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# Comparative Efficiency of Some Novel Insecticides against Fall Army Worm, *Spodoptera frugiperda* in Maize

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## ABSTRACT

The present study was carried out at the instructional farm, College of Agriculture, Bidhan Chandra Krishi Viswavidyalaya, Farm Gate, Kalna Road, Burdwan Sadar, West Bengal, India for successive 2 terms of crop during *kharif* (June to September, 2020) and *rabi* (December to March, 2020–21). The bio-efficacy of some chemicals (Cyantraniliprole, Chlorantraniliprole, Emamectin benzoate, Flubendiamide, Spinosad, Emamectin benzoate, Broflanilide, Chlorfenapyr, Spinetoram and Teflubenzuron) and bio-pesticides (*Bacillus thuringiensis var kurstaki*, *Beauveria bassiana*, *Metarhizium anisopliae*, Azadirachtin and *Steinernema* sp.) were evaluated against Fall Army Worm (FAW) in corn at the field condition. The major parameters considered for comparing the treatments were based on percent reduction in larval population, leaf damage (%) followed by headonic scoring (0–9 scale) and attack intensity (%). All the chemical insecticides except teflubenzuron resulted more or less higher percent population reduction of FAW larva (75.39–89.17%), lower leaf damage (20.13–31.21%) along with low damage score (1.45–1.95) and lower attack intensity (3.03–6.09%). All these effects were at moderate range in case of bio-pesticides. Based on the present findings, better selection of suitable insecticides is possible to manage FAW in corn.

**KEYWORDS:** Efficacy, insecticides, bio-pesticides, corn, army worm, *Spodoptera frugiperda*

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***Data Availability Statement:*** Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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## 1. INTRODUCTION

The maize is cultivated globally for an area of about 150 mha. In India during 2020–21, approximately 31.51 mt of dry corn grains are harvested from 9.9 million hectares (Anonymous, 2022) throughout the year covering three main different seasons. This crop supplies significant amount of nutrients, vitamins and minerals to human beings and animals resulting numerous health profits from ancient period. It has huge potential for sustaining human health and farmers' living standard. Soil fertility is judged by growing maize as an indicator crop. Wet milling, production of bio-fuel, ethanol and other by-products are treated as trade use of corn (Adiaha, 2017).

Such great cereal is damaged by more than 250 species of insect pests (Mathur, 1991). Among them the Fall Army Worm (FAW) i.e. *Spodoptera frugiperda* can consume about 353 host plants under 76 families resulting remarkable loss in crop production (Montezano et al., 2018). Its brutal infestation in maize was accounted in African countries in 2016 (Goergen et al., 2016) having subsequent diverse level of damage (Mideaga et al., 2018; Baudron et al., 2019; Fotso et al., 2019). This culprit as invasive enemy of maize entered to South India during May, 2018 (Ganiger et al., 2018; Sharanabasappa et al., 2018a; Anonymous, 2018b). It matched genetically with South African strain originated from the Western Hemisphere (Nagoshi et al., 2019). It was able to spread and establish at maize ecosystem in most states of India (Mahadevaswamy et al., 2018; Sharanabasappa et al., 2018b; Swamy et al., 2018). A rapid roving survey in Karnataka showed 9–62.5% damage on maize by FAW larva (Ganiger et al., 2018; Shylesha et al., 2018). Quickly, it moved to Thailand, Sri Lanka, Bangladesh, Myanmar, Vietnam, Laos, and China (Guo et al., 2018; Wu et al., 2019; Anonymous, 2019a, b). Presently, the FAW is a key threat to corn cultivation of West Bengal like other states of India with a lot of economic damage that may invite food insecurity in near future (Patel and Zaman, 2022).

The corn farmers prefer to protect FAW by application of different types of conventional insecticides. They are not aware about fate of conventional insecticides apropos less competence and creating miscellaneous grave nuisance including harmful residues on foods, destruction of predators and parasitoids, environmental pollution, human illness, insect resistance, resurgence and biotype development along with other negative effects (Sabry et al., 2016; Kwizera and Susurluk, 2017; Prasanna et al., 2018; Sisay et al., 2019). So, modern insecticides with specific action may be better to solve such manmade problems. Initially, different insecticides were used for 2 to 3 times lacking testing their efficiency. The management is somewhat difficult due to inhabiting nature of FAW within leaf whorl (Anonymous, 2018). Repeated sprays of same insecticides can cause resistance (Gutierrez-Moreno et al., 2019). There are recommendations for using insecticides like Chlorantraniliprole, Spinetoram, Emamectin benzoate, Thiodicarb, Chlorantraniliprole++Lambda-cyhalothrin, Cyantraniliprole++Thiamethoxam, Emamectin benzoate ++Lufenuron, Novaluron++Emamectin benzoate and bio-pesticides such as *Metarhizium anisopliae, Metarhizium rileyi* (*Nomuraea rileyi*), *Beauveria bassiana, Verticillium lecanii, Bacillus thuringiensis var. Kurstaki* and NPV (Anonymous, 2023). Very recently launched chemicals like broflanilide and cyantraniliprole have been tested against FAW (Patel and Zaman, 2022). All these above mentioned insecticides have diverse amazing modes of action against lepidopteran larva. Chimweta et al. (2020) has suggested locally available chemical and biological tools for managing FAW in corn. Acknowledging this, the present work is executed to find out comparative efficacy of some important available novel insecticides including chemicals, botanical and bio-agents against FAW in field maize.

## 2. MATERIALS AND METHODS

The trial was carried out at instructional farm (Latitude 23.24°N and Longitude 87.90°E) of College of Agriculture (BCKV, Burdwan Sadar, West Bengal, India) for successive 2 terms of crop during *kharif* (June to September, 2020) and *rabi* (December to March, 2020–21) following randomized block design for 16 treatments with 3 replications (Table 1) including untreated control. The improved variety 'Sindhu' is grown as per standard recommended agronomic practices for tillage, spacing, nutrition, irrigation etc. Two sprays @ 500 l $ha^{-1}$ for each treatment are given in each season at 15 days interval using hollow cone nozzle in knap sack sprayer. Spray fluid is thrown to wet both leaves and whorls in first spray, whereas only whorls are wetted after second spray.

Necessary data on larval population and percent leaf damage were calculated following the methodology adopted by Patel and Zaman (2022). Whereas, pest attack intensity utilizing leaf damage scale was derived as per guidelines of Davis et al. (1992) in Table 2.

The following formula was used to transform recorded score.

$$I = (\sum(n \times v)/ZN) \times 100\%$$

Where, I=Attack intensities, n=Number of the damaged leaves, v=Damage scores, Z=Highest scores, N=Number of leaves observed.

Cob (green) yield per plot was taken and changed into tonnes per hectare. All collected data was transformed in suitable form for their necessary statistical analysis using OP stat.

Table 1: List of different treatments against fall army worm in corn

| Treat-ment | Chemical name | Formulation dose (ml or g/500 lit of water) | Commercial name | Manufactured by | Mode of action* | Chemical group |
|---|---|---|---|---|---|---|
| $T_1$ | Cyantraniliprole 10.26 OD | 900 | Benevia | FMC | RRM | Anthranilic Diamides |
| $T_2$ | Chlorantraniliprole 18.5 SC | 200 | Coragen | FMC | RRM | Anthranilic Diamides |
| $T_3$ | Emamectin benzoate 5SG | 300 | Proclaim | Syngenta | CCA | Avermectins |
| $T_4$ | Spinosad 45SC | 170 | Tracer | DOW | NARAA | Spinosyns |
| $T_5$ | Flubendiamide 20WG | 150 | Takumi | TATA | RRM | Diamides |
| $T_6$ | Teflubenzuron 15 SC | 200 | Nomolt | BASF | CSI | Benzoyl phenylurea |
| $T_7$ | Novaluron 5.25++ indoxacarb 4.5 SC | 375 | Plethora | AADAMA | CSI+VSB | Benzoyl phenylurea+ Oxadiazine |
| $T_8$ | Broflanilide 30 SC | 62 | Exponus | BASF | GCAA | Meta-diamides |
| $T_9$ | Chlorfenapyr 24 SC | 325 | Intrepid | BASF | DAP | Halogenated pyrroles |
| $T_{10}$ | *Bacillus thuringiensis* var *kurstaki* 0.5 WP | 500 | Mahastra | Int. Panacea | Septicemia | Bioagent |
| $T_{11}$ | Spinoterum 11.7 SC | 170 | Delegate | Dow | NARAA | Spinosyns |
| $T_{12}$ | *Beauveria bassiana* 1 WP | 3000 | Daman | Int. Panacea | PAI | Bioagent |
| $T_{13}$ | *Metarhizium anisopliae* 1 WP | 3000 | Kalichakra | Int. Panacea | PAI | Bioagent |
| $T_{14}$ | Azadirachtin 1EC | 3000 | Nimbecidine | T. Stanes | EA/M | Botanicals |
| $T_{15}$ | *Steinernema* sp. | $2.5\times10^9$ IJ | - | NIPHM | SNBC | Bioagent |
| $T_{16}$ | Untreated control | - | - | - | - | - |

*Ryanodine receptor modulator (RRM), Chloride channel activators (CCA), Nicotinic acetylcholine receptor allosteric activators (NARAA), Chitin synthesis inhibitor (CSI), Voltage-dependent sodium channel blockers (VSB), GABA-gated Cl– channel allosteric modulator (GCAA), Distrupt ATP production (DAP), Ecdysone agonists/moulting (EA/M), Septicemia through nematode bacterium complex (SNBC), Physiological activity inhibitor (PAI)

Table 2: Leaf damage assessment using visual rating scales

| Scale | Description |
|---|---|
| 0 | No visible leaf damage |
| 1 | Only pinhole damage on leaves |
| 2 | Pinhole and shot hole damage to the leaf |
| 3 | Small elongated lesions (5–10 mm) on 1–3 leaves |
| 4 | Midsized lesions (10–30 mm) on 4–7 leaves |
| 5 | Large elongated lesions (>30 mm) or small portions have eaten on 3–5 leaves |
| 6 | Elongated lesions (>30 mm) and large portions have eaten on 3–5 leaves |
| 7 | Elongated lesions (>30 cm) and 50% of leaf eaten |
| 8 | Elongated lesions (30 cm) and large portions have eaten on 70% of leaves |
| 9 | Most leaves with long lesions and complete defoliation observed |

## 3. RESULTS AND DISCUSSION

### 3.1. *Effect of insecticides (Kharif, 2020)*

First season (*Kharif*, 2020): Pre-spray larval population was counted at one day before insecticide use. It varied non significantly between 0.80 to 1.00 plant$^{-1}$ (Table 3). All insecticides were significantly superior over non treated control plot as per observed data at 3$^{rd}$, 5$^{th}$, 7$^{th}$ and 10$^{th}$ days after each spray for two times. The best treatments were Broflanilide 30 SC @ 62 ml ha$^{-1}$ and Cyantraniliprole 10.26 OD @ 900 ml ha$^{-1}$ resulting 89.17% overall decreasing in larval population for each insecticide over untreated control. It was more or less close with others like Chlorantraniliprole 18.5 SC @ 200 ml ha$^{-1}$ (88.52%), Novaluron 5.25++Indoxacarb 4.5 SC @ 375 ml ha$^{-1}$ (87.20%), Flubendiamide 20WG @ 150 g ha$^{-1}$ (86.88%), Emamectin benzoate 5SG @ 300 g ha$^{-1}$ (85.89%), Spinetorum 11.7 SC @ 170 ml ha$^{-1}$ (83.27%), Spinosad 45SC @ 170 ml ha$^{-1}$ (82.28%). The lowest

Table 3: Bio-efficacy of insecticides against fall army worm in maize during *kharif* 2020 and *rabi* 2020–21

| Treat-ments | *Kharif*, 2020 | | | | | *Rabi*, 2020–21 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. of larvae Plant$^{-1}$ | | | | Overall % reduction over control | No. of larvae Plant$^{-1}$ | | | Pooled Mean of 1st and 2nd spray | Overall % reduction over control |
| | 1 DBS | Pooled mean of 3, 5, 7 and 10 DAS | | Pooled Mean of 1st and 2nd spray | | 1 DBS | Pooled mean of 3, 5, 7 and 10 DAS | | | |
| | | 1st spray | 2nd spray | | | | 1st spray | 2nd spray | | |
| $T_1$ | 1.00 (1.41) | 0.13 (1.06) | 0.14 (1.06) | 0.14 | 89.17 | 0.97 (1.40) | 0.11 (1.05) | 0.18 (1.09) | 0.15 | 88.52 |
| $T_2$ | 0.90 (1.38) | 0.16 (1.08) | 0.13 (1.06) | 0.15 | 88.52 | 0.87 (1.36) | 0.14 (1.06) | 0.18 (1.08) | 0.16 | 87.86 |
| $T_3$ | 0.80 (1.34) | 0.18 (1.09) | 0.18 (1.09) | 0.18 | 85.89 | 0.87 (1.36) | 0.16 (1.07) | 0.21 (1.10) | 0.19 | 85.56 |
| $T_4$ | 0.90 (1.38) | 0.25 (1.12) | 0.18 (1.12) | 0.21 | 82.28 | 0.83 (1.35) | 0.23 (1.11) | 0.21 (1.10) | 0.22 | 82.94 |
| $T_5$ | 0.97 (1.40) | 0.19 (1.09) | 0.14 (1.09) | 0.17 | 86.88 | 0.93 (1.39) | 0.17 (1.08) | 0.18 (1.08) | 0.17 | 86.55 |
| $T_6$ | 0.97 (1.40) | 0.52 (1.23) | 0.41 (1.23) | 0.46 | 63.58 | 0.93 (1.39) | 0.46 (1.03) | 0.44 (1.20) | 0.45 | 64.57 |
| $T_7$ | 1.00 (1.41) | 0.21 1.10) | 0.12 (1.10) | 0.16 | 87.20 | 0.97 (1.40) | 0.19 (1.09) | 0.16 (1.08) | 0.17 | 86.55 |
| $T_8$ | 0.87 (1.37) | 0.15 (1.07) | 0.13 (1.07) | 0.14 | 89.17 | 0.83 (1.35) | 0.13 (1.06) | 0.17 (1.08) | 0.15 | 88.52 |
| $T_9$ | 1.00 (1.41) | 0.33 (1.16) | 0.29 (1.14) | 0.31 | 75.39 | 0.97 (1.40) | 0.28 (1.13) | 0.29 (1.14) | 0.28 | 77.69 |
| $T_{10}$ | 0.97 (1.40) | 0.49 (1.22) | 0.46 (1.21) | 0.47 | 62.93 | 0.90 (1.38) | 0.43 (1.19) | 0.49 (1.22) | 0.46 | 63.91 |
| $T_{11}$ | 0.93 (1.39) | 0.23 (1.11) | 0.20 (1.10) | 0.21 | 83.27 | 0.90 (1.38) | 0.19 (1.09) | 0.23 (1.11) | 0.21 | 83.27 |
| $T_{12}$ | 0.90 (1.38) | 0.65 (1.28) | 0.51 (1.23) | 0.58 | 54.40 | 0.93 (1.39) | 0.48 (1.21) | 0.54 (1.24) | 0.51 | 53.41 |
| $T_{13}$ | 0.97 (1.40) | 0.59 (1.26) | 0.52 (1.23) | 0.55 | 56.36 | 0.93 (1.39) | 0.59 (1.26) | 0.55 (1.25) | 0.57 | 55.38 |
| $T_{14}$ | 0.93 (1.39) | 0.57 (1.25) | 0.52 (1.24) | 0.54 | 57.35 | 0.87 (1.37) | 0.53 (1.24) | 0.55 (1.25) | 0.54 | 57.68 |
| $T_{15}$ | 0.90 (1.38) | 0.73 (1.32) | 0.65 (1.28) | 0.69 | 45.54 | 0.87 (1.37) | 0.55 (1.24) | 0.68 (1.30) | 0.62 | 45.21 |
| $T_{16}$ | 0.93 (1.39) | 1.20 (1.48) | 1.33 (1.53) | 1.27 | - | 0.90 (1.38) | 1.17 (1.49) | 1.37 (1.54) | 1.27 | - |
| SEm± | 0.02 | 0.02 | 0.02 | - | - | 0.02 | 0.05 | 0.02 | - | - |
| CD ($p$=0.05) | 0.06 | 0.06 | 0.06 | - | - | 0.06 | 0.14 | 0.06 | - | - |

*Figures in the parentheses are $\sqrt{X+0.5}$ transformed value; DBS: Day before Spray; DAS: Days after Spray; $T_1$: Cyantraniliprole 10.26 OD @ 900 ml ha$^{-1}$; $T_2$: Chlorantraniliprole 18.5 SC @ 200 ml ha$^{-1}$; $T_3$: Emamectin benzoate 5SG @ 300 g ha$^{-1}$; $T_4$: Spinosad 45SC @ 170 ml ha$^{-1}$; $T_5$: Flubendiamide 20WG @ 150 g ha$^{-1}$; $T_6$: Teflubenzuron 15 SC @ 200 ml ha$^{-1}$; $T_7$: Novaluron 5.25++Indoxacarb 4.5 SC @ 375 ml ha$^{-1}$; $T_8$: Broflanilide 30 SC @ 62 ml ha$^{-1}$, $T_9$: Chlorfenapyr 24 SC @ 325 ml ha$^{-1}$; $T_{10}$: *Bacillus thuringiensis* var *kurstaki* 0.5 WP @ 500 g ha$^{-1}$, $T_{11}$: Spinoterum 11.7 SC @ 170 ml ha$^{-1}$; $T_{12}$: *Beauveria bassiana* 1 WP @ 3000 g ha$^{-1}$; $T_{13}$: *Metarhizium anisopliae* 1 WP @ 3000 g ha$^{-1}$; $T_{14}$: Azadirachtin 1EC @ 3000 ml ha$^{-1}$, $T_{15}$: *Steinernema* sp @ 2.5×10$^9$ IJ ha$^{-1}$, $T_{16}$: Untreated control efficacy (45.54%) was recorded by spraying of one important Entomo Pathogenic Nematode (EPN) *Steinernema* sp.@ $2.5\times10^9$ IJ $ha^{-1}$ followed by *Beauveria bassiana* 1 WP @ 3 kg $ha^{-1}$ (54.40%), *Metarhizium anisopliae* 1 WP @ 3 kg $ha^{-1}$ (56.36%), Azadirachtin 1EC @ 3 l $ha^{-1}$ (57.35%), *Bacillus thuringiensis var kurstaki* 0.5 WP @ 500 g $ha^{-1}$ (62.93%), Teflubenzuron 15 SC @ 200 ml $ha^{-1}$ (63.58%), Chlorfenapyr 24 SC @ 325 ml $ha^{-1}$ (75.39%).

*3.1.1. Second season (rabi, 2020–21)*

The similar tendency as observed during *kharif* (2020) with respect to effect of some treatments against *S. frugiperda* in maize was also portrayed in *rabi*, 2020–21 (Table 3). Pre-treatment population of larva differed non significantly from 0.83 to 0.97 $plant^{-1}$. The average larval numbers $plant^{-1}$ at taken treatments differed statistically between 0.07 to 0.87, considering two times spraying of them. While, the highest population as 1.43 $plant^{-1}$ was noted from control plot. Cyantraniliprole 10.26 OD @ 900 ml $ha^{-1}$ resulted the highest overall mortality (88.52%) of fall army worm, followed by significantly at par effect with Broflanilide 30 SC @ 62 ml $ha^{-1}$ (87.99%) and Chlorantraniliprole 18.5 SC @ 200 ml $ha^{-1}$ (87.86%). Effect of these three chemicals were very close to some other treatments such as Novaluron 5.25++Indoxacarb 4.5 SC @ 375 ml $ha^{-1}$ (86.55%), Flubendiamide 20WG @ 150 g $ha^{-1}$ (86.55%), Emamectin benzoate 5SG @ 300 g $ha^{-1}$ (85.56%)[1], Spinoterum 11.7 SC @ 170 ml $ha^{-1}$ (83.27%), Spinosad 45SC @ 170 ml $ha^{-1}$ (82.94%). Apropos overall percent reduction in larval population of *S frugiperda*, the ascending trend for rest of treatments were *Steinernema* sp. @ $2.5\times10^9$ IJ $ha^{-1}$ (45.21%) <*Beauveria bassiana* 1 WP @ 3 kg $ha^{-1}$ (53.41%) <*Metarhizium anisopliae* 1 WP @ 3 kg $ha^{-1}$ (55.38%) <Azadirachtin 1EC @ 3 l $ha^{-1}$ (57.68%) <*Bacillus thuringiensis var kurstaki* 0.5 WP @ 500 g $ha^{-1}$ (63.91%) <Teflubenzuron 15 SC @ 200 ml $ha^{-1}$ (64.14%) <Chlorfenapyr 24 SC @ 325 ml $ha^{-1}$ (77.69%).

The outcomes related to insecticides Chlorantraniliprole, Emamectin benzoate and Broflanilide apropos FAW larval mortality were more or less in line of agreement with earlier work done by Patel and Zaman, 2022. The larval mortalities at field condition after exposing with Cyantraniliprole, Flubendiamide, Spinetoram and Spinosad more or less corroborated with Hardke et al., 2011. The considerable toxicity of Novaluron++Indoxacarb against larva of FAW was reported by Shareef et al. (2022). The reduced susceptibility of *S frugiperda* by Teflubenzuron was already reported by Amaral et al., 2023. Moderate larval death caused by *Beauveria bassiana* had full support with Idrees et al. (2022) who observed 45.6 to 53.6% neonate mortality by the same. Information is scanty regarding field efficacy of entomopathogenic nematode i.e *Steinernema* sp. against *S. frugiperda*. An attempt was made by the present authors to generate data in this regard and around 45% larval reduction was noted by the said EPN spray. All these findings have direct or indirect support with the results as obtained in present research.

*3.2. Effect of treatments on corn damage*

*3.2.1. First season (kharif, 2020)*

Table 4 shows the treatment wise harm disparity in maize regarding leaf damage (%), scoring (1–9 scale) and leaf attack intensity (%) at 5 and 10 days later for each of 2 times sprays. Cyantraniliprole depicted the overall lowest leaf damage (20.13%), score (1.45) and leaf attack intensity (3.03%) and that was statistically more or less similar with Flubendiamide (20.37%, 1.52, 3.19%), Chlorantraniliprole (20.37%, 1.48 and 3.18%), Novaluron++Indoxacarb (21.32%, 1.55 and 3.49%), Broflanilide (22.62%, 1.52 and 3.70%), Emamectin benzoate (22.94%, 1.63 and 3.91%), Spinosad (24.32%, 14.79 and 4.43%) and Spinetoram (24.68%, 1.68 and 4.38%). Considering same damage parameters as mentioned above the ascending tendency for other scheduled treatments were as follows: Chlorfenapyr (30.72%, 1.89 and 6.09%) <Teflubenzuron (34.35%, 1.98 and 6.97%) <Btk (35.02%, 2.07 and 7.65%) <Azadirachtin (38.38%, 1.94 and 7.89%), *Metarhizium anisopliae* (39.44%, 2.11 and 8.71%), *Beauveria bassiana* (41.32%, 2.19 and 9.51%) <*Steinernema* sp. (50.15%, 2.18 and 11.21%). While the untreated control depicted highest damage effect (58.38%, 2.91 and 17.17%) due to attack of *S. frugiperda* in corn.

*3.2.2. Second season (rabi, 2020-21)*

Treatment wise damage variations at 5 and 10 days after sprays for 2 times during *rabi* 2020–21 has been presented in table 4. Almost similar trend was recorded just like 1st season of trial. Here also, the overall lowest leaf damage (20.73%), score (1.57) and leaf attack intensity (3.60%) were observed with the insecticide Cyantraniliprole followed by Chlorantraniliprole (20.90%, 1.60 and 3.71%), Flubendiamide (20.93%, 1.68 and 3.90%), Novaluron++Indoxacarb (21.38%, 1.66 and 3.96%), Emamectin benzoate (23.36%, 1.76 and 4.56%), Spinosad (24.54%, 1.86 and 5.08%) and Spinetoram (24.88%, 1.76 and 4.88%). However, somewhat lesser effect was recorded for other scheduled treatments where leaf damage varied from 31.21 to 50.80%, score varied from 1.95 to 2.32 and leaf attack intensity ranged from 8.07 to 12.60%. The untreated control depicted the highest damage (leaf damage -58.93%, Score -3.13 and leaf attack intensity -20.24%) caused by larva of *S. frugiperda* in corn field.

Reviews are limited regarding effect of insecticides on different damage parameters of corn as reflected in this

Table 4: Damage (Percent leaf, leaf damage rating or scoring in 1–9 scale and percent leaf attack intensity) caused by *S. frugiperda* in corn at different treatments during *kharif*, 2020 and *rabi* 2020–21 (Based on mean of observation made on 5 and 10 Days after each spray)

| Treat-ments | *Kharif*, 2020 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1st spray | | | 2nd spray | | | Pooled mean of 1st and 2nd spray | | |
| | Leaf damage (%) | Score on leaf damage | Leaf attack intensity (%) | Leaf damage (%) | Score on leaf damage | Leaf attack intensity (%) | Leaf damage (%) | Score on leaf damage | Leaf attack intensity (%) |
| $T_1$ | 19.11 (25.89) | 1.47 | 3.12 (10.10) | 21.15 (27.37) | 1.44 | 3.36 (8.71) | 20.13 | 1.45 | 3.03 |
| $T_2$ | 20.11 (26.62) | 1.49 | 3.31 (10.50) | 20.66 (23.91) | 1.47 | 3.37 (8.77) | 20.38 | 1.48 | 3.18 |
| $T_3$ | 22.58 (28.32) | 1.57 | 3.91 (11.40) | 23.30 (28.85) | 1.70 | 4.40 (9.77) | 22.94 | 1.63 | 3.91 |
| $T_4$ | 24.27 (29.49) | 1.74 | 4.66 (12.50) | 24.36 (29.56) | 1.84 | 4.95 (10.26) | 24.32 | 1.79 | 4.43 |
| $T_5$ | 19.32 (26.03) | 1.47 | 3.14 (10.20) | 21.42 (27.55) | 1.57 | 3.75 (9.09) | 20.37 | 1.52 | 3.19 |
| $T_6$ | 32.36 (34.57) | 1.89 | 6.72 (15.00) | 36.48 (37.13) | 2.07 | 8.40 (12.42) | 34.35 | 1.98 | 6.97 |
| $T_7$ | 20.26 (26.70) | 1.50 | 3.40 (10.60) | 22.39 (28.21) | 1.60 | 4.00 (9.19) | 21.32 | 1.55 | 3.49 |
| $T_8$ | 19.45 (26.13) | 1.45 | 3.15 (10.20) | 25.80 (30.48) | 1.58 | 4.58 (9.81) | 22.62 | 1.52 | 3.70 |
| $T_9$ | 29.62 (32.93) | 1.79 | 5.83 (13.90) | 31.82 (34.32) | 2.00 | 7.07 (11.82) | 30.72 | 1.89 | 6.09 |
| $T_{10}$ | 33.99 (35.92) | 1.89 | 7.19 (15.50) | 35.55 (36.58) | 2.25 | 8.89 (12.91) | 35.02 | 2.07 | 7.65 |
| $T_{11}$ | 23.83 (29.20) | 1.57 | 4.16 (11.70) | 25.53 (30.33) | 1.79 | 5.06 (10.16) | 24.68 | 1.68 | 4.38 |
| $T_{12}$ | 40.07 (39.24) | 1.94 | 8.56 (17.00) | 42.57 (40.70) | 2.45 | 11.58 (14.29) | 41.32 | 2.19 | 9.51 |
| $T_{13}$ | 37.30 (37.60) | 1.90 | 7.87 (16.30) | 41.60 (40.13) | 2.32 | 10.70 (13.83) | 39.44 | 2.11 | 8.71 |
| $T_{14}$ | 36.83 (37.33) | 1.77 | 7.27 (15.60) | 39.92 (39.17) | 2.12 | 9.40 (13.03) | 38.38 | 1.94 | 7.89 |
| $T_{15}$ | 50.25 (45.13) | 2.04 | 11.13 (19.60) | 50.07 (45.02) | 2.32 | 12.90 (14.81) | 50.15 | 2.18 | 11.21 |
| $T_{16}$ | 63.18 (52.64) | 2.42 | 16.97 (2.430) | 53.58 (47.0) | 3.40 | 20.26 (18.46) | 58.38 | 2.91 | 17.17 |
| SEm± | 0.99 | 0.07 | 0.4 | 0.83 | 0.09 | 0.32 | - | - | - |
| CD ($p$=0.05) | 2.85 | 0.21 | 1.3 | 2.39 | 0.24 | 0.92 | - | - | - |

Table 4: Continue...

| Treatments | *Rabi* 2020–21 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1st spray | | | 2nd spray | | | Pooled mean of 1st and 2nd spray | | |
| | Leaf damage (%) | Score on leaf damage | Leaf attack intensity (%) | Leaf damage (%) | Score on leaf damage | Leaf attack intensity (%) | Leaf damage (%) | Score on leaf damage | Leaf attack intensity (%) |
| $T_1$ | 19.69 (26.31) | 1.55 | 3.39 (10.60) | 21.77 (27.80) | 1.58 | 3.82 (11.24) | 20.73 | 1.57 | 3.60 |
| $T_2$ | 20.73 (27.07) | 1.58 | 3.65 (11.01) | 21.08 (27.29) | 1.62 | 3.76 (11.17) | 20.90 | 1.60 | 3.71 |
| $T_3$ | 23.12 (28.70) | 1.72 | 4.40 (12.09) | 23.61 (29.05) | 1.80 | 4.72 (12.53) | 23.36 | 1.76 | 4.56 |
| $T_4$ | 24.15 (29.40) | 1.77 | 4.76 (12.56) | 24.94 (29.94) | 1.95 | 5.40 (13.42) | 24.54 | 1.86 | 5.08 |
| $T_5$ | 20.61 (26.98) | 1.62 | 3.72 (11.08) | 21.26 (27.43) | 1.74 | 4.09 (11.65) | 20.93 | 1.68 | 3.90 |
| $T_6$ | 32.88 (34.99) | 1.95 | 7.07 (15.39) | 36.61 (37.20) | 2.23 | 9.09 (17.52) | 34.74 | 2.09 | 8.08 |
| $T_7$ | 19.55 (26.21) | 1.55 | 3.38 (10.56) | 23.22 (28.76) | 1.77 | 4.55 (12.30) | 21.38 | 1.66 | 3.96 |
| $T_8$ | 19.62 (26.27) | 1.47 | 3.21 (10.28) | 26.20 (30.77) | 1.67 | 4.86 (12.71) | 22.90 | 1.57 | 4.03 |
| $T_9$ | 30.34 (33.40) | 1.88 | 6.31 (14.53) | 32.10 (34.47) | 2.02 | 7.19 (15.54) | 31.21 | 1.95 | 6.74 |
| $T_{10}$ | 34.58 (31.00) | 1.90 | 7.29 (15.62) | 34.46 (35.93) | 2.32 | 8.87 (17.31) | 34.52 | 2.11 | 8.07 |
| $T_{11}$ | 23.82 (29.19) | 1.67 | 4.44 (12.12) | 25.95 (30.58) | 1.85 | 5.32 (13.31) | 24.88 | 1.76 | 4.88 |
| $T_{12}$ | 40.48 (39.49) | 2.05 | 9.18 (17.62) | 42.06 (40.41) | 2.59 | 12.08 (20.31) | 41.27 | 2.32 | 10.63 |
| $T_{13}$ | 37.43 (37.68) | 1.97 | 8.21 (16.60) | 42.23 (40.51) | 2.65 | 12.43 (20.62) | 39.82 | 2.31 | 10.32 |
| $T_{14}$ | 38.14 (38.11) | 2.09 | 8.82 (17.25) | 40.28 (39.37) | 2.23 | 9.95 (18.38) | 39.20 | 2.16 | 9.38 |
| $T_{15}$ | 51.22 (45.72 | 2.18 | 12.43 (20.62) | 50.38 (45.20) | 2.29 | 12.78 (20.92) | 50.80 | 2.23 | 12.60 |
| $T_{16}$ | 63.47 (52.81) | 2.57 | 18.12 (25.16) | 54.40 (47.52) | 3.70 | 22.37 (28.20) | 58.93 | 3.13 | 20.24 |
| SEm± | 0.97 | 0.10 | 0.57 | 0.89 | 0.08 | 0.48 | - | - | - |
| CD ($p$=0.05) | 2.82 | 0.28 | 1.63 | 2.58 | 0.23 | 1.38 | - | - | - |

*Figure in parenthesis is angular transformed values, DBS: Day before Spray; DAS: Days after Spray; $T_1$: Cyantraniliprole 10.26 OD @ 900 ml ha$^{-1}$; $T_2$: Chlorantraniliprole 18.5 SC @ 200 ml ha$^{-1}$; $T_3$: Emamectin benzoate 5SG @ 300 g ha$^{-1}$; $T_4$: Spinosad 45SC @ 170 ml ha$^{-1}$; $T_5$: Flubendiamide 20WG @ 150 g ha$^{-1}$; $T_6$: Teflubenzuron 15 SC @ 200 ml ha$^{-1}$; $T_7$: Novaluron 5.25++Indoxacarb 4.5 SC @ 375 ml ha$^{-1}$; $T_8$: Broflanilide 30 SC @ 62 ml ha$^{-1}$, $T_9$: Chlorfenapyr 24 SC @ 325 ml ha$^{-1}$; $T_{10}$: *Bacillus thuringiensis* var *kurstaki* 0.5 WP @ 500 g ha$^{-1}$, $T_{11}$: Spinoterum 11.7 SC @ 170 ml ha$^{-1}$; $T_{12}$: *Beauveria bassiana* 1 WP @ 3000 g ha$^{-1}$; $T_{13}$: *Metarhizium anisopliae* 1 WP @ 3000 g ha$^{-1}$; $T_{14}$: Azadirachtin 1EC @ 3000 ml ha$^{-1}$, $T_{15}$: *Steinernema* sp @ 2.5×10$^9$ IJ ha$^{-1}$, $T_{16}$: Untreated control experiment. However, the present findings related to insecticides Chlorantraniliprole, Emamectin benzoate and Broflanilide apropos leaf damage along with scoring and intensity were more or less in line of agreement with earlier work done by Patel and Zaman, 2022. Response of other treatments for leaf damage parameters reported probably for first time targeting the corn pest FAW.

### *3.3. Effect on yield*

Table 5 presents the data on yield of corn from different treatments. There was significant increase in yield at varied level for different treatments over untreated control during both season of trial (*kharif*, 2020 and *rabi*, 2020–21). More or less statistically at par yield were obtained in case of treatments with Cyantraniliprole (10.27 and 12.62 t ha$^{-1}$), Flubendiamide ( 10.26 and 12.61 t ha$^{-1}$), Chlorantraniliprole (10.26 and 12.59 t ha$^{-1}$), Broflanilide (10.24 and 12.58 t ha$^{-1}$), Novaluron++Indoxacarb (10.16 and 12.44 t ha$^{-1}$), Spinetoram (10.12 and 12.22 t ha$^{-1}$). Emamectin benzoate (9.86 and 12.46 t ha$^{-}$1) and Spinosad (9.78 and 12.18 t ha$^{-1}$). Among the treatments, the lowest yield were noted in *Steinernema* sp. (8.29 and 9.78 t ha$^{-1}$) followed by *Beauveria bassiana* (8.47 and 10.00 t ha$^{-1}$), *Metarhizium anisopliae* (8.64 and 10.11 t ha$^{-1}$), Azadirachtin (8.67 and 10.28 t ha$^{-1}$), Btk (8.70 and 10.56 t ha$^{-1}$), Teflubenzuron (8.93 and 10.62 t ha$^{-1}$) and Chlorfenapyr (9.20 and 11.11 t ha$^{-1}$). Whereas, the lowest yield was obtained from untreated control treatment (7.95 and 9.40 t ha$^{-1}$).

Table 5: Effect of different chemicals on cob yield of corn during year 2020 (*Kharif*) and 2020–21 (*Rabi*)

| Treatments | Dosage (ml ha$^{-1}$) | Yield (t ha$^{-1}$) | |
|---|---|---|---|
| | | 2020 (*Kharif*) | 2020-21 (*Rabi*) |
| Cyantraniliprole 10.26 OD | 900 | 10.27 | 12.62 |
| Chlorantraniliprole 18.5 SC | 200 | 10.26 | 12.59 |
| Emamectin benzoate 5SG | 300 | 9.86 | 12.44 |
| Spinosad 45SC | 170 | 9.78 | 12.18 |
| Flubendiamide 20WG | 150 | 10.26 | 12.61 |
| Teflubenzuron 15 SC | 200 | 8.93 | 10.62 |
| Novaluron 5.25+ Indoxacarb 4.5 SC | 375 | 10.16 | 12.45 |
| Broflanilide 30 SC | 62 | 10.24 | 12.58 |
| Chlorfenapyr 24 SC | 325 | 9.20 | 11.11 |
| *Bacillus thuringiensis* var *kurstaki* 0.5 WP | 500 | 8.70 | 10.56 |
| Spinetorum 11.7 SC | 170 | 10.10 | 12.22 |
| *Beauveria bassiana* 1 WP | 3000 | 8.47 | 10.00 |
| *Metarhizium anisopliae* 1 WP | 3000 | 8.64 | 10.11 |
| Azadirachtin 1EC | 3000 | 8.67 | 10.28 |
| *Steinernema* sp. | 2.5×10$^{9}$ IJ | 8.25 | 9.78 |
| Untreated control | - | 7.95 | 9.40 |
| SEm± | - | 1.37 | 4.05 |
| CD (*p*=0.05) | - | 3.98 | 11.74 |

Literature pertaining to yield of corn by different insecticide treatments for FAW is limited. However, Nonci et al. (2021) found the highest average yield of corn in the insecticide treatment Spinetoram (10.7 t ha$^{-1}$) followed by Emamectin benzoate (9.3 t ha$^{-1}$) and Chlorantraniliprole (8.9 t ha$^{-1}$). Higher yield in maize was also previously obtained by Patel and Zaman (2022) for the treatments like Broflanilide, Chlorantraniliprole and Emamectin benzoate.

## 4. CONCLUSION

Cyantraniliprole, broflanilide, chlorantraniliprole, novaluron++indoxacarb, flubendiamide, emamectin benzoate, spinetoram, spinosad and chlorfenapyr were quite effective for management of FAW larva in corn. The insect growth regulator (teflubenzuron) and bio-pesticides (Btk, *Azadirachtin*, *Metarhizium* and *Beauveria*) had moderate efficacy for the same. So, their intelligent selection and alternate uses are required for successful management of FAW larva in corn.

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