International Journal of Environment and Climate Change

Volume 13, Issue 11, Page 3010-3020, 2023; Article no.IJECC.109211
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Field Efficacy of Insecticides against Fall Army Worm, *Spodoptera frugiperda* (J. E. Smith) on Maize (*Zea mays* L.)

Ashok Sakharam Chandar [a] and Anoorag R. Tayde [a*]

[a] Department of Entomology, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, 211007, (U.P), India.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2023/v13i113470

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/109211

Original Research Article

Received: 03/09/2023
Accepted: 08/11/2023
Published: 15/11/2023

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

**Corresponding author: E-mail: aurag.tayde@shiats.edu.in;*

(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).

Keywords: Efficacy; insecticides; maize; Spodoptera frugiperda.

1. 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" [1]. "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" [2].

"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" [3]. 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" [4].

"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 leve"l [5]. "Amongst all, shoot fly, *Atherigona orientalis*, Maize stem borer, *Chilo partellus,* Swinhoe 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" [6].

"Fall armyworm causes economic losses in so many crops, such as maize, cotton, soybean and beans" [7]. "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" [7].

"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" [8]. "In India, fall armyworm (FAW) was firstly reported in the research fields of maize at the University of Agricultural and Horticultural Sciences, Shimoga, Karnataka" [9]. "In Chhattisgarh the *Spodoptera frugiperda* was first reported at Raipur" [10]. 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 [11]. Due to its migratory behavior the fall armyworm was known as a sporadic pest.

2. 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. Five plants were randomly selected in each treatment and observation was taken one day before spraying application three, seven and fourteen-day spraying. 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) 1st 30 days young plants show 15% whorl infestation [12]. Some fungi, such *Metarhizium anisopliae* and *Beauveria bassiana*, have the ability to infect and kill fall armyworms. These fungi can be used as biopesticides and are available commercially.

3. RESULTS AND DISCUSSION

3.1 Efficacy of *Spodoptera frugiperda Kharif* 2021 (First Spray)

3.1.1 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_9 Emamectin benzoate 5 SG (2.86) followed by T_1 Chlorantraniliprole 18.5 SC (2.93), T_{10} Indoxacarb 15.8 EC (3.00), T_3 Thiamethoxam 25 WG (3.13), T_2 Lambda cyhalothrin 2.5% EC (3.20) and T_8 Spinosad 45 SC (3.33). In this T_4 Profenophos 50 EC (3.40), T_5 Cypermethrin 10 EC (3.46), T_7 *Verticillium lecani* 1.15 WP (3.53) T_6 Neem oil 3% (3.60) T_{11} NSKE 5% (3.66) is found to be least effective than all the treatments and is significantly superior over the T_0 control (4.60).

3.1.2 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_9 Emamectin benzoate 5 SG (1.86) followed by T_1 Chlorantraniliprole 18.5 SC (2.06), T_{10} Indoxacarb 15.8 EC (2.20), T_3 Thiamethoxam 25 WG (2.33), T_2 Lambda cyhalothrin 2.5% EC (2.40) and T_8 Spinosad 45 SC (2.53). In this T_4 Profenophos 50 EC (2.60), T_5 Cypermethrin 10 EC (2.66), T_7 *Verticillium lecani* 1.15 WP (2.73) T_6 Neem oil 3% (2.80) T_{11} NSKE 5% (2.86) is found to be least effective than all the treatments and is significantly superior over the T_0 control (4.93).

3.1.3 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_9 Emamectin benzoate 5 SG (2.00) followed by T_1 Chlorantraniliprole 18.5 SC (2.26), T_{10} Indoxacarb 15.8 EC (2.40), T_3 Thiamethoxam 25

WG (2.53), T_2 Lambda cyhalothrin 2.5% EC (2.60) and T_8 Spinosad 45 SC (2.73). In this T_4 Profenophos 50 EC (2.80), T_5 Cypermethrin 10 EC (2.86), T_7 *Verticillium lecani* 1.15 WP (2.93) T_6 Neem oil 3% (3.00) T_{11} NSKE 5% (3.06) is found to be least effective than all the treatments and is significantly superior over the T_0 control (5.46).

3.1.4 Overall mean of first spray

The data on the larval population of fall armyworm on mean (3rd, 7th and 14th 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_9 Emamectin benzoate 5 SG (2.24) followed by T_1 Chlorantraniliprole 18.5 SC (2.41), T_{10} Indoxacarb 15.8 EC (2.53), T_3 Thiamethoxam 25 WG (2.66), T_2 Lambda cyhalothrin 2.5% EC (2.73) and T_8 Spinosad 45 SC (2.86). In this T_4 Profenophos 50 EC (2.93), T_5 Cypermethrin 10 EC (2.99), T_7 *Verticillium lecani* 1.15 WP (3.06) T_6 Neem oil 3% (3.13) T_{11} NSKE 5% (3.19) is found to be least effective than all the treatments and is significantly superior over the T_0 control (4.99).

3.2 Efficacy of *Spodoptera frugiperda* *Kharif* 2021 (Second Spray)

3.2.1 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_9 Emamectin benzoate 5 SG (1.13) followed by T_1 Chlorantraniliprole 18.5 SC (1.46), T_{10} Indoxacarb 15.8 EC (1.60), T_3 Thiamethoxam 25 WG (1.73), T_2 Lambda cyhalothrin 2.5% EC (1.80) and T_8 Spinosad 45 SC (1.93). In this T_4 Profenophos 50 EC (2.00), T_5 Cypermethrin 10 EC (2.06), T_7 *Verticillium lecani* 1.15 WP (2.13), T_6 Neem oil 3% (2.20) T_{11} NSKE 5% (2.26) is found to be least effective than all the treatments and is significantly superior over the T_0 control (5.86).

3.2.2 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_9 Emamectin benzoate 5 SG (0.60) followed by T_1 Chlorantraniliprole 18.5 SC (0.73), T_{10} Indoxacarb 15.8 EC (0.80), T_3 Thiamethoxam 25 WG (0.93), T_2 Lambda cyhalothrin 2.5% EC (1.00) and T_8 Spinosad 45 SC (1.13). In this T_4 Profenophos 50 EC (1.20), T_5 Cypermethrin 10 EC (1.26), T_7 *Verticillium lecani* 1.15 WP (1.33) T_6 Neem oil 3% (1.40) T_{11} NSKE 5% (1.46) is found to be least effective than all the treatments and is significantly superior over the T_0 control (6.13).

3.2.3 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_9 Emamectin benzoate 5 SG (0.73) followed by T_1 Chlorantraniliprole 18.5 SC (0.86), T_{10} Indoxacarb 15.8 EC (1.00), T_3 Thiamethoxam 25 WG (1.13), T_2 Lambda cyhalothrin 2.5% EC (1.20) and T_8 Spinosad 45 SC (1.33). In this T_4 Profenophos 50 EC (1.40), T_5 Cypermethrin 10 EC (1.46), T_7 *Verticillium lecani* 1.15 WP (1.53) T_6 Neem oil 3% (1.60) T_{11} NSKE 5% (1.66) is found to be least effective than all the treatments and is significantly superior over the T_0 control (6.60).

3.2.4 Overall mean of second spray

The data on the larval population of fall armyworm on mean (3rd, 7th and 14th 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_9 Emamectin benzoate 5 SG (0.82) followed by T_1 Chlorantraniliprole 18.5 SC (1.01), T_{10} Indoxacarb 15.8 EC (1.13), T_3 Thiamethoxam 25 WG (1.26), T_2 Lambda cyhalothrin 2.5% EC (1.33) and T_8 Spinosad 45 SC (1.46). In this T_4 Profenophos 50 EC (1.53), T_5 Cypermethrin 10 EC (1.59), T_7 *Verticillium lecani* 1.15 WP (1.66) T_6 Neem oil 3% (1.73) T_{11} NSKE 5% (1.79) is found to be least effective than all the treatments and is significantly superior over the T_0 control (6.19).

3.3 Efficacy of *Spodoptera frugiperda* *Kharif* 2022 (First Spray)

3.3.1 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_9 Emamectin benzoate 5 SG (4.13) followed by T_1 Chlorantraniliprole 18.5 SC (4.20), T_{10} Indoxacarb 15.8 EC (4.26), T_3 Thiamethoxam 25 WG (4.33), T_2 Lambda cyhalothrin 2.5% EC (4.40) and T_8 Spinosad 45 SC (4.46). In this T_4 Profenophos 50 EC (4.53), T_5 Cypermethrin 10 EC (4.66), T_7 *Verticillium lecani* 1.15 WP (4.73), T_6 Neem oil 3% (4.80) T_{11} NSKE 5% (4.86) is found to be least effective than all the treatments and is significantly superior over the T_0 control (6.00).

3.3.2 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_9 Emamectin benzoate 5 SG (3.26) followed by T_1 Chlorantraniliprole 18.5 SC (3.53), T_{10} Indoxacarb 15.8 EC (3.66), T_3 Thiamethoxam 25 WG (3.73), T_2 Lambda cyhalothrin 2.5% EC (3.80) and T_8 Spinosad 45 SC (3.86). In this T_4 Profenophos 50 EC (3.93), T_5 Cypermethrin 10 EC (4.06), T_7 *Verticillium lecani* 1.15 WP (4.13), T_6 Neem oil 3% (4.20) T_{11} NSKE 5% (4.26) is found to be least effective than all the treatments and is significantly superior over the T_0 control (6.40).

3.3.3 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_9 Emamectin benzoate 5 SG (3.46) followed by T_1 Chlorantraniliprole 18.5 SC (3.73), T_{10} Indoxacarb 15.8 EC (3.86), T_3 Thiamethoxam 25 WG (3.93), T_2 Lambda cyhalothrin 2.5% EC (4.00) and T_8 Spinosad 45 SC (4.06). In this T_4 Profenophos 50 EC (4.13), T_5 Cypermethrin 10 EC (4.26), T_7 *Verticillium lecani* 1.15 WP (4.33), T_6 Neem oil 3% (4.40), T_{11} NSKE 5% (4.53) is found to be least effective than all the treatments and is significantly superior over the T_0 control (6.80).

3.3.4 Overall mean of first spray

The data on the larval population of fall armyworm on mean (3rd, 7th and 14th 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_9 Emamectin benzoate 5 SG (3.61) followed by T_1 Chlorantraniliprole 18.5 SC (3.82), T_{10} Indoxacarb 15.8 EC (3.92), T_3 Thiamethoxam 25 WG (3.99), T_2 Lambda cyhalothrin 2.5% EC (4.06) and T_8 Spinosad 45 SC (4.12). In this T_4 Profenophos 50 EC (4.19), T_5 Cypermethrin 10 EC (4.32), T_7 *Verticillium lecani* 1.15 WP (4.39), T_6 Neem oil 3% (4.46) T_{11} NSKE 5% (4.55) is found to be least effective than all the treatments and is significantly superior over the T_0 control (6.40).

3.4 Efficacy of *Spodoptera frugiperda* *Kharif* 2022 (Second Spray)

3.4.1 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_9 Emamectin benzoate 5 SG (2.73) followed by T_1 Chlorantraniliprole 18.5 SC (2.93), T_{10} Indoxacarb 15.8 EC (3.06), T_3 Thiamethoxam 25 WG (3.13), T_2 Lambda cyhalothrin 2.5% EC (3.20) and T_8 Spinosad 45 SC (3.26). In this T_4 Profenophos 50 EC (3.33), T_5 Cypermethrin 10 EC (3.46), T_7 *Verticillium lecani* 1.15 WP (3.53), T_6 Neem oil 3% (3.60) T_{11} NSKE 5% (3.80) is found to be least effective than all the treatments and is significantly superior over the T_0 control (6.93).

3.4.2 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_9 Emamectin benzoate 5 SG (2.13) followed by T_1 Chlorantraniliprole 18.5 SC (2.20), T_{10} Indoxacarb 15.8 EC (2.26), T_3 Thiamethoxam 25 WG (2.33), T_2 Lambda cyhalothrin 2.5% EC (2.40) and T_8 Spinosad 45 SC (2.46). In this T_4 Profenophos 50 EC (2.53), T_5 Cypermethrin 10 EC (2.66), T_7 *Verticillium lecani* 1.15 WP (2.73), T_6 Neem oil 3% (2.80) T_{11} NSKE 5% (2.86) is found to be least effective than all the treatments and is significantly superior over the T_0 control (7.26).

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	
T_1	Chlorantraniprole 18.5 % SC	4.33	2.93^{fg}	2.06^{gh}	2.26^{gh}	2.41^{fg}	1.46^{g}	0.73^{fg}	0.86^{hi}	1.01^{fg}	1.71
T_2	Lambda Cyhalothrin 5% EC	4.40	3.20^{def}	2.40^{def}	2.60^{def}	2.73^{cdef}	1.80^{def}	1.00^{def}	1.20^{efg}	1.33^{cdef}	2.03
T_3	Thiamethoxam 25% WG	4.46	3.13^{efg}	2.33^{efg}	2.53^{efg}	2.66^{def}	1.73^{efg}	0.93^{ef}	1.13^{fg}	1.26^{def}	1.96
T_4	Profenophos 50% EC	4.40	3.40^{bcde}	2.60^{bcde}	2.80^{bcde}	2.93^{bcd}	2.00^{bcde}	1.20^{bcde}	1.40^{cde}	1.53^{bcd}	2.23
T_5	Cypermethrin 10% EC	4.53	3.46^{bcd}	2.66^{bcd}	2.86^{bcd}	2.99^{bcd}	2.06^{bcd}	1.26^{bcd}	1.46^{bcd}	1.59^{bcd}	2.29
T_6	Neem oil 3%	4.80	3.60^{bc}	2.80^{bc}	3.00^{bc}	3.13^{b}	2.20^{bc}	1.40^{bc}	1.60^{bc}	1.73^{b}	2.43
T_7	*Verticillium lecani* 1.15 % WP	4.60	3.53^{bc}	2.73^{bc}	2.93^{bc}	3.06^{bc}	2.13^{bc}	1.33^{bc}	1.53^{bcd}	1.66^{bc}	2.36
T_8	Spinosad 45% SC	4.53	3.33^{cde}	2.53^{cde}	2.73^{cde}	2.86^{bcde}	1.93^{cde}	1.13^{cde}	1.33^{def}	1.46^{bcde}	2.16
T_9	Emamectin benzoate 5 % SG	4.06	2.86^{g}	1.86^{h}	2.00^{h}	2.24^{g}	1.13^{h}	0.60^{g}	0.73^{i}	0.82^{g}	1.53
T_{10}	Indoxacarb 15.8% EC	4.20	3.00^{fg}	2.20^{fg}	2.40^{fg}	2.53^{efg}	1.60^{fg}	0.80^{fg}	1.00^{gh}	1.13^{efg}	1.83
T_{11}	NSKE 5 %	4.73	3.66^{b}	2.86^{b}	3.06^{b}	3.19^{b}	2.26^{b}	1.46^{b}	1.66^{b}	1.79^{b}	2.49
T_0	Control	4.20	4.60^{a}	4.93^{a}	5.46^{a}	4.99^{a}	5.86^{a}	6.13^{a}	6.60^{a}	6.19^{a}	5.59
F-test		NS	S	S	S	S	S	S	S	S	S
S.Ed (±)		0.21	0.14	0.12	0.13	0.18	0.13	0.14	0.12	0.16	0.43
C.D. (P=0.05)		-	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	
T_1	Chlorantraniprole 18.5 % SC	5.40	4.20^{f}	3.53^{gh}	3.73^{gh}	3.82^{gh}	2.93^{gh}	2.20^{f}	2.26^{gh}	2.46^{gh}	3.14^{b}	2.42^{cd}
T_2	Lambda Cyhalothrin 5% EC	5.60	4.40^{cdef}	3.80^{defg}	4.00^{defg}	4.06^{defg}	3.20^{defg}	2.40^{cdef}	2.60^{defg}	2.73^{efg}	3.39^{b}	2.71^{bcd}
T_3	Thiamethoxam 25% WG	5.53	4.33^{def}	3.73^{efg}	3.93^{efg}	3.99^{efg}	3.13^{efg}	2.33^{def}	2.53^{efg}	2.66^{fg}	3.32^{b}	2.64^{bcd}
T_4	Profenophos 50% EC	5.73	4.53^{bcdef}	3.93^{bcdef}	4.13^{cdef}	4.19^{cdef}	3.33^{cdef}	2.53^{bcdef}	2.73^{bcde}	$2.86c^{def}$	3.52^{b}	2.87^{bcd}
T_5	Cypermethrin 10% EC	5.73	4.66^{bcde}	4.06^{bcde}	4.26^{bcde}	4.32^{bcde}	3.46^{bcde}	2.66^{bcde}	2.86^{bcde}	2.99^{bcde}	3.65^{b}	2.97^{bcd}
T_6	Neem oil 3%	5.86	4.80^{bc}	4.20^{bc}	$4.40^{b}c$	4.46^{bc}	3.60^{bc}	2.80^{bc}	3.00^{bc}	3.13^{bc}	3.79^{b}	3.11^{bc}
T_7	*Verticillium lecani* 1.15 % WP	5.80	4.73^{bcd}	4.13^{bcd}	4.33^{bcd}	4.39^{bcd}	3.53^{bcd}	2.73^{bcd}	$2.93b^{cd}$	3.06^{bcd}	3.72^{b}	3.04^{bcd}
T_8	Spinosad 45% SC	5.66	4.46^{bcdef}	3.86^{cdefg}	4.06^{cdefg}	4.12^{defg}	3.26^{cdefg}	2.46^{bcdef}	2.66^{cdef}	2.79^{def}	3.45^{b}	2.80^{bcd}
T_9	Emamectin benzoate 5 % SG	5.33	4.13^{f}	3.26^{h}	3.46^{h}	3.61^{h}	2.73^{h}	2.13^{f}	2.13^{h}	2.33^{h}	2.90^{b}	2.25^{d}
T_{10}	Indoxacarb 15.8% EC	5.46	4.26^{ef}	3.66^{fg}	3.86^{fg}	3.92^{fgh}	3.06^{fgh}	2.26^{ef}	2.33^{fgh}	2.55^{fgh}	3.23^{b}	2.53^{bcd}
T_{11}	NSKE 5 %	5.86	4.86^{b}	4.26^{b}	4.53^{b}	4.55^{b}	3.80^{b}	2.86^{b}	3.06^{b}	3.24^{b}	3.89^{b}	3.19^{b}
T_0	Control	5.40	6.00^{a}	6.40^{a}	6.80^{a}	6.40^{a}	6.93^{a}	7.26^{a}	7.40^{a}	7.19^{a}	6.79^{a}	6.19^{a}
F-test		NS	S	S	S	S	S	S	S	S	S	S
S.Ed (±)		0.19	0.20	0.17	0.17	0.15	0.18	0.20	0.18	0.15	0.35	0.04
C.D. (P=0.05)		-	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

3.4.3 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_9 Emamectin benzoate 5 SG (2.13) followed by T_1 Chlorantraniliprole 18.5 SC (2.26), T_{10} Indoxacarb 15.8 EC (2.33), T_3 Thiamethoxam 25 WG (2.53), T_2 Lambda cyhalothrin 2.5% EC (2.60) and T_8 Spinosad 45 SC (2.66). In this T_4 Profenophos 50 EC (2.73), T_5 Cypermethrin 10 EC (2.86), T_7 *Verticillium lecani* 1.15 WP (2.93), T_6 Neem oil 3% (3.00), T_{11} NSKE 5% (3.06) is found to be least effective than all the treatments and is significantly superior over the T_0 control (7.40).

3.4.4 Overall mean of second spray

The data on the larval population of fall armyworm on mean (3rd, 7th and 14th 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_9 Emamectin benzoate 5 SG (2.33) followed by T_1 Chlorantraniliprole 18.5 SC (2.46), T_{10} Indoxacarb 15.8 EC (2.55), T_3 Thiamethoxam 25 WG (2.66), T_2 Lambda cyhalothrin 2.5% EC (2.73) and T_8 Spinosad 45 SC (2.79). In this T_4 Profenophos 50 EC (2.86), T_5 Cypermethrin 10 EC (2.99), T_7 *Verticillium lecani* 1.15 WP (3.06), T_6 Neem oil 3% (3.13) T_{11} NSKE 5% (3.24) is found to be least effective than all the treatments and is significantly superior over the T_0 control (7.19).

3.4.5 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_9 Emamectin benzoate 5 SG (2.25) followed by T_1 Chlorantraniliprole 18.5 SC (2.42), T_{10} Indoxacarb 15.8 EC (2.53), T_3 Thiamethoxam 25 WG (2.64), T_2 Lambda cyhalothrin 2.5% EC (2.71) and T_8 Spinosad 45 SC (2.80). In this T_4 Profenophos 50 EC (2.87), T_5 Cypermethrin 10 EC (2.97), T_7 *Verticillium lecani* 1.15 WP (3.04) T_6 Neem oil 3% (3.11) T_{11} NSKE 5% (3.19) is found to be least effective than all the treatments and is significantly superior over the T_0 control (6.19).

4. DISCUSSION

4.1 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" [13]. Among the treatments lowest larval population of fall armyworm was recorded in T_9 Emamectin benzoate 5 SG (1.53) followed by T_1 Chlorantraniliprole 18.5 SC (1.71), T_{10} Indoxacarb 15.8 EC (1.83), T_3 Thiamethoxam 25 WG (1.96), T_2 Lambda cyhalothrin 2.5% EC (2.03) and T_8 Spinosad 45 SC (2.16). In this T_4 Profenophos 50 EC (2.23), T_5 Cypermethrin 10 EC (2.29), T_7 *Verticillium lecani* 1.15 WP (2.36) T_6 Neem oil 3% (2.43) T_{11} NSKE 5% (2.49) is found to be least effective than all the treatments and is significantly superior over the T_0 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 [14], Phani Kumar et al. [15] 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. [16] and Bharadwaj et al. [17]. 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. [18] and Ravikumar et al. [19]. 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. [20].

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., [17]. 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. [20] and Sangle et al. [21]. 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 Sangle et al. [21]. 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. [19].

4.2 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_9 Emamectin benzoate 5 SG (2.97) followed by T_1 Chlorantraniliprole 18.5 SC (3.14), T_{10} Indoxacarb 15.8 EC (3.23), T_3 Thiamethoxam 25 WG (3.32), T_2 Lambda cyhalothrin 2.5% EC (3.39) and T_8 Spinosad 45 SC (3.45). In this T_4 Profenophos 50 EC (3.52), T_5 Cypermethrin 10 EC (3.65), T_7 *Verticillium lecani* 1.15 WP (3.72) T_6 Neem oil 3% (3.79) T_{11} NSKE 5% (3.89) is found to be least effective than all the treatments and is significantly superior over the T_0 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. [18] and Ramesh and Tayde [22]. 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. [16] and Suthar et al. [23]. 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. [18] and Ravikumar et al. [19]. 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. [20].

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. [17]. 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. [20] and Sangle et al. [21]. 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 Sangle et al. [21]. 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. [19], Thumar et al. [24].

5. 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Jeyaraman S. Field crops production and management vol. I. New Delhi: Oxford; 2017.
2. Farrar Jr. RR, Shepard BM, Shapiro M, Hassell RL, Schaffer ML, Smith CM. Supplemental control of lepidopterous pests on Bt transgenic sweet corn with

biologically-based spray treatments. Journal of Insect Science. 2009;9(1):8.
3. FAO; 2019.
4. Bateman ML, Day RK, Luke B, Edgington S, Kuhlmann U, Cock MJ. Assessment of potential biopesticide options for managing fall armyworm (*Spodoptera frugiperda*) in Africa. Journal of Applied Entomology. 2018;142(9):805-819.
5. Nagoshi RN, Meagher RL. FR tandem repeat sequence in fall armyworm *(*Lepidoptera*: Noctuidae*) host strains. Annals of the Entomological Society of America. 2003;96:329-335.
6. Porter P, Schuster G, Morrison P, Toxclair N, Cronholm G, Patrick C, Parker R. BT corn technology in texas: a practical view. Texas Agricultural Extension Service, Texas A and M University System, College Station, Texas. Bull. no. 6090; 2000
7. Pogue GM. A world revision of the genus Spodoptera Guenee (Lepidoptera: *Noctuidae*). Memoirs of the American Entomological Society. 2002; 43:1-202.
8. Goergen G, Kumar PL, Sankung SB, Togola A, Tamò M. First report of outbreaks of the fall armyworm *Spodoptera frugiperda* (JE Smith) (Lepidoptera, *Noctuidae*), a new alien invasive pest in West and Central Africa. PloS one. 2016; 11(10):e0165632.
9. Sharanabasappa. Biology of invasive fall army worm *spodoptera frugiperda* (J.E.smith) (lepidoptera: noctuidae) on maize. Indian Journal of Entomology. 2018;80(3):540-543.
10. Deole S, Paul N. First report of fall army worm, *Spodoptera frugiperda* (JE Smith), their nature of damage and biology on maize crop at Raipur, Chhattisgarh. Journal of Entomology and Zoology Studies. 2018;6(6):219-221.
11. Smith JE. First record of the fall armyworm, *Spodoptera frugiperda* (Lepidoptera: *Noctuidae*). African Entomology. 1797;26 (1):244-246.
12. Tahir AH, Tariq M, Mazhar A, Shehzad M. *Spodoptera frugiperda* (Lepidoptera: *Noctuidae*), an invasive pest in agricultural crops and its management. Plant Protection. 2020; 4(3):149-153.
13. Tayde AR, Patil RG. Evaluation of Beauveria Bassiana, Neem Oil and Selected Insecticides on Population of Fall Armyworm Spodoptera frugiperda (JE Smith) on Maize (*Zea mays* L.). International Journal of Plant & Soil Science. 2022 Sep 30;34(23):304-8.
14. Appalanaidu B, Kumar A. Comparative efficacy of selected chemicals and biopesticides against fall army worm [*Spodoptera frugiperda* (J. E. Smith)] on maize (*Zea mays* L.) at Prayagraj (U.P). The Pharma Innovation Journal. 2022;11 (5):1472-1476.
15. Phani Kumar K, Mohan Vishnuvardhan K, Kamakshi N, Murthy DK, Rao MK. Field efficacy of selected insecticides against invasive pest, fall armyworm *Spodoptera frugiperda* (J. E. Smith) on maize crop. The Pharma Innovation Journal, 2021;10(10) :884-889.
16. Ompraksh S, Reddy SS, Reddy ML, Reddy RU. Evaluation of differentmodules for the management of fall army worm *Spodoptera frugiperda* in maize. Journal of Pharmacognosy and Phytochemistry, 2020 ;9(3):1765-1767.
17. Bharadwaj G, Mutkule D, Thakre B, Jadhav A. Bio-efficacy of different insecticides against fall armyworm, *Spodoptera frugiperda* (JE Smith) on Maize. Journal of Phamacognosy and Phytochemistry. 2020;9(5):603-607.
18. Deshmukh S, Pavithra HB, Kalleshwaraswamy CM, Shivanna BK, Maruthi MS. Mota-Sanchez D. Field efficacy of insecticides for management of invasive fall armyworm, *Spodoptera frugiperda* (JE Smith) (Lepidoptera: *Noctuidae*) on maize in India. Florida Entomologist. 2020;103(2):221-227.
19. Ravikumar A, Basavaraj K, Kumar VA. Evaluation of cypermethrin 10%+ indoxacarb 10% sc against fall armyworm, *Spodoptera frugiperda* and stem borer in maize. Journal of Experimental Zoology. 2022;25(1):259-265.
20. Mallapur CP, Naik AK, Hagari S, Praveen T, Naik M. Laboratory and field evaluation of new insecticide molecules against fall armyworm, *Spodoptera frugiperda* (JE Smith) on maize. Journal Entomology Zoological Studies. 2019;7(4): 869-875.
21. Sangle SV, Jayewar NE, Kadam DR. Efficacy of insecticides on larval population of fall armyworm, *Spodoptera frugiperda* on maize. Journal of Entomology and Zoology Studies. 2020;8(6):1831-1834.
22. Ramesh M, Tayde AR. Comparative efficacy of selected chemicals and

biopesticides against fall army worm, *Spodoptera frugiperda* (JE Smith) on Maize (*Zea mays* L.). International Journal of Plant and Soil Science. 2022; 466-470.

23. Suthar M, Zala MB, Varma HS, Lunagariya M, Patel MB, Patel BN, Borad PK. Bio-efficacy of granular insecticides against fall armyworm, *Spodoptera frugiperda* (JE Smith) in maize. International Journal of Chemical Studies. 2020;8(4):174-179.

24. Thumar RK, Zala MB, Varma HS, Dhobi CB, Patel BN, Patel MB, Borad PK. Evaluation of insecticides against fall armyworm, *Spodoptera frugiperda* (JE Smith) infesting maize. International Journal of Chemical Studies. 2020;8(4): 100-104.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/109211