

## Original Research Article

### **Field efficacy of insecticides against fall army worm, *Spodoptera frugiperda*(J. E. Smith) on maize (*Zea mays* L.)**

#### **Abstract:**

The field investigation was carried out during the *Kharif* season 2021 and 2022 in Central Research Farm (CRF), Naini Agriculture Institute, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj, Uttar Pradesh, India. The experiment was laid in Randomized Block Design with twelve treatments each replicated thrice viz., Chlorantraniliprole 18.5 SC (0.5 ml/l), Lambda cyhalothrin 2.5% EC (10 ml/l), Thiamethoxam 25 WG (10 gm/kg), Profenophos 50 EC (3ml/l), Cypermethrin 10 EC (4 ml/l), Neem oil 3% (30 ml/l), *Verticillium lecani*1.15 WP (15 ml/l), Spinosad 45 SC (0.3 ml/l), Emamectin benzoate 5 SG (0.40 gm/kg), Indoxacarb 15.8 EC (1.5 ml/l), NSKE 5% (50 ml/l) and control plot. The result on *Spodoptera frugiperda* larval population after first and second spray in kharif 2021 and kharif 2022 evaluated that all the treatments were significantly superior over the control. Among the all treatments Emamectin benzoate 5 SG (2.24), (0.82) and (3.61), (2.33) was recorded minimum larval population of the both spray followed by, Chlorantraniliprole 18.5 SC (2.41), (1.01) and (3.82), (2.46), Indoxacarb 15.8 EC (2.53), (1.13) and (3.92), (2.55), Thiamethoxam 25 WG (2.66), (1.26) and (3.99), (2.66), Lambda cyhalothrin 2.5% EC (2.73), (1.33) and (4.06), (2.73) and Spinosad 45 SC (2.86), (1.46) and (4.12), (3.79). In this Profenophos 50 EC (2.93), (1.53) and (4.19), (2.86), Cypermethrin 10 EC (2.99), (1.59) and (4.32), (2.99), *Verticillium lecani*1.15 WP (3.06), (1.66) and (4.39), (3.06), Neem oil 3% (3.13), (1.73) and (4.46), (3.13), NSKE 5% (3.19), (1.79) and (4.55), (3.24) is found to be least effective than all the treatments and is significantly superior over the control (4.99), (6.19) and (6.40), (7.19).

**Key words:** Efficacy, Insecticides, Maize, *Spodoptera frugiperda*.

#### **INTRODUCTION:**

Maize, *Zea mays* L. is a member of the family: Poaceae also known as corn. It is one of the most flexible growing crops with greater adaptability to different agro-climatic conditions. Because of higher genetic yield potential among the cereals, this crop is globally

popular as the “Queen of cereals” (**Jeyaraman, 2017**). In around 5,000 BC, the maize crop originated in central Mexico. It is the day neutral, cross pollinated and C4 plant. Maize is an economically important cereal crop among the various cereals cultivated, which is generally cultivated in tropical as well as in sub-tropical parts of the world. Leafy stalks of maize produce ears, which contain the grain and are called kernels or seeds. The kernels of maize are most commonly used as starch in cooking. The six major types of maize (corn) are dent corn, pod corn, flint corn, popcorn, flour corn, and sweet corn (**Ferroret et al., 2009**).

The United States produces about 40 per cent of the world's harvest of maize; while other top producing countries include China, Brazil, Mexico, Indonesia, India, France and Argentina. Maize is the third most important food crop in India after rice and wheat, accounting for about 20 percent of the global area under cereals (**FAO, 2019**). India's main maize producing states, that contributes more than 80 per cent of the total maize production are Andhra Pradesh (20.9 %), Karnataka (16.5 %), Rajasthan (9.9 %), Maharashtra (9.1 %), Bihar (8.9 %), Uttar Pradesh (6.1 %), Madhya Pradesh (5.7 %), Himachal Pradesh (4.4 %).

In 2017-18 the world maize production is estimated at about 1,047 million metric tonnes, cultivated in 186 m ha area by International Grain Council Report. Among the countries United States of America was stood first in maize production with 371.52 million tonnes followed by China (256 mt), Brazil (94.50 mt), European Union (59.50 mt), Argentina (42.50 mt), and India (26.50 mt). In Chhattisgarh, it is cultivated on an area of 207.82 ha with 254.13 million tons of output and 1693 kg per hectare of productivity (**Bateman et al., 2018**).

Although about 139 insect pests cause varying degree of damage to maize crop, but only about a dozen of these are quite serious and require control measures, *i.e.*, maize stalk borer, pink stem borer, and shoofly are the insects of national importance, while the armyworm, jassid, thrips, pyrilla, grasshopper, white grub, cut worm, hairy caterpillar, termite, and the leaf miner are more serious pest of regional level (**NIPMP, 2001**). Amongst all, shoot fly, *Atherigona orientalis*, Maize stem borer, *Chilo partellus*, Swimhoe and Pink stem borer, *Sesamia inferens* Walker are the most serious pest in India. In the past few years, a new pest, fall armyworm, has become an invasive challenge across the world. However, the relatively high damage by fall armyworm is occasionally reported (**Porter et al., 2000**).

Fall armyworm causes economic losses in so many crops, such as maize, cotton, soybean and beans (**Pogue, 2002**). In maize, fall armyworm attacks in all stages of the plant, from seedling until tasseling and causing defoliation, killing young plant, resulting in grain

damage and subsequently reduces quantity and quality of yield. Their damage appears as ragged-edged holes on leaves and tassels. Severe feeding by FAW, may give the appearance of corn that has been damaged by hail. When an outbreak takes place, the severity of the problem is compounded by the ability of FAW to damage a range of vegetative to reproductive plant structures, creating the opportunity to cause devastating crop losses. The recent studies conducted by Center for Agriculture and Bioscience International (CABI), which was done in 12 maize-producing African countries showed that without proper management, FAW can cause maize yield losses ranging from 8-21 million tonnes.

Fall armyworm, *Spodoptera frugiperda* (J. E. Smith) belongs to the order Lepidoptera and family Noctuidae is native to tropical and subtropical regions of the Americas. It was reported for the first time from the African continent, in Nigeria, Sao Tomé, Benin and Togo region (Goergen *et al.*, 2016). In India, fall armyworm (FAW) was firstly reported in the research fields of maize at the University of Agricultural and Horticultural Sciences, Shimoga, Karnataka (Sharanabasappa, 2018). In Chhattisgarh the *Spodoptera frugiperda* was first reported at Raipur (Deole and Paul, 2018). The name “fall armyworm” originates by their nature of damage, where infestations sometimes resemble as an army, as they move across large agriculture fields and earned their common name by eat all plant matter and the yen counter in their wide dispersals, like a large army (Smith, 1797). Due to its migratory behavior the fall armyworm was known as a sporadic pest.

### **Materials and Methods:**

The experiment was conducted during *kharif* season 2021 and 2022 at Central Research Farm (CRF), SHUATS, Prayagraj, Uttar Pradesh, India in a Randomized Block Design with twelve treatments replicated three times using variety Shivam in a plot size of (2m×2m) at a spacing of (60×20cm) with a recommended package of practices excluding plant protection. The treatments used in experiment are *viz.*, Chlorantraniliprole 18.5 SC (0.5 ml/l), Lambda cyhalothrin 2.5% EC (10 ml/l), Thiamethoxam 25 WG (10 gm/kg), Profenophos 50 EC (3ml/l), Cypermethrin 10 EC (4 ml/l), Neem oil 3% (30 ml/l), *Verticillium lecani* 1.15 WP (15 ml/l), Spinosad 45 SC (0.3 ml/l), Emamectin benzoate 5 SG (0.40 gm/kg), Indoxacarb 15.8 EC (1.5 ml/l), NSKE 5% (50 ml/l) and control.

Two sprays were carried out at interval of 15 days during the experiments to assess the effectiveness of insecticides when the *Spodoptera frugiperda* larval population. The economic threshold level or ETL (when control measures have to be taken to prevent from

pest population increase and keep them from economic injury level (EIL) of the pest is the benchmark level. There are 3 ETL levels of FAW which are following: A) 1-2 Larvae per each whorl. B) 5% to 6% Seedling are cut. C) 1<sup>st</sup> 30 days young plants show 15% whorl infestation **Tahir *et al.*, (2020)**. Five plants were randomly selected in each treatment and observation was taken one day before spraying application three, seven and fourteen-day spraying.

## **Result and Discussion:**

### **Efficacy of *Spodoptera frugiperda* Kharif 2021 (First Spray).**

#### **Three Days After Spraying:**

The data on the larval population of fall armyworm on three days after spray revealed that all treatments were significantly superior over control. Among the treatments lowest larval population of fall armyworm was recorded in T<sub>9</sub> Emamectin benzoate 5 SG (2.86) followed by T<sub>1</sub> Chlorantraniliprole 18.5 SC (2.93), T<sub>10</sub> Indoxacarb 15.8 EC (3.00), T<sub>3</sub> Thiamethoxam 25 WG (3.13), T<sub>2</sub> Lambda cyhalothrin 2.5% EC (3.20) and T<sub>8</sub> Spinosad 45 SC (3.33). In this T<sub>4</sub> Profenophos 50 EC (3.40), T<sub>5</sub> Cypermethrin 10 EC (3.46), T<sub>7</sub> *Verticillium lecanii* 1.15 WP (3.53) T<sub>6</sub> Neem oil 3% (3.60) T<sub>11</sub> NSKE 5% (3.66) is found to be least effective than all the treatments and is significantly superior over the T<sub>0</sub> control (4.60).

#### **Seven Days After Spraying:**

The data on the larval population of fall armyworm on seven days after spray revealed that all treatments were significantly superior over control. Among the treatments lowest larval population of fall armyworm was recorded in T<sub>9</sub> Emamectin benzoate 5 SG (1.86) followed by T<sub>1</sub> Chlorantraniliprole 18.5 SC (2.06), T<sub>10</sub> Indoxacarb 15.8 EC (2.20), T<sub>3</sub> Thiamethoxam 25 WG (2.33), T<sub>2</sub> Lambda cyhalothrin 2.5% EC (2.40) and T<sub>8</sub> Spinosad 45 SC (2.53). In this T<sub>4</sub> Profenophos 50 EC (2.60), T<sub>5</sub> Cypermethrin 10 EC (2.66), T<sub>7</sub> *Verticillium lecanii* 1.15 WP (2.73) T<sub>6</sub> Neem oil 3% (2.80) T<sub>11</sub> NSKE 5% (2.86) is found to be least effective than all the treatments and is significantly superior over the T<sub>0</sub> control (4.93).

#### **Fourteen Days After Spraying:**

The data on the larval population of fall armyworm on fourteen days after spray revealed that all treatments were significantly superior over control. Among the treatments lowest larval population of fall armyworm was recorded in T<sub>9</sub> Emamectin benzoate 5 SG

(2.00) followed by T<sub>1</sub> Chlorantraniliprole 18.5 SC (2.26), T<sub>10</sub> Indoxacarb 15.8 EC (2.40), T<sub>3</sub> Thiamethoxam 25 WG (2.53), T<sub>2</sub> Lambda cyhalothrin 2.5% EC (2.60) and T<sub>8</sub> Spinosad 45 SC (2.73). In this T<sub>4</sub> Profenophos 50 EC (2.80), T<sub>5</sub> Cypermethrin 10 EC (2.86), T<sub>7</sub> *Verticillium lecani* 1.15 WP (2.93) T<sub>6</sub> Neem oil 3% (3.00) T<sub>11</sub> NSKE 5% (3.06) is found to be least effective than all the treatments and is significantly superior over the T<sub>0</sub> control (5.46).

### **Overall Mean of First Spray:**

The data on the larval population of fall armyworm on mean (3<sup>rd</sup>, 7<sup>th</sup> and 14<sup>th</sup> DAS) days after spray revealed that all treatments were significantly superior over control. Among the treatments lowest larval population of fall armyworm was recorded in T<sub>9</sub> Emamectin benzoate 5 SG (2.24) followed by T<sub>1</sub> Chlorantraniliprole 18.5 SC (2.41), T<sub>10</sub> Indoxacarb 15.8 EC (2.53), T<sub>3</sub> Thiamethoxam 25 WG (2.66), T<sub>2</sub> Lambda cyhalothrin 2.5% EC (2.73) and T<sub>8</sub> Spinosad 45 SC (2.86). In this T<sub>4</sub> Profenophos 50 EC (2.93), T<sub>5</sub> Cypermethrin 10 EC (2.99), T<sub>7</sub> *Verticillium lecani* 1.15 WP (3.06) T<sub>6</sub> Neem oil 3% (3.13) T<sub>11</sub> NSKE 5% (3.19) is found to be least effective than all the treatments and is significantly superior over the T<sub>0</sub> control (4.99).

### **Efficacy of *Spodoptera frugiperda* Kharif 2021 (Second Spray).**

#### **Three Days After Spraying:**

The data on the larval population of fall armyworm on three days after spray revealed that all treatments were significantly superior over control. Among the treatments lowest larval population of fall armyworm was recorded in T<sub>9</sub> Emamectin benzoate 5 SG (1.13) followed by T<sub>1</sub> Chlorantraniliprole 18.5 SC (1.46), T<sub>10</sub> Indoxacarb 15.8 EC (1.60), T<sub>3</sub> Thiamethoxam 25 WG (1.73), T<sub>2</sub> Lambda cyhalothrin 2.5% EC (1.80) and T<sub>8</sub> Spinosad 45 SC (1.93). In this T<sub>4</sub> Profenophos 50 EC (2.00), T<sub>5</sub> Cypermethrin 10 EC (2.06), T<sub>7</sub> *Verticillium lecani* 1.15 WP (2.13), T<sub>6</sub> Neem oil 3% (2.20) T<sub>11</sub> NSKE 5% (2.26) is found to be least effective than all the treatments and is significantly superior over the T<sub>0</sub> control (5.86).

#### **Seven Days After Spraying:**

The data on the larval population of fall armyworm on seven days after spray revealed that all treatments were significantly superior over control. Among the treatments lowest larval population of fall armyworm was recorded in T<sub>9</sub> Emamectin benzoate 5 SG (0.60) followed by T<sub>1</sub> Chlorantraniliprole 18.5 SC (0.73), T<sub>10</sub> Indoxacarb 15.8 EC (0.80), T<sub>3</sub> Thiamethoxam 25 WG (0.93), T<sub>2</sub> Lambda cyhalothrin 2.5% EC (1.00) and T<sub>8</sub> Spinosad 45

SC (1.13). In this T<sub>4</sub>Profenophos 50 EC (1.20), T<sub>5</sub> Cypermethrin 10 EC (1.26), T<sub>7</sub>*Verticillium lecani*1.15 WP (1.33) T<sub>6</sub> Neem oil 3% (1.40) T<sub>11</sub> NSKE 5% (1.46) is found to be least effective than all the treatments and is significantly superior over the T<sub>0</sub> control (6.13).

#### **Fourteen Days After Spraying:**

The data on the larval population of fall armyworm on fourteen days after spray revealed that all treatments were significantly superior over control. Among the treatments lowest larval population of fall armyworm was recorded in T<sub>9</sub>Emamectin benzoate 5 SG (0.73) followed by T<sub>1</sub> Chlorantraniliprole 18.5 SC (0.86), T<sub>10</sub> Indoxacarb 15.8 EC (1.00), T<sub>3</sub> Thiamethoxam 25 WG (1.13), T<sub>2</sub> Lambda cyhalothrin 2.5% EC (1.20) and T<sub>8</sub> Spinosad 45 SC (1.33). In this T<sub>4</sub>Profenophos 50 EC (1.40), T<sub>5</sub> Cypermethrin 10 EC (1.46), T<sub>7</sub>*Verticillium lecani*1.15 WP (1.53) T<sub>6</sub> Neem oil 3% (1.60) T<sub>11</sub> NSKE 5% (1.66) is found to be least effective than all the treatments and is significantly superior over the T<sub>0</sub> control (6.60).

#### **Overall Mean of Second Spray:**

The data on the larval population of fall armyworm on mean (3<sup>rd</sup>, 7<sup>th</sup> and 14<sup>th</sup> DAS) days after spray revealed that all treatments were significantly superior over control. Among the treatments lowest larval population of fall armyworm was recorded in T<sub>9</sub>Emamectin benzoate 5 SG (0.82) followed by T<sub>1</sub> Chlorantraniliprole 18.5 SC (1.01), T<sub>10</sub> Indoxacarb 15.8 EC (1.13), T<sub>3</sub> Thiamethoxam 25 WG (1.26), T<sub>2</sub> Lambda cyhalothrin 2.5% EC (1.33) and T<sub>8</sub> Spinosad 45 SC (1.46). In this T<sub>4</sub>Profenophos 50 EC (1.53), T<sub>5</sub> Cypermethrin 10 EC (1.59), T<sub>7</sub>*Verticillium lecani*1.15 WP (1.66) T<sub>6</sub> Neem oil 3% (1.73) T<sub>11</sub> NSKE 5% (1.79) is found to be least effective than all the treatments and is significantly superior over the T<sub>0</sub> control (6.19).

### **Efficacy of *Spodoptera frugiperda* Kharif 2022 (First Spray).**

#### **Three Days After Spraying:**

The data on the larval population of fall armyworm on three days after spray revealed that all treatments were significantly superior over control. Among the treatments lowest larval population of fall armyworm was recorded in T<sub>9</sub>Emamectin benzoate 5 SG (4.13) followed by T<sub>1</sub> Chlorantraniliprole 18.5 SC (4.20), T<sub>10</sub> Indoxacarb 15.8 EC (4.26), T<sub>3</sub> Thiamethoxam 25 WG (4.33), T<sub>2</sub> Lambda cyhalothrin 2.5% EC (4.40) and T<sub>8</sub> Spinosad 45 SC (4.46). In this T<sub>4</sub>Profenophos 50 EC (4.53), T<sub>5</sub> Cypermethrin 10 EC (4.66), T<sub>7</sub>*Verticillium*

*lecani*1.15 WP (4.73), T<sub>6</sub> Neem oil 3% (4.80) T<sub>11</sub> NSKE 5% (4.86) is found to be least effective than all the treatments and is significantly superior over the T<sub>0</sub> control (6.00).

#### **Seven Days After Spraying:**

The data on the larval population of fall armyworm seven days after spray revealed that all treatments were significantly superior over control. Among the treatments lowest larval population of fall armyworm was recorded in T<sub>9</sub> Emamectin benzoate 5 SG (3.26) followed by T<sub>1</sub> Chlorantraniliprole 18.5 SC (3.53), T<sub>10</sub> Indoxacarb 15.8 EC (3.66), T<sub>3</sub> Thiamethoxam 25 WG (3.73), T<sub>2</sub> Lambda cyhalothrin 2.5% EC (3.80) and T<sub>8</sub> Spinosad 45 SC (3.86). In this T<sub>4</sub> Profenophos 50 EC (3.93), T<sub>5</sub> Cypermethrin 10 EC (4.06), T<sub>7</sub> *Verticillium lecani*1.15 WP (4.13), T<sub>6</sub> Neem oil 3% (4.20) T<sub>11</sub> NSKE 5% (4.26) is found to be least effective than all the treatments and is significantly superior over the T<sub>0</sub> control (6.40).

#### **Fourteen Days After Spraying:**

The data on the larval population of fall armyworm fourteen days after spray revealed that all treatments were significantly superior over control. Among the treatments lowest larval population of fall armyworm was recorded in T<sub>9</sub> Emamectin benzoate 5 SG (3.46) followed by T<sub>1</sub> Chlorantraniliprole 18.5 SC (3.73), T<sub>10</sub> Indoxacarb 15.8 EC (3.86), T<sub>3</sub> Thiamethoxam 25 WG (3.93), T<sub>2</sub> Lambda cyhalothrin 2.5% EC (4.00) and T<sub>8</sub> Spinosad 45 SC (4.06). In this T<sub>4</sub> Profenophos 50 EC (4.13), T<sub>5</sub> Cypermethrin 10 EC (4.26), T<sub>7</sub> *Verticillium lecani*1.15 WP (4.33), T<sub>6</sub> Neem oil 3% (4.40), T<sub>11</sub> NSKE 5% (4.53) is found to be least effective than all the treatments and is significantly superior over the T<sub>0</sub> control (6.80).

#### **Overall Mean of First Spray:**

The data on the larval population of fall armyworm mean (3<sup>rd</sup>, 7<sup>th</sup> and 14<sup>th</sup> DAS) days after spray revealed that all treatments were significantly superior over control. Among the treatments lowest larval population of fall armyworm was recorded in T<sub>9</sub> Emamectin benzoate 5 SG (3.61) followed by T<sub>1</sub> Chlorantraniliprole 18.5 SC (3.82), T<sub>10</sub> Indoxacarb 15.8 EC (3.92), T<sub>3</sub> Thiamethoxam 25 WG (3.99), T<sub>2</sub> Lambda cyhalothrin 2.5% EC (4.06) and T<sub>8</sub> Spinosad 45 SC (4.12). In this T<sub>4</sub> Profenophos 50 EC (4.19), T<sub>5</sub> Cypermethrin 10 EC (4.32), T<sub>7</sub> *Verticillium lecani*1.15 WP (4.39), T<sub>6</sub> Neem oil 3% (4.46) T<sub>11</sub> NSKE 5% (4.55) is found to be least effective than all the treatments and is significantly superior over the T<sub>0</sub> control (6.40).

#### **Efficacy of *Spodoptera frugiperda* Kharif 2022 (Second Spray).**

### **Three Days After Spraying:**

The data on the larval population of fall armyworm on three days after spray revealed that all treatments were significantly superior over control. Among the treatments lowest larval population of fall armyworm was recorded in T<sub>9</sub> Emamectin benzoate 5 SG (2.73) followed by T<sub>1</sub> Chlorantraniliprole 18.5 SC (2.93), T<sub>10</sub> Indoxacarb 15.8 EC (3.06), T<sub>3</sub> Thiamethoxam 25 WG (3.13), T<sub>2</sub> Lambda cyhalothrin 2.5% EC (3.20) and T<sub>8</sub> Spinosad 45 SC (3.26). In this T<sub>4</sub> Profenophos 50 EC (3.33), T<sub>5</sub> Cypermethrin 10 EC (3.46), T<sub>7</sub> *Verticillium lecani* 1.15 WP (3.53), T<sub>6</sub> Neem oil 3% (3.60) T<sub>11</sub> NSKE 5% (3.80) is found to be least effective than all the treatments and is significantly superior over the T<sub>0</sub> control (6.93).

### **Seven Days After Spraying:**

The data on the larval population of fall armyworm on seven days after spray revealed that all treatments were significantly superior over control. Among the treatments lowest larval population of fall armyworm was recorded in T<sub>9</sub> Emamectin benzoate 5 SG (2.13) followed by T<sub>1</sub> Chlorantraniliprole 18.5 SC (2.20), T<sub>10</sub> Indoxacarb 15.8 EC (2.26), T<sub>3</sub> Thiamethoxam 25 WG (2.33), T<sub>2</sub> Lambda cyhalothrin 2.5% EC (2.40) and T<sub>8</sub> Spinosad 45 SC (2.46). In this T<sub>4</sub> Profenophos 50 EC (2.53), T<sub>5</sub> Cypermethrin 10 EC (2.66), T<sub>7</sub> *Verticillium lecani* 1.15 WP (2.73), T<sub>6</sub> Neem oil 3% (2.80) T<sub>11</sub> NSKE 5% (2.86) is found to be least effective than all the treatments and is significantly superior over the T<sub>0</sub> control (7.26).

### **Fourteen Days After Spraying:**

The data on the larval population of fall armyworm on fourteen days after spray revealed that all treatments were significantly superior over control. Among the treatments lowest larval population of fall armyworm was recorded in T<sub>9</sub> Emamectin benzoate 5 SG (2.13) followed by T<sub>1</sub> Chlorantraniliprole 18.5 SC (2.26), T<sub>10</sub> Indoxacarb 15.8 EC (2.33), T<sub>3</sub> Thiamethoxam 25 WG (2.53), T<sub>2</sub> Lambda cyhalothrin 2.5% EC (2.60) and T<sub>8</sub> Spinosad 45 SC (2.66). In this T<sub>4</sub> Profenophos 50 EC (2.73), T<sub>5</sub> Cypermethrin 10 EC (2.86), T<sub>7</sub> *Verticillium lecani* 1.15 WP (2.93), T<sub>6</sub> Neem oil 3% (3.00), T<sub>11</sub> NSKE 5% (3.06) is found to be least effective than all the treatments and is significantly superior over the T<sub>0</sub> control (7.40).

### **Overall Mean of Second Spray:**

The data on the larval population of fall armyworm on mean (3<sup>rd</sup>, 7<sup>th</sup> and 14<sup>th</sup> DAS) days after spray revealed that all treatments were significantly superior over control. Among the treatments lowest larval population of fall armyworm was recorded in

T<sub>9</sub>Emamectin benzoate 5 SG (2.33) followed by T<sub>1</sub> Chlorantraniliprole 18.5 SC (2.46), T<sub>10</sub> Indoxacarb 15.8 EC (2.55), T<sub>3</sub> Thiamethoxam 25 WG (2.66), T<sub>2</sub> Lambda cyhalothrin 2.5% EC (2.73) and T<sub>8</sub> Spinosad 45 SC (2.79). In this T<sub>4</sub>Profenophos 50 EC (2.86), T<sub>5</sub> Cypermethrin 10 EC (2.99), T<sub>7</sub>*Verticillium lecani*1.15 WP (3.06), T<sub>6</sub> Neem oil 3% (3.13) T<sub>11</sub> NSKE 5% (3.24) is found to be least effective than all the treatments and is significantly superior over the T<sub>0</sub> control (7.19).

**Pooled Mean:**

The data on the larval population of fall armyworm on pooled mean revealed that all treatments were significantly superior over control. Among the treatments lowest larval population of fall armyworm was recorded in T<sub>9</sub>Emamectin benzoate 5 SG (2.25) followed by T<sub>1</sub> Chlorantraniliprole 18.5 SC (2.42), T<sub>10</sub> Indoxacarb 15.8 EC (2.53), T<sub>3</sub> Thiamethoxam 25 WG (2.64), T<sub>2</sub> Lambda cyhalothrin 2.5% EC (2.71) and T<sub>8</sub> Spinosad 45 SC (2.80). In this T<sub>4</sub>Profenophos 50 EC (2.87), T<sub>5</sub> Cypermethrin 10 EC (2.97), T<sub>7</sub>*Verticillium lecani*1.15 WP (3.04) T<sub>6</sub> Neem oil 3% (3.11) T<sub>11</sub> NSKE 5% (3.19) is found to be least effective than all the treatments and is significantly superior over the T<sub>0</sub> control (6.19).

**Table: 1 Efficacy against *Spodoptera frugiperda* Kharif-2021**

Treatments		Larval population on number basis/5 plants									Overall Mean
		One day before spray	After First Spray				After Second Spray				
			3 DAS	7 DAS	14 DAS	Mean	3 DAS	7 DAS	14 DAS	Mean	
<b>T<sub>1</sub></b>	Chlorantraniprole 18.5 % SC	4.33	2.93 <sup>fg</sup>	2.06 <sup>gh</sup>	2.26 <sup>gh</sup>	2.41 <sup>fg</sup>	1.46 <sup>g</sup>	0.73 <sup>fg</sup>	0.86 <sup>hi</sup>	1.01 <sup>fg</sup>	1.71
<b>T<sub>2</sub></b>	Lambda Cyhalothrin 5% EC	4.40	3.20 <sup>def</sup>	2.40 <sup>def</sup>	2.60 <sup>def</sup>	2.73 <sup>cdef</sup>	1.80 <sup>def</sup>	1.00 <sup>def</sup>	1.20 <sup>efg</sup>	1.33 <sup>cdef</sup>	2.03
<b>T<sub>3</sub></b>	Thiamethoxam 25% WG	4.46	3.13 <sup>efg</sup>	2.33 <sup>efg</sup>	2.53 <sup>efg</sup>	2.66 <sup>def</sup>	1.73 <sup>efg</sup>	0.93 <sup>ef</sup>	1.13 <sup>fg</sup>	1.26 <sup>def</sup>	1.96
<b>T<sub>4</sub></b>	Profenophos 50% EC	4.40	3.40 <sup>bcde</sup>	2.60 <sup>bcde</sup>	2.80 <sup>bcde</sup>	2.93 <sup>bcd</sup>	2.00 <sup>bcde</sup>	1.20 <sup>bcde</sup>	1.40 <sup>cde</sup>	1.53 <sup>bcd</sup>	2.23
<b>T<sub>5</sub></b>	Cypermethrin 10% EC	4.53	3.46 <sup>bcd</sup>	2.66 <sup>bcd</sup>	2.86 <sup>bcd</sup>	2.99 <sup>bcd</sup>	2.06 <sup>bcd</sup>	1.26 <sup>bcd</sup>	1.46 <sup>bcd</sup>	1.59 <sup>bcd</sup>	2.29
<b>T<sub>6</sub></b>	Neem oil 3%	4.80	3.60 <sup>bc</sup>	2.80 <sup>bc</sup>	3.00 <sup>bc</sup>	3.13 <sup>b</sup>	2.20 <sup>bc</sup>	1.40 <sup>bc</sup>	1.60 <sup>bc</sup>	1.73 <sup>b</sup>	2.43
<b>T<sub>7</sub></b>	<i>Verticillium lecani</i> 1.15 % WP	4.60	3.53 <sup>bc</sup>	2.73 <sup>bc</sup>	2.93 <sup>bc</sup>	3.06 <sup>bc</sup>	2.13 <sup>bc</sup>	1.33 <sup>bc</sup>	1.53 <sup>bcd</sup>	1.66 <sup>bc</sup>	2.36

<b>T<sub>8</sub></b>	Spinosad 45% SC	4.53	3.33 <sup>cde</sup>	2.53 <sup>cde</sup>	2.73 <sup>cde</sup>	2.86 <sup>bcde</sup>	1.93 <sup>cde</sup>	1.13 <sup>cde</sup>	1.33 <sup>def</sup>	1.46 <sup>bcde</sup>	2.16
<b>T<sub>9</sub></b>	Emamectin benzoate 5 % SG	4.06	2.86 <sup>g</sup>	1.86 <sup>h</sup>	2.00 <sup>h</sup>	2.24 <sup>g</sup>	1.13 <sup>h</sup>	0.60 <sup>g</sup>	0.73 <sup>i</sup>	0.82 <sup>g</sup>	1.53
<b>T<sub>10</sub></b>	Indoxacarb 15.8% EC	4.20	3.00 <sup>fg</sup>	2.20 <sup>fg</sup>	2.40 <sup>fg</sup>	2.53 <sup>efg</sup>	1.60 <sup>fg</sup>	0.80 <sup>fg</sup>	1.00 <sup>gh</sup>	1.13 <sup>efg</sup>	1.83
<b>T<sub>11</sub></b>	NSKE 5 %	4.73	3.66 <sup>b</sup>	2.86 <sup>b</sup>	3.06 <sup>b</sup>	3.19 <sup>b</sup>	2.26 <sup>b</sup>	1.46 <sup>b</sup>	1.66 <sup>b</sup>	1.79 <sup>b</sup>	2.49
<b>T<sub>0</sub></b>	Control	4.20	4.60 <sup>a</sup>	4.93 <sup>a</sup>	5.46 <sup>a</sup>	4.99 <sup>a</sup>	5.86 <sup>a</sup>	6.13 <sup>a</sup>	6.60 <sup>a</sup>	6.19 <sup>a</sup>	5.59
<b>F-test</b>		<b>NS</b>	<b>S</b>	<b>S</b>	<b>S</b>	<b>S</b>	<b>S</b>	<b>S</b>	<b>S</b>	<b>S</b>	<b>S</b>
<b>S.Ed (±)</b>		0.21	0.14	0.12	0.13	0.18	0.13	0.14	0.12	0.16	0.43
<b>C.D. (P=0.05)</b>		-	0.29	0.26	0.28	0.38	0.27	0.30	0.26	0.34	1.16

**DBS- Day Before Spraying, DAS- Day After Spraying, NS-Nonsignificant, S-Significant**

**Table: 2. Efficacy against *Spodoptera frugiperda* Kharif-2022**

Treatments		Larval population on number basis/5 plants									Overall Mean	Pooled Mean
		One day before spray	After First Spray				After Second Spray					
			3 DAS	7 DAS	14 DAS	Mean	3 DAS	7 DAS	14 DAS	Mean		
<b>T<sub>1</sub></b>	Chlorantraniprole 18.5 % SC	5.40	4.20 <sup>f</sup>	3.53 <sup>gh</sup>	3.73 <sup>gh</sup>	3.82 <sup>gh</sup>	2.93 <sup>gh</sup>	2.20 <sup>f</sup>	2.26 <sup>gh</sup>	2.46 <sup>gh</sup>	3.14 <sup>b</sup>	2.42 <sup>cd</sup>
<b>T<sub>2</sub></b>	Lambda Cyhalothrin 5% EC	5.60	4.40 <sup>cdef</sup>	3.80 <sup>defg</sup>	4.00 <sup>defg</sup>	4.06 <sup>defg</sup>	3.20 <sup>defg</sup>	2.40 <sup>cdef</sup>	2.60 <sup>defg</sup>	2.73 <sup>efg</sup>	3.39 <sup>b</sup>	2.71 <sup>bcd</sup>
<b>T<sub>3</sub></b>	Thiamethoxam 25% WG	5.53	4.33 <sup>def</sup>	3.73 <sup>efg</sup>	3.93 <sup>efg</sup>	3.99 <sup>efg</sup>	3.13 <sup>efg</sup>	2.33 <sup>def</sup>	2.53 <sup>efg</sup>	2.66 <sup>fg</sup>	3.32 <sup>b</sup>	2.64 <sup>bcd</sup>
<b>T<sub>4</sub></b>	Profenophos 50% EC	5.73	4.53 <sup>bcde</sup> <sub>f</sub>	3.93 <sup>bcd</sup> <sub>ef</sub>	4.13 <sup>cdef</sup>	4.19 <sup>cdef</sup>	3.33 <sup>cdef</sup>	2.53 <sup>bcdef</sup>	2.73 <sup>bcde</sup>	2.86 <sup>cdef</sup>	3.52 <sup>b</sup>	2.87 <sup>bcd</sup>
<b>T<sub>5</sub></b>	Cypermethrin 10% EC	5.73	4.66 <sup>bcde</sup>	4.06 <sup>bcd</sup> <sub>e</sub>	4.26 <sup>bcde</sup>	4.32 <sup>bcde</sup>	3.46 <sup>bcde</sup>	2.66 <sup>bcde</sup>	2.86 <sup>bcde</sup>	2.99 <sup>bcde</sup>	3.65 <sup>b</sup>	2.97 <sup>bcd</sup>
<b>T<sub>6</sub></b>	Neem oil 3%	5.86	4.80 <sup>bc</sup>	4.20 <sup>bc</sup>	4.40 <sup>b<sub>c</sub></sup>	4.46 <sup>bc</sup>	3.60 <sup>bc</sup>	2.80 <sup>bc</sup>	3.00 <sup>bc</sup>	3.13 <sup>bc</sup>	3.79 <sup>b</sup>	3.11 <sup>bc</sup>
<b>T<sub>7</sub></b>	<i>Verticillium</i> <i>lecani</i> 1.15 % WP	5.80	4.73 <sup>bcd</sup>	4.13 <sup>bcd</sup>	4.33 <sup>bcd</sup>	4.39 <sup>bcd</sup>	3.53 <sup>bcd</sup>	2.73 <sup>bcd</sup>	2.93 <sup>b<sub>cd</sub></sup>	3.06 <sup>bcd</sup>	3.72 <sup>b</sup>	3.04 <sup>bcd</sup>

<b>T<sub>8</sub></b>	Spinosad 45% SC	5.66	4.46 <sup>bcde</sup> <sub>f</sub>	3.86 <sup>cdef</sup> <sub>g</sub>	4.06 <sup>cdefg</sup>	4.12 <sup>defg</sup>	3.26 <sup>cdefg</sup>	2.46 <sup>bcdef</sup>	2.66 <sup>cdef</sup>	2.79 <sup>def</sup>	3.45 <sup>b</sup>	2.80 <sup>bcd</sup>
<b>T<sub>9</sub></b>	Emamectin benzoate 5 % SG	5.33	4.13 <sup>f</sup>	3.26 <sup>h</sup>	3.46 <sup>h</sup>	3.61 <sup>h</sup>	2.73 <sup>h</sup>	2.13 <sup>f</sup>	2.13 <sup>h</sup>	2.33 <sup>h</sup>	2.90 <sup>b</sup>	2.25 <sup>d</sup>
<b>T<sub>10</sub></b>	Indoxacarb 15.8% EC	5.46	4.26 <sup>ef</sup>	3.66 <sup>fg</sup>	3.86 <sup>fg</sup>	3.92 <sup>fgh</sup>	3.06 <sup>fgh</sup>	2.26 <sup>ef</sup>	2.33 <sup>fgh</sup>	2.55 <sup>fgh</sup>	3.23 <sup>b</sup>	2.53 <sup>bcd</sup>
<b>T<sub>11</sub></b>	NSKE 5 %	5.86	4.86 <sup>b</sup>	4.26 <sup>b</sup>	4.53 <sup>b</sup>	4.55 <sup>b</sup>	3.80 <sup>b</sup>	2.86 <sup>b</sup>	3.06 <sup>b</sup>	3.24 <sup>b</sup>	3.89 <sup>b</sup>	3.19 <sup>b</sup>
<b>T<sub>0</sub></b>	Control	5.40	6.00 <sup>a</sup>	6.40 <sup>a</sup>	6.80 <sup>a</sup>	6.40 <sup>a</sup>	6.93 <sup>a</sup>	7.26 <sup>a</sup>	7.40 <sup>a</sup>	7.19 <sup>a</sup>	6.79 <sup>a</sup>	6.19 <sup>a</sup>
<b>F-test</b>		NS	S	S	S	S	S	S	S	S	S	S
<b>S.Ed (±)</b>		0.19	0.20	0.17	0.17	0.15	0.18	0.20	0.18	0.15	0.35	0.04
<b>C.D. (P=0.05)</b>		-	0.42	0.36	0.35	0.33	0.38	0.41	0.37	0.32	0.95	0.10

**DBS- Day Before Spraying, DAS- Day After Spraying, NS-Nonsignificant, S-Significant**

## DISCUSSION

### Overall mean (first and second spray) *Spodoptera frugiperda* (Kharif 2021)

The data on the larval population of fall armyworm on overall mean (first and second spray) revealed that all treatments were significantly superior over control. Among the treatments lowest larval population of fall armyworm was recorded in T<sub>9</sub> Emamectin benzoate 5 SG (1.53) followed by T<sub>1</sub> Chlorantraniliprole 18.5 SC (1.71), T<sub>10</sub> Indoxacarb 15.8 EC (1.83), T<sub>3</sub> Thiamethoxam 25 WG (1.96), T<sub>2</sub> Lambda cyhalothrin 2.5% EC (2.03) and T<sub>8</sub> Spinosad 45 SC (2.16). In this T<sub>4</sub> Profenophos 50 EC (2.23), T<sub>5</sub> Cypermethrin 10 EC (2.29), T<sub>7</sub> *Verticillium lecani* 1.15 WP (2.36) T<sub>6</sub> Neem oil 3% (2.43) T<sub>11</sub> NSKE 5% (2.49) is found to be least effective than all the treatments and is significantly superior over the T<sub>0</sub> control (5.59).

Among all the treatments, Emamectin benzoate 5 % SG was found to be most effective in managing the larval population of fall armyworm. The values obtained in the first and second spray were (2.24) and (0.82). These results are supported by **Appalanaidu and Kumar (2022)**, **Phani Kumar et al., (2021)** and **Bharadwaj et al., (2020)**. Chlorantraniliprole 18.5% SC was also found to be very effective in reducing the larval population of fall armyworm. The values obtained in the first and second spray were (2.41) and (1.01). The same results were observed by **Omprakash et al., (2020)** and **Bharadwaj et al., (2020)**. The application of Indoxacarb 15.8% EC reduced the larval population of fall armyworm. Where the observations of first and second sprays obtained were (2.53) and (1.13). These results are supported by **Deshmukh et al., (2020)** and **Ravikumar et al., (2022)**. The efficacy of Thiamethoxam 25% WG on fall armyworm in first and second spray were (2.66) and (1.26). These results are as per the findings of **Mallapur et al., (2019)**.

The next best treatment was found to be Lambda Cyhalothrin 5% EC in which the efficacy values of first and second spray were (2.73) and (1.33) respectively to the similar findings of **Bharadwaj et al., (2020)**. The next best treatment was found to be Spinosad 45% SC in which the efficacy values of first and second spray were (2.86) and (1.46) respectively; these results were supported by **Mallapur et al., (2019)** and **Sangleet et al., (2020)**. The next effective treatment was found to be Profenophos 50% EC in which efficacy values of first and second sprays were (2.93) and (1.53) respectively; these results were supported by **Sangleet et al., (2020)**. The efficacy of Cypermethrin 10% EC on fall armyworm in first and second

spray were (2.99) and (1.59). These results are as per the findings of **Ravikumar et al.,(2022)**.

### **Overall mean (first and second spray) *Spodoptera frugiperda*(Kharif 2022)**

The data on the larval population of fall armyworm on overall mean (first and second spray) revealed that all treatments were significantly superior over control. Among the treatments lowest larval population of fall armyworm was recorded in T<sub>9</sub> Emamectin benzoate 5 SG (2.97) followed by T<sub>1</sub> Chlorantraniliprole 18.5 SC (3.14), T<sub>10</sub> Indoxacarb 15.8 EC (3.23), T<sub>3</sub> Thiamethoxam 25 WG (3.32), T<sub>2</sub> Lambda cyhalothrin 2.5% EC (3.39) and T<sub>8</sub> Spinosad 45 SC (3.45). In this T<sub>4</sub> Profenophos 50 EC (3.52), T<sub>5</sub> Cypermethrin 10 EC (3.65), T<sub>7</sub> *Verticillium lecani* 1.15 WP (3.72) T<sub>6</sub> Neem oil 3% (3.79) T<sub>11</sub> NSKE 5% (3.89) is found to be least effective than all the treatments and is significantly superior over the T<sub>0</sub> control (6.79).

Among all the treatments, Emamectin benzoate 5 % SG was found to be most effective in managing the larval population of fall armyworm. The values obtained in the first and second spray were (3.61) and (2.33). These results are supported by **Deshmukh et al.,(2020)** and **Ramesh and Tayde (2022)**. Chlorantraniliprole 18.5% SC was also found to be very effective in reducing the larval population of fall armyworm. The values obtained in the first and second spray were (3.82) and (2.46). The same results were observed by **Omprakash et al., (2020),) and Suthar et al., (2020)**. The application of Indoxacarb 15.8% EC reduced the larval population of fall armyworm. Where the observations of first and second sprays obtained were (3.92) and (2.55). These results are supported by **Deshmukh et al.,(2020)** and **Ravikumar et al.,(2022)**. The efficacy of Thiamethoxam 25% WG on fall armyworm in first and second spray were (3.99) and (2.66). These results are as per the findings of **Mallapur et al.,(2019)**.

The next best treatment was found to be Lambda Cyhalothrin 5% EC in which the efficacy values of first and second spray were (4.06) and (2.73) respectively to the similar findings of **Bharadwaj et al., (2020)**. The next best treatment was found to be Spinosad 45% SC in which the efficacy values of first and second spray were (4.12) and (3.79) respectively; these results were supported by **Mallapur et al.,(2019)** and **Sangleet et al., (2020)**. The next effective treatment was found to be Profenophos 50% EC in which efficacy values of first and second sprays were (4.19) and (2.86) respectively; these results were supported by **Sangleet et al., (2020)**. The efficacy of Cypermethrin 10% EC on fall armyworm in first and second

spray were (4.32) and (2.99). These results are as per the findings of **Ravikumar et al.,(2022)**.

### **Conclusion:**

From the present study, the results showed that Emamectin benzoate 5% SG followed by Chlorantraniliprole 18.5% SC, Indoxacarb 15.8% EC are the most effective treatments against maize fall armyworm, pink stem borer and spotted stem borer and produced maximum yield and recorded the highest Cost-Benefit ratio compared to other treatments. Thiamethoxam 25% WG, Lambda Cyhalothrin 5% EC, Spinosad 45% SC and Profenophos 50% EC have shown average results in managing fall armyworm, pink stem borer and spotted stem borer. Cypermethrin 10% EC, *Verticillium lecani* 1.15 % WP, Neem oil 3%, NSKE 5 % found to be the least effective in managing all the pests of maize. Therefore, it is recommended to incorporate effective insecticides into existing Integrated Pest Management programs, with a focus on preventing issues such as insecticide resistance and pest resurgence. Botanical substances play a crucial role in Integrated Pest Management by reducing the indiscriminate use of pesticides that can harm the environment and have minimal impact on beneficial insects.

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