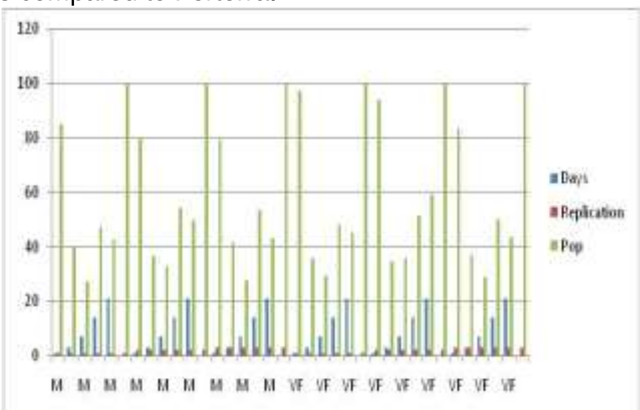

Figure 21: Mean comparisons of population reduction against Match (M) and Volium flexi (VF) after 3,7,14 and 21 days.

DISCUSSION

The research was to determine the comparative toxicity of different formulations of new chemistry insecticides against maize fall armyworm (*Spodoptera frugiperda*) under field conditions. In the present study, nine different insecticides, Ferterra 0.4 G, Virtako 40 WG, Coragen 20% SC, Match 5% EC, Radiant120 SC, Proclaim 1.9 EC, Xtall 43.6 EC, Volium flexi 300 SC and Ampligo150ZC were evaluated to check the comparative toxicity against *S. frugiperda* under field conditions. Results showed that mortality (%) of fall armyworm were different against the toxicity of ferterra gives 89.66, 90.33%, 19.66 and 21.33%, Volium Floxi gives 53.33, 60, 60 and 66.66%, match 25.33, 22.64%, 46% and 49.51%, gives Proclaim gives 21%, 19.76%, 39.33% and 41.75% xtall 39.33, 60, 60 and 66.66%, and 66.66%, Coragen gives 20.83%, 18.22%, 86.66 and 87%, Radiant gives 10.33, 8.73% 43% and 32.71% %, virtako gives 80,93.33, 23.67 and 25.31% and ampligo gives 40, 53.33, 60 and 66.66% mortality after 3, 7, 14 and 21 days of treatment application respectively.

This study was correlated with Hardke et al. (2011) conducted experiments of laboratory toxicity and field toxicity of selected insecticides against fall armyworm (FAW). Four newly produced insecticides (Chlorantraniliprole, Cyantraniliprole, Flubendiamide, and Spinetoram) as well as five randomly selected insecticides were tested in these trials. These results suggest that modern insecticides are as effective as conventional insecticides against fall armyworms. New chemistry insecticides were most beneficial due to their low LC_{50} values as compared to new Pyrethroids.

Similar with Mallapur et al. (2019) performed a laboratory and field evaluation of new insecticide formulations against *S. frugiperda* on maize. According to laboratory findings, spinetoram 11.7 SC and Emamectin benzoate 5 SG were better than other treatments with mortality at 60 hrs after treatment. Spinoteram, Emamectin Benzoate and Spinosad 45 SC were all found to be substantially superior to all other treatments in the field study with the larval decreases of 98.13, 96.26 and 96.26% respectively at 7 days after treatment implementation. Thiamethoxam 0.25%WG and Fipronil 0.5 SC were also the least productive of the insecticides studied, with infant mortality of 68.65 and 73.14% respectively. Results were significant from all used formulations. Similar findings were observed with Deshmukh et al. (2020) assessing the effectiveness of insecticides in the field for the control of invasive fall armyworm. Insecticides with distinct modes of action were tested by leaf-dip methods for controlling second-instar larvae. With a per leaf dip bioassay, Emamectin benzoate exhibited the greatest toxicity accompanied by Chlorantraniliprole, Spinetoram, Indoxacarb, Flubendiamide, Lambda-cyhalothrin and Novaluron. These findings suggest that Chlorantraniliprole, Emamectin benzoate and Spinetoram are effective fall armyworm pest management elements. Results were also similar to Zhao et al. *(*2020) concluded the susceptibility of *S. frugiperda* towards eight Chinese insecticides with a specific lambda-cyhalothrin. In this experiment, the sensitivity of fall armyworms to eight insecticides was evaluated using a synthetic diet implementation strategy. Emamectin Benzoate, Spintoram, Chlorantraniliprole, Chlorfenpyr and Lufenuron were reported to have greater efficacy against this pest than Lambda-cyhalothrin and Azadirachtin. Insecticides show variable degree of toxicity. Fourth larval instar fed by maize plant whorls showed higher toxicity of Emamectin Benzoate, Spintoram, Chlorantraniliprole, Chlorfenpyr and Lufenuron after 48 and 72 hours respectively. The findings would help in the development of effective insecticides and the control of *S. frugiperda*. In the present research, several insecticides were examined to evaluate the efficacy against *S. frugiperda* in the field. Similar results was observed with Shinde et al. (2021) tested various whorl applications for the management of *S. frugiperda*. There were nine whorls included Carbofuran 3G 33 Kg/ha, Ash 35 kg/ha, Sand + Lime (9:1) 62 kg/ha, Entomopathogenic nematode 5 Kg/ha, Poison bait (Wheat bran 10 Kg + Jaggary 2 Kg + 3 lit. Water + Thiodicarb 100 g) 44 kg/ha, *Beauveria bassiana* 2.5 kg/ha, *Metarhizium anisopliae* 2.5 kg/ha, *Nomuraearileyi* 2.5 kg/ha was laid out in Randomized Block Design with three replications along with untreated control.

Results also correlated with El-Sayed A. and El-Sheikh (2015) compared the toxicity and sublethal effects of Emamectin Benzoate, Lufenuron and

Spinosad on *Spodoptera littoral*. When Emamectin Benzoate, Lufenuron, and Spinosad were used together, they produced exaggerated and contradicting results, indicating that a single application of these insecticides is more beneficial than a combination. Emamectin benzoate killed 3rd and 5th instar *S. littoralis* larvae qiucker than Lufenuron and Spinosad, significantly decreased adaptive response and nutritional damage in 3rd instar larvae and induced 100 percent mortality in 5th instar larvae throughout larval growth. These findings suggest that in comparison to Lufenuron and Spinosad, Emamectin benzoate is a helpful chemical for controlling *S. littoralis*. Bhatnagar et al. (2013) examined the toxicity of insecticide against *Spodoptera litura*. At LC_{50}, Indoxacarb was 66.32 times more hazardous than Cartap hydrochloride after 24 hours. At 24 hours and 48hours, Indoxacarb (66.32, 82.5) >Flubendiamide (11.45, 49.5) Cartap hydrochloride and at 72hours Flubendiamide (118.33) > Indoxacarb (71). Cartap hydrochloride, Flubendiamide and Indoxacarb respectively. Having low LC_{50} Findings was also correlated with Sharan abasa ppa et al. (2021) evaluating the field trial to see how effective pesticides are in controlling the invasive fall armyworm, *S. frugiperda* on maize. The leaf-dip method revealed that Emamectin benzoate 5 SG had the largest toxicity by Chlorantraniliprole 18.5 SC and Spinetoram 11.7 SC, while the leaf-dip method revealed that the toxicities of Flubendiamide 480 SC, indoxacarb 14.5 SC, lambda-cyhalothrin5 EC, and novaluron10 EC were comparable. The most effective pesticides were Chlorantraniliprole 18.5 SC, Emamectin benzoate 5 SG, Spinetoram 11.7 SC, Flubendiamide 480 SC, indoxacarb 14.5 SC, lambda-cyhalothrin 5 EC, and novaluron 10 EC, according to the results of field efficiency for two sowing dates (Jun and Sep sown crop). Abdullah et al. (2019) assessed the effectiveness of certain insecticides against Spodoptera litura in fodder crops, they found similar results. Used two common insecticides Emamectin benzoate and Lufenuron of all larval instars of *S. litura* after 48 hours of application. Emamectin benzoate provided the control 69-91% and Leufenuron 70-85% and 79.32% reduced the larval population in the application of Emamectin benzoate and 73.55% with the application of Leufenuron reduction occurred in the laboratory as well as in field on the prevailing in stars in two fodder crops Lucerne and alfalfa. The current investigation was compared to a maize study conducted by Suthar et al. (2020) to assess the bio efficacy of granular insecticides against Spodoptera frugiperda.. Fall armyworm in corn was tested with eight different granular insecticides. The analysis indicates that whorl applications of Fipronil 0.6 % GRand Chlorantraniliprole 0.4 GR 20 kg/ha, applied first at the first sign of fall armyworm and then again after 15 days were successful in reducing larval population plant damage and cob injury as well as increasing grain and grain yield.

CONCLUSIONS

The research was to determine the comparative toxicity of different formulations of new chemistry insecticides against maize fall armyworm (*Spodoptera frugiperda*) under field conditions. In the present study, nine different insecticides, Ferterra 0.4 G, Virtako 40 WG, Coragen 20% SC, Match 5% EC , Radiant120 SC, Proclaim 1.9 EC, Xtall 43.6 EC,Volium flexi 300 SC and Ampligo150ZC were evaluated to check the comparative toxicity against *S. frugiperda* under field conditions. Results showed that mortality (%) of fall armyworm were different against the toxicity of ferterra gives 89.66, 90.33%, 19.66 and 21.33%, Volium Floxi gives 53.33, 60, 60 and 66.66%, match 25.33, 22.64%, 46% and 49.51%, gives Proclaim gives 21%, 19.76%, 39.33% and 41.75% xtall 39.33, 60, 60 and 66.66%, and 66.66%, Coragen gives 20.83%, 18.22%, 86.66 and 87%, Radiant gives 10.33, 8.73% 43% and 32.71% %, virtako gives 80,93.33, 23.67 and 25.31% and ampligo gives 40, 53.33, 60 and 66.66% mortality after 3, 7, 14 and 21 days of treatment application respectively.

Supplementary materials

The supplementary material / supporting this article can be found online and downloaded from Google Scholar, Research Gate.

Author contributions

Shehroz Mehmood Ali Butt designs the research and conducts the research trials. The remaining authors contribute equally to data collection and analysis.

Funding statement

This study was supported by None,

Institutional Review Board Statement

The study was approved by the Bioethical Committee of Agriculture University Faisalabad.

Informed Consent Statement

Not applicable.

Data Availability Statement

All of the data is included in the article/Supplementary Material.

Acknowledgments

We thank all authors for their contribution in this manuscript.

Conflict of interest:

The authors declare no conflict of interest.

Publisher's note/Disclaimer

All claims stated in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher. ISISnet remains neutral with regard to jurisdictional claims in published maps and institutional affiliations. ISISnet and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.

Peer Review: ISISnet follows double blind peer review policy and thanks the anonymous reviewer(s) for their contribution to the peer review of this article.

REFERENCES

Abdullah, A., M.I. Ullah, A. Raza, M. Arshad, M. Afzal, S. Ali, N. Altaf and N. Mehmood. 2019. Testing Efficacy of Selected Insecticides against *Spodoptera litura* (Lepidoptera: Noctuidae) in Fodder Crops and Effects on Beneficial Insects. Egypt. Acad. J. Biol. Sci. 12(6):81-90.

Abd-ur-Rahman, M.M.Z., A.Raza, M.S. Mushtaq, Z. Hussain, M.A. Sabri, and S. Ahmed. 2017. Evaluation of oxidative stress induced by insecticides on *Brassica oleracea* infested with *Spodoptera litura*. Nat. Sci. *15*:54-60.

Abebe, Z. and H. Feyisa, 2017. Effects of nitrogen rates and time of application on yield of maize: rainfall variability influenced time of N application. Int. J. Agron.13(6):60-65.

Abrahams, P., M. Bateman, T. Beale, V. Clottey, M. Cock, Y. Colmenarez, N. Corniani, R. Day, R. Early, J.L. Godwin, J. Gomez, P. Gonzalez-Moreno, S.T. Murphy, B. Oppong-Mensah, N. Phiri, C. Pratt, G. Richards, S. Silvestri and A. Witt. 2017. Fall Armyworm: Impacts and implications for Africa. CABI, UK.

Ahmad, M., M.A.Saleem and A.H. Sayyed. 2009. Efficacy of insecticide mixtures against pyrethroid and organophosphate-resistant populations of *Spodoptera litura* (Lepidoptera: Noctuidae). Pest Manag. Sci. 65(3):266-274.

All, J.N. 1988. Fall armyworm (Lepidoptera: Noctuidae) infestations in no-tillage cropping systems. Fla.Entomol. 268-272.

Al-Sarar, A., F.R. Hall and R.A. Downer, 2006. Impact of spray application methodology on the development of resistance to cypermethrine and spinosad by fall armyworm *Spodopterafrugiperda*. Pest Manag. Sci. Pesti. Sci. 62:1023-1031.

Anonymous, 2020. Ministry of finance. GOP.http://www.finance.govt.pk/survey 2019-20.

Asi, M.R., M.H. Bashir, M. Afzal, K. Zia and M. Akram. 2013. Potential of entomopathogenic fungi for biocontrol of *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae). J Anim Plant Sci. 23(3):913-918.

Assefa, F. and D. Ayalew. 2019. Status and control measures of fall armyworm (*Spodoptera frugiperda*) infestations in maize fields in Ethiopia: A review. **Cogent food** agric. 5(1), 1641902.

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

Barr, W.B. 1988. Following febrile convulsions in infancy to subsequent temporal. Current Bibliographies in Medicine. Fla. Entomol. 90:1-10.

Barrera-Cubillos, G.P., Gómez-Valderrama, J. A., and Rivero, L.F.V. 2017. Efficacy of microencapsulated nucleopolyhedroviruses from Colombia as biological insecticides against Spodoptera frugiperda (Lepidoptera: Noctuidae). *Acta Agronómica*, *66*(2):267-274.

Baudron, F., Zaman-Allah, M. A., Chaipa, I., Chari, N., and P. Chinwada. 2019. Understanding the factors influencing fall armyworm (*Spodoptera frugiperda*JE Smith) damage in African smallholder maize fields and quantifying its impact on yield. A case study in Eastern Zimbabwe. Crop Prot.120:141-150.

Belay, B.K. 2011. Genetic variability and gene flow of the fall armyworm *Spodoptera frugiperda* (J.E. Smith) in the western hemisphere and susceptibility to insecticides. Entomol. Res. 272-278.

Bhatti, S. S., M. Ahmad, K. Yousaf, and M. Naeem. 2013. Pyrethroids and new chemistry insecticides mixtures against *Spodoptera litura* (Noctuidae: Lepidoptera) under laboratory conditions. Asian J. Agric. Biol, *1*(2):45-50.

Capinera, J. L. 2000. Fall armyworm, *Spodoptera frugiperda* (J.E Smith) (Insecta: Lepidoptera: Noctuidae). The University of Florida, Institute of Food and Agricultural Sciences.(UF/IFAS), Gainesville, FL.5(2):35-250

Chen, J. Jiang, W. Hu, H. Ma, X. Li, Q. X. Song, X. Ren and Ma, Y. (2019). Joint toxicity of methoxyfenozide and lufenuron on larvae of *Spodoptera exigua* Hübner (Lepidoptera: Noctuidae). J. Asia Pac. Entomol. *22*(3):795-801.

Chimweta, M. Nyakudya, I.W. Nyakudya, L. Jimu, and A.B. Mashingaidze. 2020. Fall armyworm *Spodoptera frugiperda* (J.E Smith) damage in maize: management options for flood-recession cropping smallholder farmers. Int. J. Pest Manag.*66*(2):142-154.

Chourdakis, M., Kraus, M.M. Tzellos, T. Sardeli, C. Peftoulidou, M. Vassilakos, D. and D, Kouvelas. 2012. Effect of early compared with delayed enteral nutrition on endocrine function in patients with traumatic brain injury: an open-labeled randomized trial. J Parenter. Enteral. Nutr, 36:108-116.

Cole, L.M. R. A. Nicholson,and J. E. Casida. 1993. Action of phenylpyrazole insecticides at the GABA-gated chloride channel. *Pesticide Biochemistry and Physiology*.*46*1:47-54.

Cook, D.R., B.R. Leonard and J. Gore. 2004. Field and laboratory performance of novel insecticides against armyworms. Fla. Entomol. 87:433-439.

Deshmukh, S., H.B. Pavithra, C.M. Kalleshwaraswamy, B.K. Shivanna, M.S. Maruthi and D. Mota-Sanchez. 2020. Field efficacy of insecticides for management of invasive fall armyworm, *S. frugiperda* on maize in India. Fla. Entomol. 103:221-227.

Durmuşoğlu, E., A.,Hatipoğlu, M.O Gürkan and G.Moores. 2015. Comparison of different bioassay methods for determining insecticide resistance in European Grapevine Moth, Lobesiabotrana (Denis &Schiffermüller) (Lepidoptera: Tortricidae). *Turkish Journal of Entomology*, *39*(3):271-276.

Ebbinghaus, D., H.J. Schnorbach, and A. Elbert. 2007. Field development of flubendiamide (Belt®, Fame®, Fenos®, Amoli®)-a new insecticide for the control of lepidopterous pests. *Pflanzenschutz-Nachrichten Bayer 60*(2):219-246.

Ehler, L. 1998. Conservation biological control: past, present, and future. In Conservation biological control (pp. 1-8). AP.

El-Sheikh, E.S.A. 2015. Comparative toxicity and sublethal effects of emamectin benzoate, lufenuron and spinosad on Spodoptera littoralisBoisd.(Lepidoptera: Noctuidae). Crop Protection.*67*:228-234.

Fernandes, F.O., J.A. Abreu, L.M. Christ, A.F. da Silva, A.P.S.A., da Rosa, L.C. Belarmino, and J.F. Martins.2019. Impact of fall armyworm (Lepidoptera: noctuidae) in the performance of corn crops associated to insecticides in lowland environment. J. Agric. Sci. 11(18):155-165.

Fisher, M.H., and H. Mrozik. 1992. The chemistry and pharmacology of avermectins. Annual Review of Pharmacology and Toxicology. *32*(1):537-553.

Gilal, A.A., L. Bashir, M. Faheem, A. Rajput, J.A. Soomro, S. Kunbharr and J.G.M. Sahito, 2020. First record of invasive fall armyworm (*Spodoptera frugiperda*) in corn fields of Sindh, Pakistan. Pak. J. Agri. Res. 33(2):247.

Gomez, J., J. Guevara, P. Cuartas, C. Espinel and L. Villamizar, 2013. Microencapsulated *Spodoptera frugiperda*nucleopolyhedrovirus, insecticidal activity and effect on arthropod populations in maize. Biocontrol Sci. Technol. 23:829-846.

Gómez, J., J. Guevara, P. Cuartas, C. Espinel, and L. Villamizar 2013. Microencapsulated Spodoptera frugiperdanucleopolyhedrovirus: insecticidal activity and effect on arthropod populations in maize. Biocontrol Sci Technol .*23*(7):829-846.

Guillebeau, L.P., and J.N. All.1991. Use of pyrethroids, methomyl, and chlorpyrifos to control fall armyworm (Lepidoptera: Noctuidae) in whorl stage field corn, sweet corn, and sorghum. Fla. Entmol. 261-270.

Guo, J., S. Zhang, F. Huang, C.He.K. D. Babendreier, and Z. Wang. 2020. Prospects for microbial control of the fall armyworm *Spodoptera frugiperda*: A review on biocontrol. *65*(6): 647-662.

Gutierrez-Moreno, R., D. Mota-Sanchez, C.A. Blanco, M.E. Whalon, H. Teran-Santofimio, J.C. Rodriguez-Maciel and C. Difonzo, 2019. Field-evolved resistance of the fall armyworm (Lepidoptera: Noctuidae) to synthetic insecticides in Puerto Rico and Mexico. J. Econ. Entomol. 112(2):792-802.

Hardke, J.T., J.H. Temple, B.R. Leonard and R.E. Jackson, 2011. Laboratory toxicity and field efficacy of selected insecticides against fall armyworm. Fla. Entomol. 272-278.

Harrison, R.D., C. Thierfelder, F.Baudron, P. Chinwada, C. Midega, U. Schaffner, andJ.van den Berg. 2019. Agro-ecological options for fall armyworm (Spodoptera frugiperda JE Smith) management: Providing low-cost, smallholder friendly solutions to an invasive pest. J. Environ. Manage. *243*:318-330.

Hofer, D., and F. Brandl, 1999. Cruiser/Adage performance features of thiamethoxam as a seed treatment in worldwide cotton. In Proceedings.

Hruska, A.J. 2019. Fall armyworm (Spodoptera frugiperda) management by smallholders. CAB *Rev*, 14(043):1-11.

Ishaaya, I., 2002. Ecologically sound plant protection technologies. Pest Manag. Sci. 58:1089.

Jeschke, P. and R. Nauen, 2008. Neonicotinoids from to hero in insecticide chemistry. Pest Manag. Sci. 64:1084-1098.

Jing, W.A.N., C.HUANG, C.Y. LI, H.X. ZHOU, Y.L. REN, Z.Y. LI, and F. H. WAN, 2021. Biology, invasion and management of the agricultural invader: Fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae). J. Integr. Agric.*20*(3):646-663.

Johnson, S.J. 1987. Migration and the life history strategy of the fall armyworm, *Spodoptera frugiperda* in the western hemisphere. *International Journal of Tropical Insect Science*, 8(4-5-6):543-549.

Karuppaiah, V., C. Srivastava, S. Subramanian, and P.Čupr. 2017. Variation in insecticide detoxification enzymes activity in Spodoptera litura (Fabricius) of different geographic origin. *J. Entomol. Zool. Stud*, *5*(3):770-773.

Khan, R.R., S. Ahmed, and S. Nisar, 2011. Mortality responses of *Spodoptera litura* (Fab.)(Lepidoptera: Noctuidae) against some conventional and new chemistry insecticides under laboratory conditions. Pak. Entomol. *33*(2):147-150.

Kumela, T., J. Simiyu, B. Sisay, P.Likhayo, E. Mendesil, L. Gohole, and T. Tefera. 2019. Farmers' knowledge, perceptions, and management practices of the new invasive pest, fall armyworm (*Spodoptera frugiperda*) in Ethiopia and Kenya.Int. J. Pest Manag.*65*(1): 1-9.

Lahm, G.P., D. Cordova, and J.D. Barry.2009. New and selective ryanodine receptor activators for insect control. Bioorganic & medicinal chemistry.17(12):4127-4133.

Lahm, G.P., T.M. Stevenson, T.P. Selby, J.H. Freudenberger, D. Cordova, L. Flexner and Rynaxypyr, 2007. A new insecticidal anthranilic diamide that acts as a potent and selective ryanodine receptor activator. Bio. Med. Chem. Lett. 17:6274-6279.

Lasota, J.A., and R.A Dybas, 1990. Abamectin as a pesticide for agricultural use. Acta Leidensia. *59*(1-2):217-225.

Mallapur, C.P., A.K. Naik, S. Hagari, T. Praveen, and M.Naik. 2019. Laboratory and field evaluation of new insecticide molecules against fall armyworm, Spodoptera frugiperda (J.E Smith) on maize. J. Entomol. Zool. Stud.*7*(4):869-875.

Marcon, P.J., K. Heldreth, G. Hannig, M. Ziegler, B. Stanley, L. Flexner, and A. Lund, 2007. DuPont™ Rynaxypyr™ global baseline susceptibility program: Foundation for proactive susceptibility management of a selective insecticide in a novel chemical class and mode of action.13(6):576-740

Marcon, P.J., K. Heldreth, G. Hanning, M. Ziegler, B. Stanley and L. Flexner, 2007. Foundation for proactive susceptibility management of a selective insecticide in a novel chemical class and mode of action. ESA Ann. Meet. 32-676.

Matova, P.M., C.N. Kamutando, C. Magorokosho, D.Kutywayo, F. Gutsa, and M. Labuschagne, 2020. Fall-armyworm invasion, control practices and resistance breeding in Sub-Saharan Africa. Crop Science60(6): 2951.

Meagher, R.L., R.N. Nagoshi, J.S. Armstrong, J. Niogret, N.D. Epsky, and K.L Flanders. 2013. Captures and host strains of fall armyworm (Lepidoptera: Noctuidae) males in traps baited with different commercial pheromone blends. Fla. Entomol. 29(10):729-740.

Midega, C.A., J.O. Pittchar, J.A. Pickett, G.W. Hailu, and Z.R. Kha. 2018. A climate-adapted push-pull system effectively controls fall armyworm, *Spodoptera frugiperda* (J.E Smith), in maize in East Africa. Crop protect. *105*:10-15.

Montezano, D.G., A. Specht, D.R. Sosa-Gomez, V.F. Roque-Specht, J.C. Sousa-Sliva, S.V.D. Paula-Moraes, J.A. Peterson and T.E. Hunt, 2018. Host plants of *Spodoptera frugiperda* in the Americas. Afr. Entomol. 26(2):286-300.

Muraro, D.S.,R.F. Stacke,G.E. Cossa,D.N. Godoy, C.G. Garlet, I. Valmorbida, and O. Bernardi, 2020. Performance of seed treatments applied on Bt and non-Bt maize against fall armyworm (Lepidoptera: Noctuidae). Environ. Entomol. *49*(5):1137-1144.

Murugaraj, P., R.M. Nachiappan, and V. Selvanarayanan, 2006. Efficacy of Emamectin benzoate (Proclaim 05 SG) against tomato fruit borer, Helicoverpaarmigera (Hubner). *Pestology*, *30*(1): 11-16.

Nagoshi, R.N., G. Goergen, K.A. Tounou, K. Agboka, D. Koffi, and R.L. Meagher. 2018. Analysis of strain distribution, migratory potential, and invasion history of fall armyworm populations in northern Sub-Saharan Africa. Scientific reports.*8*(1):1-10.

Nagoshi, R.N., R.L. Meagher, and M. Hay-Roe, 2012. Inferring the annual migration patterns of fall armyworm (Lepidoptera: Noctuidae) in the United States from mitochondrial haplotypes. Ecology and evolution *2*(7):1458-1467.

Ndoro, T. 2018. Evaluation of the Efficacies of Different Insecticides in Fall Armyworm *(Spodoptera Frugiperda)* Control in Maize *(Zea Mays)* (Doctoral dissertation, BUSE).

Oliver, A.D. 1981. Biology and illustrated key for the identification of twenty species of economically important noctuid pests. 22(12):576-734

Ōmura, S., and K. Shiomi. 2007. Discovery, chemistry, and chemical biology of microbial products. Pure and applied chemistry. *79*(4):581-591.

Otim, M.H., S. AdumoAropet, M. Opio, D. Kanyesigye, H. Nakelet Opolot, and W. Tek Tay, 2021. Parasitoid distribution and parasitism of the fall armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in different maize producing regions of Uganda. Insects. *12*(2):121.

Penagos, D.I., J. Cisneros, O. Hemandez and T. Williams, 2005. Lethal and sublethal effects of the naturally derived insecticide spinosad on parasitoids of *Spodoptera frugiperda.* Biocontrol Sci. Technol. 15(1):81-95.

Penagos, D.I., J. Cisneros, O. Hernández, and T. Williams, 2005. Lethal and sublethal effects of the naturally derived insecticide spinosad on parasitoids of *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Bio. Sci. and Technol *15*(1): 81-95.

Phambala, K., Y. Tembo, T. Kasambala, V. Kabambe, H. Stevenson, and S.R.Belmain. 2020. Bioactivity of common pesticidal plants on fall armyworm larvae (*Spodoptera frugiperda*). Plants. *9*(1):112.

Pineda, S., G. Smagghe, M.I. Schneider, P. Del Estal, E. Viñuela, A.M. Martínez, and F. Budia, 2006. Toxicity and pharmacokinetics of spinosad and methoxyfenozide to *Spodoptera littoralis* (Lepidoptera: Noctuidae). Environ. Entomol. 35(4):856-864.

Pitterna, T., J. Cassayre, O.F. Hüter, P.M. Jung, P. Maienfisch, F.M. Kessabi, and H. Tobler. 2009. New ventures in the chemistry of avermectins. Bio. and medic. chem. 17(12):4085-4095.

Pitterna, T., J. Cassayre, O.F. Hüter, P.M. Jung, P. Maienfisch, F.M Kessabi, and H. Tobler. 2009. New ventures in the chemistry of avermectins. Bioorganic & medicinal chemistry. 17(12):4085-4095.

Ponsankar, A., P. Vasantha-Srinivasan, V. Senthil-Nathan, V. Thanigaivel, E.S. Edwin, S. Selin-Rani, and N.A. Al-Dhabi, 2016. Target and non-target toxicity of botanical insecticide derived from Couroupitaguianensis L. flower against generalist herbivore, *Spodoptera litura* Fab. and an earthworm, Eisenia foetida Savigny. Ecotoxicology and environmental safety.133:260-270.

Prasanna, B.M., A. Bruce, S. Winter, M. Otim, G. Asea, S. Sevgan, and M. Ba, 2018. Host plant resistance to fall armyworm. Fall armyworm in Africa.15(5): 45-62.

Prasanna, B.M., J.E. Huesing, R. Eddy and V.M. Peschke, 2018. Fall armyworm in Africa: a guide for integrated pest management. Crop. Prot. 7:23-48.

Prasanna, B.M., J.E. Huesing, R. Eddy and V.M. Peschke, 2018. Fall armyworm in Africa: a guide for integrated pest management. Crop. Prot. 7:23-48.

Rabeena, I., N. Ganapathy, S. Nakeeran, and M.R. Srinivasan, 2017. Impact of *Bacillus subtilis* isolates on biochemical profile of *Spodoptera litura* (Fab.) larvae. J. Entomol. Zool. Stud. *5*: 1867-1870.

Ramzan, M., H. Ilahi, M. Adnan, A. Ullah and A. Ullah, 2021. Observation on Fall Armyworm, Spodoptera frugiperda (Lepidoptera: Noctuidae) on Maize Under Laboratory Conditions. Egypt. Acad. J. Biol. Sci. 4:99-104.

Rauh, J.J., S.C. Lummis, and D.B. Sattelle, 1990. Pharmacological and biochemical properties of insect GABA receptors. Tren. in Pharm. sci. 11(8):325-329.

Rauh, J.J., S.C. Lummis, D.B. Sattelle, 1990. Pharmacological and biochemical properties of insects GABA receptors. Trends Pharmacol. Sci. 8:325-329.

Riddick, E.W. 2017. Spotlight on the positive effects of the ladybird *Harmonia axyridis* on agriculture. BioControl 62(3):319-330.

Saeed, Q., M.A. Saleem, M.A. and M. Ahmad. 2012. Toxicity of some commonly used synthetic insecticides against *Spodoptera exigua* (Fab) (Lepidoptera: Noctuidae). Pak. J. of Zool*. 44*(5):1197-1201.

Shad, S.A., A.H. Sayyed and M.A. Saleem, 2010. Cross resistance, mode of inheritance and stability of resistance to emamectin in *Spodoptera litura*. Pest Manag. Sci. 66:839-846.

Shad, S.A., A.H. Sayyed, M.A. Saleem, 2010. Cross-resistance, mode of inheritance and stability of resistance to emamectin in *Spodoptera litura* (Lepidoptera: Noctuidae). Pest. Manag. Sci 66(8):839-846.

Siddhartha, K., C. Chinniah and M. Shanthi. 2019. In vitro bioassay of certain botanical oils for their efficacy against maize fall army worm Spodoptera frugiperda (Lepidoptera: Noctuidae). J. Entomol. Zool. Stud. 7: 606-609.

Sisay, B., J. Simiyu, P. Malusi, P. Likhayo, E. Mendesil and N. Elibariki. 2018. First report of the fall armyworm, *Spodoptera frugiperda* natural enemies from Africa. J. App. Entomol. 142: 800-4.

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

Sisay, B., T. Tefera, M. Wakgari, G. Ayalew and E. Mendesil. 2019. The efficacy of selected synthetic insecticides and botanicals against fall armyworm in maize. Insects. 10:45.

Song, X.P., Y.J. Liang, X.Q. Zhang, Z.Q. Qin, J.J. Wei, Y.R. Li, and J.M. Wu, 2020. Intrusion of fall armyworm (*Spodoptera frugiperda*) in sugarcane and its control by drone in China. Sugar Tech. *22*(4):734-737.

Soyel, k.J. 2020. Evaluation of synthetic insecticides for control of fall armyworm (*Spodoptera frugiperda* J.E smith) in the guinea savannah agro ecology of ghana (doctoral dissertation). 20:667-721.

Spindola, A.F., C.S.A. Silva-Torres, A.R.S. Rodrigues and J.B. Torres. 2013. Survival and behavioural responses of the predatory ladybird beetle, Eriopisconnexa populations susceptible and resistant to a pyrethroid insecticide. Bull. Entomol. Res. 103: 485.

Suthar, M., M.B. Zala, H.S. Varma, M. Lunagariya, M.B. Patel and B.P.P. Borad. 2020. Bioefficacy of granular insecticides against fall armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae) and its predator *Eriopisconnexo* (Coleoptera: Coccinellidae). J. Environ. Sci. Health Part B. 45: 557-561.

Tariq, M. and H. Iqbal, 2010. Maize in Pakistan-An overview. Agric. Nat. Res. 44:757-763.

Thumar, R.K., M.B. Zala, H.S. Varma, C.B. Dhobi, B.N. Patel, M.B. Patel and P.K. Borad. 2020. Evaluation of insecticides against fall armyworm, Spodoptera frugiperda (JE Smith) infesting maize. Inter. J. Chem. Stud., 8: 100-104.

Togola, A., S. Meseka, A. Menkir, B.O. Badu-AprakuBoukar, M. Tamo and R. Djouska. 2018. Measurement of pesticide residues from chemical control of the invasive Spodoptera frugiperda (Lepidoptera: Noctuidae) in a maize experimental field in Mokwa, Nigeria. Inter. J. Environ. Res. Pub, health, 15: 849.

Tohnishi, M., H. Nakao, T. Furuva, A. Seo, H. Kodama, K. Tsubata, S. Fujioka, H. Kodama, T. Hirooka and T. Nishimatsu. 2005. Flubendiamide, a novel insecticide highly active against lepidopterous insect pest. J. Pestic. Sci., 30: 354-360.

Toth, S. and J. Sparks, 2007. Effect of Temperature on Toxicity and Knockdown Activity of cis-Permethrin, Esfenvalerate, and λ-Cyhalothrin in the Cabbage Looper (Lepidoptera: Noctuidae). J. Econ. Entomol.83:342-346.

Truong, K.M. and I.N. Pessah. 2019. Comparison of chlorantranilipole and flubendiamide activity toward wild-type and malignant hyperthermia-susceptible ryanodine receptors and heat stress intolerance. Toxicol. Sci. 167: 509-523.

Tufa, B. and H. Ketema. 2016. Effects of different termite management practices on maize production in Assosa district, Benishangul Gumuz Region, Western Ethiopia. J. Biol. Agri. Healthcare, 6: 27-33.

Varshney, R., B. Poornesha, A. Raghavendra, Y. Lalitha, V. Apoorva, B. Ramanujam and V. Pandit. 2020. Biocontrol-based management of fall armyworm, *Spodoptera frugiperda* (J.E Smith) (Lepidoptera: Noctuidae) on Indian Maize. J. Plant Diseases Protec., 1-9.

Vassilakos, T.N., C.G. Athanassiou, O. Saglam, A.S. Chloridis and J.E. Dripps. 2012. Insecticidal effect of spinetoram against six major stored grain insect species. J. Stored Prod. Res., 51: 69-73.

Vivan, L.M., J.B. Torres and P.L.S. Fernandes. 2017. Activity of selected formulated biorational and synthetic insecticides against larvae of *Helicoverpaarmigera* (Lepidoptera: Noctuidae). J. Econ. Entomol., 110: 118-126.

Worku, M. and Y. Ebabuye. 2019. Evaluation of efficacy of insecticides against the fall army worm *Spodoptera frugiperda*. Ind. J. Entomol., 81: 13-15.

Yang, F.W., Y.X. Li, F.Z. Ren, R. Wang, and G.F Pang. 2022. National Center for Biotechnology Information PubChem Compound Summary for Triazophos. ESA Ann. Meet. 87:12-13

Yu, S.J. 1991. Insecticide resistance in the fall armyworm. Pesticide Biochem. Physio, 39: 84 91.

Yu, S.J., 1991. Insecticide resistance in the fall armyworm. Pestic. Biochem. Physio. 39:84-91.

Zhao, Y.X., J.M. Huang, H. Ni, D. Guo, F.X. Yang, X. Wang and C.F. Gao, 2020. Susceptibility of fall armyworm to eight insecticides in china with special refrance to lambda cyhalothrin. Pestic. Biochem. Physio. 168:10-462.

Zhao, Y.X., J.M. Huang, H. Ni, D. Guo, F.X. Yang, X. Wang and C.F. Gao, 2020. Susceptibility of fall armyworm to eight insecticides in china with special refrance to lambda cyhalothrin. Pestic. Biochem. Physio. 168:10-462.

Zhao, Y.X., J.M. Huang, H. Ni, D. Guo, F.X. Yang, X. Wang and C.F. Gao. 2020. Susceptibility of fall armyworm to eight insecticides in china with special refrance to lambda cyhalothrin. Pestic. Biochem. Physiol., 10462.