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LS Chaudhary
Department of Entomology, N M College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

CJ Patel
ASPEE Shakilam Biotechnology Institute, Navsari Agricultural University Surat, Gujarat, India

LV Ghetiya
Department of Entomology, N M College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

HK Chaudhary
Department of Entomology, N M College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

HG Patel
Department of Entomology, N M College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

DK Ajudia
Department of Entomology, N M College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

Corresponding Author:
LS Chaudhary
Department of Entomology, N M College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

Bioefficacy of different insecticides against fall armyworm, *Spodoptera frugiperda* (J. E. Smith) under South Gujarat condition

LS Chaudhary, CJ Patel, LV Ghetiya, HK Chaudhary, HG Patel and DK Ajudia

Abstract
The field trials for bioefficacy of insecticides against fall armyworm was carried out at College Farm, NMCA, NAU, Navsari during summer, 2022. The lowest larval population of *S. frugiperda* was observed when crop was treated with emamectin benzoate (0.025%) and which was at par with spinosad (0.018%) and chlorantraniliprole (0.005%). The next effective treatment was thiodicarb (1.1%) which remained at par with indoxacarb (0.0094%). The maximum larval population in among different insecticidal treatments was found in lambda cyhalothrin (0.0038%) followed by profenophos (0.0125%) and both were at par with control treatment. The order of effectiveness of various treatments against *S. frugiperda* was emamectin benzoate (0.025%) ≥ spinosad (0.018%) ≥ chlorantraniliprole (0.005%) ≥ thiodicarb (1.1%) ≥ indoxacarb (0.0094%) ≥ profenophos (0.0125%) ≥ lambda cyhalothrin (0.0038%) > control (water spray). The maximum (68%) reduction of larval population was recorded in T_4- spinosad (0.018%) followed by 67 percent in T_2- emamectin benzoate (0.025%). The order of reduction of larval population over control of various treatments against *S. frugiperda* was spinosad (68%) ≥ emamectin benzoate (67%) ≥ chlorantraniliprole (65%) ≥ thiodicarb (52%) ≥ indoxacarb (51%) ≥ profenophos (42%) ≥ lambda cyhalothrin (26%).

Keywords: Efficacy, fall armyworm, Gujarat, maize, spodoptera frugiperda

Introduction
The scientific name fall armyworm, *S. frugiperda* is derived from the feeding habits of the larval life stage, *frugiperda* meaning "lost fruit" in Latin, as the pest can cause damage to crops resulting in severe yield loss. FAW (Fall armyworm) is a caterpillar, not a "worm". As befits its name, which evokes an impression of mass trooping of larvae alike to an army, creating havoc in its path. (Naganna *et al*., 2020) [11]. *S. frugiperda* is widely distributed in the Americas, occurring from South Central to Eastern Canada, coast to coast in the United States, south to Argentina and throughout the Caribbean (EPPO, 2015) [6]. In 2018, this notorious pest was reported for the first time in the Shivamogga district of Karnataka in South India (Sharanabasappa *et al*., 2018a) [13]. It is also reported from various states of India *viz*., Karnataka, Tamil Nadu, Maharashtra, Telangana, Andhra Pradesh and Gujarat infesting maize crop (Ganiger *et al*., 2018; Sharanabasappa *et al*., 2018b, Mahadevaswamy *et al*., 2018) [7, 14, 9]. The pest has been reported on other hosts *viz*., sorghum, bajra (Venkateswarlu *et al*., 2018) [16] and sugarcane (Chormule *et al*., 2019) [3] from India.
Use of insecticides has become an indispensable tool for insect pest management in modern agriculture. Insecticides are used widely as a tool in management for quick action but they should be effective as well as economic in the case of crops like maize. In spite of availability of lot many insecticides in the market, insecticides as foliar application formulations are now gaining importance. Since fall armyworm is known to inflict serious injury to the maize seedlings in the early season of crop growth, use of various insecticides as spray schedules with other convenient insecticides may further help farmers to reduce the risk of the insect damage.

Materials and Methods
The field experiment was conducted at College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari under natural field conditions to evaluate the bioefficacy of different insecticides against fall armyworm, *Spodoptera frugiperda* (J. E. Smith) on maize

crop. The evaluation on bioefficacy of seven insecticides *viz.*, chlorantraniliprole 18.5 SC @ 0.3 ml/l, emamectin benzoate 5 SG @ 0.5 g/l, thiodicarb 75 WP @ 1.5 g/l, spinosad 45 SC @ 0.4 ml/l, indoxacarb 14.5 SC @ 0.65 ml/l, lambda cyhalothrin 5 EC @ 0.75 ml/l, profenophos 50 EC @ 0.25 ml/l along with control (water spray) was carried out during summer, 2022 with application of two sprays.

In order to evaluate the efficacy of different insecticides observations on fall armyworms were recorded from ten randomly selected and tagged plants from net plot area. Number of larva(e) as well as damaged and healthy plants were counted from each treatment. Observations were recorded before the application as well as 1, 3, 5, 7, 10 and 14 days after application from each treatment.

Results and Discussion

First spray

The larval population of *S. frugiperda* recorded in different treatments at different intervals are presented in Table 1. The fall armyworm larval population in the pre-treatment observation ranged from 0.33 to 0.53 larvae/plant and all the treatments were statistically on par indicated more or less uniform larval population on the crop under experiment.

One day after treatment the larval population varied from 0.03 to 0.53 larvae/plant when the crop treated with emamectin benzoate 5 SG at 0.025 percent (0.03 larvae/plant) recorded the lowest larval population per plant which was remain at par with thiodicarb 75 WP at 1.1 percent (0.07 larvae/plant), spinosad 45 SC at 0.018 percent (0.10 larvae/plant) and indoxacarb 14.5 SC at 0.0094 percent (0.13 larvae/plant). These four treatments found significantly superior to untreated control. The next effective treatments were profenophos 50 EC at 0.0125 percent (0.20 larvae/plant) which was at par with lambda cyhalothrin 5 EC at 0.0038 percent (0.23 larvae/plant) and chlorantraniliprole 18.5 SC at 0.005 percent (0.23 larvae/plant). The maximum (0.53 larvae/plant) number of larval population was found in control (T_8).

Third day after treatments the larval population varied from 0.07 to 0.90 larvae/plant emamectin benzoate 5 SG at 0.025 percent (0.07 larvae/plant) and spinosad 45 SC at 0.018 percent (0.07 larvae/plant) recorded lowest larval populations per plant which was at par with indoxacarb 14.5 SC at 0.0094 percent (0.17 larvae/plant), lambda cyhalothrin 5 EC at 0.0038 percent (0.17 larvae/plant), chlorantraniliprole 18.5 SC at 0.005 percent (0.20 larvae/plant) and thiodicarb 75 WP at 1.1 percent (0.23 larvae/plant). These six treatments found significantly superior to untreated control. The maximum (0.90 larvae/plant) number of larval population was found in control (T_8) which was followed by profenophos 50 EC at 0.0125 percent (0.33 larvae/plant).

Fifth day after treatments the larval population varied from 0.00 to 0.90 larvae/plant chlorantraniliprole 18.5 SC at 0.005 percent (0.00 larvae/plant) recorded the lowest larval population which was at par with spinosad 45 SC at 0.018 percent (0.10 larvae/plant), emamectin benzoate 5 SG at 0.025 percent (0.20 larvae/plant) and indoxacarb 14.5 SC at 0.0094 percent (0.20 larvae/plant). These four treatments significantly superior to untreated control. The next effective treatment was thiodicarb 75 WP at 1.1 percent (0.23 larvae/plant) which was remain at par with profenophos 50 EC at 0.0125 percent (0.27 larvae/plant). The maximum (0.90 larvae/plant) number of *S. frugiperda* larval population was found in lambda cyhalothrin 5 EC at 0.0038 percent and it was at par with control (0.83 larvae/plant).

Seven day after treatments the larval population varied from 0.10 to 0.77 larvae/plant chlorantraniliprole 18.5 SC at 0.005 percent (0.10 larvae/plant) and spinosad 45 SC at 0.018 percent (0.13 larvae/plant) recorded the lowest larval populations per plant which were remain at par with emamectin benzoate 5 SG at 0.025 percent (0.17 larvae/plant), thiodicarb 75 WP at 1.1 percent (0.20 larvae/plant) and lambda cyhalothrin 5 EC at 0.0038 percent (0.23 larvae/plant). These five treatments found significantly superior to untreated control. The maximum (0.77 larvae/plant) number of *S. frugiperda* larval populations was found in control (T_8) followed by profenophos 50 EC at 0.0125 percent (0.40 larvae/plant) and indoxacarb 14.5 SC at 0.0094 percent (0.30 larvae/plant).

Ten days after treatments the larval population varied from 0.13 to 1.23 larvae/plant Chlorantraniliprole 18.5 SC at 0.005 percent (0.13 larvae/plant) recorded the lowest larval populations which was at par with thiodicarb 75 WP at 1.1 percent (0.30 larvae/plant) and spinosad 45 SC at 0.018 percent (0.40 larvae/plant). These three treatments were found significantly superior to untreated control. The next effective treatment was emamectin benzoate 5 SG at 0.025 percent (0.47 larvae/plant) was at par with profenophos 50 EC at 0.0125 percent (0.67 larvae/plant) and indoxacarb 14.5 SC at 0.0094 percent (0.70 larvae/plant). The maximum (1.23 larvae/plant) larval populations was found in control (T_8) lambda cyhalothrin 5 EC at 0.0038 percent (0.83 larvae/plant) and at par it.

Fourteen day after treatment the larval population varied from 0.70 to 2.07 larvae/plant Spinosad 45 SC at 0.018 percent (0.70 larvae/plant) and chlorantraniliprole 18.5 SC at 0.005 percent (0.80 larvae/plant) recorded the lower larval populations per plant which were at par with indoxacarb 14.5 SC at 0.0094 percent (1.10 larvae/plant), profenophos 50 EC at 0.0125 percent (1.07 larvae/plant), emamectin benzoate 5 SG at 0.025 percent (1.13 larvae/plant) and thiodicarb 75 WP at 1.1 percent (1.33 larvae/plant). Lambda cyhalothrin 5 EC at 0.0038 percent (1.77 larvae/plant) remained at par with control.

Pooled data over different period of observation after first spray presented in Table 1 revealed that the larval population varied from 0.26 to 0.98 larvae/plant. Spinosad 45 SC at 0.018 percent (0.26 larvae/plant) recorded the lowest larval population followed by chlorantraniliprole 18.5 SC at 0.005 percent (0.27 larvae/plant) and both were at par with emamectin benzoate 5 SG at 0.025 percent (0.34 larvae/plant), thiodicarb 75 WP at 1.1 percent (0.40 larvae/plant) and indoxacarb 14.5 SC at 0.0094 percent (0.43 larvae/plant). The order of effectiveness of various treatments against *S. frugiperda* was found to be spinosad (0.018%) ≥ chlorantraniliprole (0.005%) ≥ emamectin benzoate (0.025%) ≥ thiodicarb (1.1%) ≥ indoxacarb (0.0094%) ≥ profenophos (0.0125%) ≥ lambda cyhalothrin (0.0038%) ≥ control (water spray).

Second spray

The larval population of *S. frugiperda* recorded in different treatments at different intervals during second spray are presented in Table 2. The fall armyworm larval population in the pre-treatment observations ranged from 0.70 to 2.00 larvae/plant. The larval populations in thiodicarb (1.33 larvae/plant) and lambda cyhalothrin (1.50 larvae/plant) were at par with untreated control.

One day after treatment the larval population varied from 0.13 to 1.39 larvae/plant. Crop treated with emamectin benzoate 5 SG at 0.025 percent recorded lowest (0.13 larvae/plant) larval populations which was at par with spinosad 45 SC at 0.018 percent (0.27 larvae/plant), thiodicarb 75 WP at 1.1 percent (0.30 larvae/plant), chlorantraniliprole 18.5 SC at 0.005 percent (0.30 larvae/plant) and indoxacarb 14.5 SC at 0.0094 percent (0.33 larvae/plant) and these were significantly superior to untreated control. Lambda cyhalothrin 5 EC at 0.0038 percent (0.73 larvae/plant) was at par with control.

Third day after treatment the larval population varied from 0.17 to 1.00 larvae/plant. Lowest larval population (0.17 larvae/plant) was recorded in the treatment of emamectin benzoate 5 SG at 0.025 percent and it was at par with thiodicarb 75 WP at 1.1 percent (0.30 larvae/plant) and spinosad 45 SC at 0.018 percent (0.33 larvae/plant). The next effective treatment was indoxacarb 14.5 SC at 0.0094 percent (0.40 larvae/plant) which was at par with chlorantraniliprole 18.5 SC at 0.005 percent (0.50 larvae/plant), profenophos 50 EC at 0.0125 percent (0.57 larvae/plant) and lambda cyhalothrin 5 EC at 0.0038 percent (0.57 larvae/plant). The maximum (1.00 larvae/plant) larval population was recorded in control (T_8). Chlorantraniliprole 18.5 SC at 0.005 percent recorded the lowest (0.07 larvae/plant) larval populations after fifth day of treatment. However, it was at par with emamectin benzoate 5 SG at 0.025 percent (0.17 larvae/plant), thiodicarb 75 WP at 1.1 percent (0.30 larvae/plant) and spinosad 45 SC at 0.018 percent (0.33 larvae/plant). The larval population in different treatments varied from 0.07 to 1.07 larvae/plant. The next effective treatment was lambda cyhalothrin 5 EC at 0.0038 percent (0.43 larvae/plant) which remained at par with indoxacarb 14.5 SC at 0.0094 percent (0.47 larvae/plant) and profenophos 50 EC at 0.0125 percent (0.70 larvae/plant).

Seven days after treatments the larval population varied from 0.20 to 1.03 larvae/plant being lowest in emamectin benzoate 5 SG at 0.025 percent (0.20 larvae/plant) and highest in control (1.03 larvae/plant). The most effective treatment of emamectin benzoate 5 SG remained at par with thiodicarb 75 WP at 1.1 percent (0.47 larvae/plant). The next effective treatments were chlorantraniliprole 18.5 SC at 0.005 percent (0.60 larvae/plant), spinosad 45 SC at 0.018 percent (0.60 larvae/plant) and indoxacarb 14.5 SC at 0.0094 percent (0.60 larvae/plant).

Larval population in different treatments after ten days varied from 0.30 to 1.63 larvae/plant. The maximum (1.63 larvae/plant) larval population was found in treatment of lambda cyhalothrin 5 EC at 0.0038 percent. Spinosad 45 SC at 0.018 percent (0.30 larvae/plant) and emamectin benzoate 5 SG at 0.025 percent (0.37 larvae/plant) were at par in efficacy and recorded the lowest larval population. The next effective treatment was indoxacarb 14.5 SC at 0.0094 percent (0.93 larvae/plant) and thiodicarb 75 WP at 1.1 percent (1.07 larvae/plant) which remained at par with control (T_8) (1.17 larvae/plant) and profenophos 50 EC at 0.0125 percent (1.27 larvae/plant).

Fourteen days after treatment the larval population varied from 0.33 to 0.57 larvae/plant. The differences among various treatments were not significant indicated more or less uniform number of the larva on the crop under experiment.

Pooled data over different period of observation after second spray presented in Table 2 revealed that the larval population varied from 0.36 to 1.11 larvae/plant. Emamectin benzoate 5 SG at 0.025 percent recorded the lowest (0.36 larvae/plant) population which was at par with spinosad 45 SC at 0.018 percent (0.42 larvae/plant), chlorantraniliprole 18.5 SC at 0.005 percent (0.48 larvae/plant), thiodicarb 75 WP at 1.1 percent (0.60 larvae/plant), indoxacarb 14.5 SC at 0.0094 percent (0.60 larvae/plant) and profenophos 50 EC at 0.0125 percent (0.74 larvae/plant). The maximum (1.11 larvae/plant) larval population was found in control (T_8) followed by lambda cyhalothrin 5 EC at 0.0038 percent (0.90 larvae/plant). The order of effectiveness of various treatments against *S. frugiperda* was emamectin benzoate (0.025%) ≥ spinosad (0.018%) ≥ chlorantraniliprole (0.005%) ≥ thiodicarb (1.1%) ≥ indoxacarb (0.0094%) ≥ profenophos (0.0125%) ≥ lambda cyhalothrin (0.0038%) ≥ control (water spray).

Pooled

The overall pooled data of the both sprays on larval population of *S. frugiperda* recorded in different treatments at different intervals are presented in Table 3 and Figure 1. The larval population in the pre-treatment observations ranged from 0.52 to 1.30 larvae/plant. Treatment of spinosad 45 SC at 0.018 percent recorded the lowest (0.52 larvae/plant) larval population however, it was at par with chlorantraniliprole 18.5 SC at 0.005 percent (0.60 larvae/plant). Both these treatments were significantly superior to untreated control. The order of effectiveness of various treatments was spinosad (0.018%) ≥ chlorantraniliprole (0.005%) ≥ emamectin benzoate (0.025%) ≥ indoxacarb (0.0094%) = profenophos (0.0125%) ≥ thiodicarb (1.1%) > lambda cyhalothrin (0.0038%) > control (water spray).

The effectiveness of spinosad and chlorantraniliprole as observed in the present investigation provided conformity with Kalleshwaraswamy *et al*. (2022) [8], Thumar *et al*. (2020) [15] and Kumar *et al*. (2021) [1]. Rizvi and Deole (2022) [17] also reported the effectiveness of chlorantraniliprole, indoxacarb and thiodicarb after first spray.

One day after treatment the larval population of fall armyworm varied from 0.08 to 0.96 larvae/plant in different treatments. Emamectin benzoate 5 SG at 0.025 percent was significantly superior to other treatments and the average population was 0.08 larvae/plant. The next effective treatments were spinosad 45 SC at 0.018 percent and thiodicarb 75 WP at 1.1 percent which recoded 0.18 larvae/plant. However, indoxacarb 14.5 SC at 0.0094 percent (0.23 larvae/plant) and chlorantraniliprole 18.5 SC at 0.005 percent (0.27 larvae/plant) remained at par with them. The larval population in lambda cyhalothrin 5 EC at 0.0038 percent (0.48 larvae/plant) and profenophos 50 EC at 0.0125 percent (0.35 larvae/plant) remained at par with control treatment (T_8) which had highest (0.96 larvae/plant) larval population. The order of effectiveness of various treatments against *S. frugiperda* was emamectin benzoate (0.025%) > spinosad (0.018%) = thiodicarb (1.1%) ≥ indoxacarb (0.0094%) ≥ chlorantraniliprole (0.005%) ≥ profenophos (0.0125%) ≥ lambda cyhalothrin (0.0038%) > control (water spray).

The effectiveness of emamectin benzoate was confirmed by report of Thumar *et al*. (2020) [15] and Sangle *et al*. (2020) [12]. Salunkhe *et al*. (2023) [18] also recorded lowest larval population in emamectin benzoate- *Nomuraea riley* - lambda cyhalothrin treatment.

The lowest (0.12 larvae/plant) larval population at three days after treatment was calculated in the treatment of emamectin benzoate 5 SG at 0.025 percent). However, spinosad 45 SC at 0.018 percent (0.20 larvae/plant) was at par with emamectin

benzoate. The next effective treatment was thiodicarb 75 WP at 1.1 percent (0.27 larvae/plant) which was at par with indoxacarb 14.5 SC at 0.0094 percent (0.28 larvae/plant). The maximum (0.95 larvae/plant) larval population was found in control (T_8) followed by profenophos 50 EC at 0.0125 percent (0.45 larvae/plant), chlorantraniliprole 18.5 SC at 0.005 percent (0.35 larvae/plant) and lambda cyhalothrin 5 EC at 0.0038 percent (0.37 larvae/plant). The order of effectiveness of various treatments against *S. frugiperda* was emamectin benzoate (0.025%) ≥ spinosad (0.018%) > thiodicarb (1.1%) ≥ indoxacarb (0.0094%) ≥ chlorantraniliprole (0.005%) ≥ lambda cyhalothrin (0.0038%) ≥ profenophos (0.0125%) > control (water spray).

The effectiveness of emamectin benzoate as observed in the present results supported by Bharadwaj *et al.* (2020) [2] who reported the effectiveness of insecticides as emamectin benzoate > chlorantraniliprole > lambda cyhalothrin at three days after treatment. The present investigation is in close conformity with Thumar *et al*. (2020) [15] at Gujarat who reported lowest larval population in emamectin benzoate at three days after treatment and chlorantraniliprole and thiodicarb were at par with it. Mallapur *et al.* (2019) [10] also reported the order of effectiveness of insecticides as spinosad, emamectin benzoate, thiodicarb and chlorantraniliprole.

Fifth days after treatments the larval population varied from 0.03 to 0.95 larvae/plant. Most effective treatment which recorded lowest (0.03 larvae/plant) population was chlorantraniliprole 18.5 SC at 0.005 percent. The next effective treatments were emamectin benzoate 5 SG at 0.025 percent (0.18 larvae/plant) and spinosad 45 SC at 0.018 percent (0.22 larvae/plant) which remained at par with thiodicarb 75 WP at 1.1 percent (0.27 larvae/plant). The maximum (0.95 larvae/plant) larval population was found in control (T_8) followed by lambda cyhalothrin 5 EC at 0.0038 percent (0.67 larvae/plant) and profenophos 50 EC at 0.0125 percent (0.48 larvae/plant). The order of effectiveness of various treatments against *S. frugiperda* was chlorantraniliprole (0.005%) > emamectin benzoate (0.025%) ≥ spinosad (0.018%) ≥ thiodicarb (1.1%) ≥ indoxacarb (0.0094%) > profenophos (0.0125%) > lambda cyhalothrin (0.0038%) > control (water spray).

The effectiveness of chlorantraniliprole after five days of treatment supported by Mallapur *et al.* (2019) [10], Thumar *et al*. (2020) [15] and Ahir *et al*. (2021) [1].

The larval population in different treatments at seven days after treatment varied from 0.18 to 0.90 larvae/plant. Most effective treatment was emamectin benzoate 5 SG at 0.025 percent which recorded lowest larval populations *i.e*., 0.18 larvae/plant. The maximum (0.90 larvae/plant) larval population was recorded in control (T_8) followed by profenophos 50 EC at 0.0125 percent (0.52 larvae/plant). The order of effectiveness of various treatments against *S. frugiperda* was be emamectin benzoate (0.025%) > chlorantraniliprole (0.005%) ≥ thiodicarb (1.1%) ≥ spinosad (0.018%) ≥ indoxacarb (0.0094%) ≥ lambda cyhalothrin (0.0038%) ≥ profenophos (0.0125%) > control (water spray).

The present result of effectiveness of various insecticides at seven days after treatment gave more or less conformity to Dileep and Murali (2020), Bharadwaj *et al.* (2020) [2], Mallapur *et al.* (2019) [10], Sangle *et al*. (2020) [12], Thumar *et al*. (2020) [15] and Kalleshwaraswamy *et al.* (2022).

Lowest larval populations at ten days after treatment was recorded in the treatment of spinosad 45 SC at 0.018 percent (0.35 larvae/plant) followed by chlorantraniliprole 18.5 SC at 0.005 percent (0.42 larvae/plant) and emamectin benzoate 5 SG at 0.025 percent (0.42 larvae/plant). The next effective treatment was thiodicarb 75 WP at 1.1 percent (0.68 larvae/plant) followed by indoxacarb 14.5 SC at 0.0094 percent (0.82 larvae/plant) and profenophos 50 EC at 0.0125 percent (0.97 larvae/plant). The order of effectiveness of various treatments was spinosad (0.018%) ≥ chlorantraniliprole (0.005%) ≥ emamectin benzoate (0.025%) > thiodicarb (1.1%) > indoxacarb (0.0094%) ≥ profenophos (0.0125%) > lambda cyhalothrin (0.0038%) & control (water spray). The larval population in different treatments at ten days after treatment varied from 0.35 to 1.20 larvae/plant.

The effectiveness of various insecticides at ten days after treatment in present study was more or less conferred with finding of Deshmukh *et al.* (2020), Thumar *et al*. (2020) [15] and Ahir *et al*. (2021) [1].

Fourteen days after treatment larval population in different treatments varied from 0.57 to 1.32 larvae/plant. Spinosad 45 SC at 0.018 percent recorded the lowest (0.57 larvae/plant) larval populations and was at par with chlorantraniliprole 18.5 SC at 0.005 percent (0.60 larvae/plant), emamectin benzoate 5 SG at 0.025 percent (0.73 larvae/plant) and indoxacarb 14.5 SC at 0.0094 percent (0.73 larvae/plant). The maximum (1.32 larvae/plant) larval population was recorded in control (T_8) followed by lambda cyhalothrin 5 EC at 0.0038 percent (1.13 larvae/plant). The order of effectiveness of various treatments against *S. frugiperda* was spinosad (0.018%) ≥ chlorantraniliprole (0.005%) ≥ emamectin benzoate (0.025%) ≥ indoxacarb (0.0094%) > profenophos (0.0125%) ≥ thiodicarb (1.1%) > lambda cyhalothrin (0.0038%) & control (water spray).

The effectiveness of spinosad at fourteen days after treatment conferred with Dileep and Murali (2020) who reported the effectiveness chlorantraniliprole and spinosad followed by thiodicarb, emamectin benzoate, indoxacarb and lambda cyhalothrin. Bharadwaj *et al.* (2020) [2] reported lowest larval population in emamectin benzoate and maximum population in lambda cyhalothrin. Similarly, Deshmukh *et al.* (2020) revealed the lowest larval population in chlorantraniliprole and at par efficacy of emamectin benzoate. This finding is more or less similar with the findings of Sangle *et al*. (2020) [12], Thumar *et al*. (2020) [15] and Kalleshwaraswamy *et al.* (2022).

Overall, investigations of pooled over period after both sprays presented in Table 3 revealed that the larval population varied from 0.35 to 1.05 larvae/plant in different treatments. Emamectin benzoate 5 SG at 0.025 percent (0.35 larvae/plant), spinosad 45 SC at 0.018 percent (0.34 larvae/plant) and chlorantraniliprole 18.5 SC at 0.005 percent (0.37 larvae/plant) found most effective treatments as they recorded lower larval population as compared to other treatments and were at par in efficacy. The next effective treatment was thiodicarb 75 WP at 1.1 percent (0.50 larvae/plant) which was at par with indoxacarb 14.5 SC at 0.0094 percent (0.51 larvae/plant). The maximum (1.05 larvae/plant) larval population of fall armyworm was found in control (T_8) followed by lambda cyhalothrin 5 EC at 0.0038 percent (0.78 larvae/plant) and profenophos 50 EC at 0.0125 percent (0.61 larvae/plant). The order of effectiveness of various treatments against *S. frugiperda* was found to be emamectin benzoate (0.025%) ≥ spinosad (0.018%) ≥ chlorantraniliprole (0.005%) ≥ thiodicarb (1.1%) ≥ indoxacarb (0.0094%) ≥ profenophos (0.0125%) ≥ lambda cyhalothrin (0.0038%) > control (water spray).

This finding is more or less similar with the findings of Thumar *et al*. (2020) [15] who reported the order of effectiveness as emamectin benzoate, chlorantraniliprole, thiodicarb and spinosad. The present result of efficacy of various treatments are more or less supported by Dileep and Murali (2020), Ahir *et al*. (2021) [1] and Kalleshwaraswamy *et al*. (2022) [8].

Reduction of larval population

The reduction of larval population over control varied from 33 to 73 percent during first spray (Table 1). The maximum (73%) reduction of larval population over control was recorded in T_4- spinosad (0.018%) followed by 72 percent in T_1- chlorantraniliprole (0.005%), respectively. The larval reduction in the treatments emamectin benzoate (0.025%), thiodicarb (1.1%), indoxacarb (0.0094%), profenophos (0.0125%) and lambda cyhalothrin (0.0038%) were 65, 59, 56, 51 and 33 percent, respectively.

Similarly, the reduction of larval population over control during second spray varied from 19 to 68 percent (Table 2). The maximum (68%) reduction of larval population over control was recorded in T_2- emamectin benzoate (0.025%). The larval reduction in the treatments spinosad (0.018%), chlorantraniliprole (0.005%), thiodicarb (1.1%), indoxacarb (0.0094%), profenophos (0.0125%) and lambda cyhalothrin (0.0038%) were 62, 57, 46, 46, 33 and 19 percent, respectively.

As far as pooled data presented in Table 3 pertaining to larval reduction in various treatments over control showed 26 to 68 percent reduction. The maximum (68%) reduction of larval population was recorded in T_4- spinosad (0.018%) followed by 67 percent in T_2- emamectin benzoate (0.025%). The order of reduction of larval population over control of various treatments against *S. frugiperda* was spinosad (68%) ≥ emamectin benzoate (67%) ≥ chlorantraniliprole (65%) ≥ thiodicarb (52%) ≥ indoxacarb (51%) ≥ profenophos (42%) ≥ lambda cyhalothrin (26%).

This finding is more or less similar with the findings of Dileep and Murali (2020) who recorded 90.43, 89.57, 83.57, 82.37, 68.9 and 60.33 percent larval reduction in the treatments chlorantraniliprole, spinosad, thiodicarb, emamectin benzoate, indoxacarb and lambda cyhalothrin respectively, over control. Similarly, Bharadwaj *et al*. (2020) [2] recorded 85.77 percent in emamectin benzoate, 71.79 percent in chlorantraniliprole and 39.30 percent in lambda cyhalothrin. Kalleshwaraswamy *et al*. (2022) [8] revealed highest reduction in chlorantraniliprole, emamectin benzoate and spinosad.

Table 1: Efficacy of different insecticides against *S. frugiperda* infesting maize (First spray)

T. No.	Treatments	Conc. (%)	Number of larva(e)/plant								Reduction of larval population over control (%)
			Before spray	1 DAT	3 DAT	5 DAT	7 DAT	10 DAT	14 DAT	Pooled	
T_1	Chlorantraniliprole 18.5 SC	0.005	0.40	0.23	0.20	0.00	0.10	0.13	0.80	0.27	72
			(0.94)	(0.85)	(0.84)	(0.71)	(0.77)	(0.79)	(1.14)	(0.85)	
T_2	Emamectin benzoate 5 SG	0.025	0.33	0.03	0.07	0.20	0.17	0.47	1.13	0.34	65
			(0.90)	(0.73)	(0.75)	(0.84)	(0.82)	(0.98)	(1.27)	(0.90)	
T_3	Thiodicarb 75 WP	1.1	0.43	0.07	0.23	0.23	0.20	0.30	1.33	0.40	59
			(0.96)	(0.75)	(0.85)	(0.85)	(0.84)	(0.89)	(1.35)	(0.92)	
T_4	Spinosad 45 SC	0.018	0.33	0.10	0.07	0.10	0.13	0.40	0.70	0.26	73
			(0.91)	(0.77)	(0.75)	(0.77)	(0.80)	(0.94)	(1.09)	(0.85)	
T_5	Indoxacarb 14.5 SC	0.0094	0.40	0.13	0.17	0.20	0.30	0.70	1.10	0.43	56
			(0.95)	(0.80)	(0.82)	(0.84)	(0.89)	(1.09)	(1.24)	(0.94)	
T_6	Lambda cyhalothrin 5 EC	0.0038	0.47	0.23	0.17	0.90	0.23	0.83	1.77	0.66	33
			(0.98)	(0.85)	(0.82)	(1.18)	(0.85)	(1.15)	(1.50)	(1.06)	
T_7	Profenophos 50 EC	0.0125	0.43	0.20	0.33	0.27	0.40	0.67	1.07	0.48	51
			(0.96)	(0.84)	(0.91)	(0.87)	(0.95)	(1.08)	(1.24)	(0.98)	
T_8	Control (water spray)	-	0.53	0.53	0.90	0.83	0.77	1.23	2.07	0.98	-
			(1.01)	(1.01)	(1.18)	(1.15)	(1.12)	(1.31)	(1.59)	(1.23)	
Mean		-	0.95	0.83	0.86	0.90	0.88	1.03	1.30	0.97	-
SEm ±		-	0.06	0.03	0.04	0.05	0.03	0.05	0.09	0.09	-
CD at 5%		-	NS	0.10	0.11	0.14	0.10	0.16	0.27	0.27	-
CV (%)		-	10.11	6.87	7.04	9.04	6.25	8.87	11.61	8.02	-

Note: 1. DAT: Days after treatment

2. Figures in parentheses are $\sqrt{X + 0.5}$ transformed values

Table 2: Efficacy of different insecticides against *S. frugiperda* infesting maize (Second spray)

T. No.	Treatments	Conc. (%)	Number of larva(e)/plant								Reduction of larval population over control (%)
			Before spray	1 DAT	3 DAT	5 DAT	7 DAT	10 DAT	14 DAT	Pooled	
T_1	Chlorantraniliprole 18.5 SC	0.005	0.80	0.30	0.50	0.07	0.60	0.70	0.40	0.48	57
			(1.14)	(0.89)	(1.00)	(0.75)	(1.05)	(1.09)	(0.94)	(0.95)	
T_2	Emamectin benzoate 5 SG	0.025	1.13	0.13	0.17	0.17	0.20	0.37	0.33	0.36	68
			(1.27)	(0.80)	(0.81)	(0.82)	(0.84)	(0.93)	(0.90)	(0.85)	
T_3	Thiodicarb 75 WP	1.1	1.33	0.30	0.30	0.30	0.47	1.07	0.40	0.60	46
			(1.35)	(0.89)	(0.89)	(0.89)	(0.98)	(1.25)	(0.95)	(0.98)	
T_4	Spinosad 45 SC	0.018	0.70	0.27	0.33	0.33	0.60	0.30	0.43	0.42	62
			(1.09)	(0.87)	(0.91)	(0.91)	(1.05)	(0.89)	(0.95)	(0.93)	
T_5	Indoxacarb 14.5 SC	0.0094	1.10	0.33	0.40	0.47	0.60	0.93	0.37	0.60	46
			(1.24)	(0.91)	(0.95)	(0.98)	(1.05)	(1.19)	(0.93)	(1.00)	
T_6	Lambda cyhalothrin 5 EC	0.0038	1.77	0.73	0.57	0.43	0.70	1.63	0.50	0.90	19
			(1.50)	(1.11)	(1.03)	(0.96)	(1.09)	(1.45)	(0.99)	(1.11)	
T_7	Profenophos 50 EC	0.0125	1.07	0.50	0.57	0.70	0.63	1.27	0.47	0.74	33
			(1.25)	(1.00)	(1.03)	(1.09)	(1.06)	(1.32)	(0.98)	(1.08)	
T_8	Control (Water spray)	-	2.00	1.39	1.00	1.07	1.03	1.17	0.57	1.11	-
			(1.59)	(1.37)	(1.22)	(1.24)	(1.23)	(1.29)	(1.02)	(1.20)	
Mean			1.30	0.95	0.98	0.96	1.04	1.18	0.96	1.01	-
SEm ±			0.09	0.05	0.04	0.05	0.05	0.07	0.06	0.08	-
CD at 5%			0.27	0.16	0.12	0.16	0.16	0.20	NS	0.25	-
CV (%)			11.61	9.58	6.87	9.84	8.55	9.66	10.73	8.733	-

Note: 1. DAT: Days after treatment
2. Figures in parentheses are $\sqrt{X + 0.5}$ transformed values

Table 3: Efficacy of different insecticides against *S. frugiperda* infesting maize (Pooled over spray)

T. No.	Treatments	Conc. (%)	Number of larva(e)/plant								Reduction of larval population over control (%)
			Before spray	1 DAT	3 DAT	5 DAT	7 DAT	10 DAT	14 DAT	Pooled	
T_1	Chlorantraniliprole 18.5 SC	0.005	0.60	0.27	0.35	0.03	0.35	0.42	0.60	0.37	65
			(1.05)	(0.87)	(0.92)	(0.73)	(0.91)	(0.94)	(1.04)	(0.90)	
T_2	Emamectin benzoate 5 SG	0.025	0.73	0.08	0.12	0.18	0.18	0.42	0.73	0.35	67
			(1.11)	(0.76)	(0.78)	(0.82)	(0.82)	(0.96)	(1.08)	(0.87)	
T_3	Thiodicarb 75 WP	1.1	0.88	0.18	0.27	0.27	0.33	0.68	0.87	0.50	52
			(1.18)	(0.82)	(0.87)	(0.87)	(0.91)	(1.07)	(1.15)	(0.95)	
T_4	Spinosad 45 SC	0.018	0.52	0.18	0.20	0.22	0.37	0.35	0.57	0.34	68
			(1.01)	(0.82)	(0.83)	(0.84)	(0.92)	(0.92)	(1.02)	(0.89)	
T_5	Indoxacarb 14.5 SC	0.0094	0.75	0.23	0.28	0.33	0.45	0.82	0.73	0.51	51
			(1.12)	(0.85)	(0.88)	(0.91)	(0.97)	(1.14)	(1.08)	(0.97)	
T_6	Lambda cyhalothrin 5 EC	0.0038	1.12	0.48	0.37	0.67	0.47	1.23	1.13	0.78	26
			(1.27)	(0.98)	(0.92)	1.07)	(0.97)	(1.30)	(1.25)	(1.08)	
T_7	Profenophos 50 EC	0.0125	0.75	0.35	0.45	0.48	0.52	0.97	0.77	0.61	42
			(1.12)	(0.92)	(0.97)	(0.98)	(1.00)	(1.20)	(1.11)	(1.03)	
T_8	Control (water spray)	--	1.30	0.96	0.95	0.95	0.90	1.20	1.32	1.05	-
			(1.34)	(1.21)	(1.20)	(1.20)	(1.18)	(1.30)	(1.31)	(1.21)	
Mean			1.15	0.89	0.92	0.93	0.96	1.10	1.13	0.99	-
SEm ± Treatment (T)			-	-	-	-	-	-	-	0.02	-
Spray (S)			-	-	-	-	-	-	-	0.01	-
Period (P)			-	-	-	-	-	-	-	0.01	-
T × S			-	-	-	-	-	-	-	0.03	-
T × P			-	-	-	-	-	-	-	0.04	-
S × P			-	-	-	-	-	-	-	0.02	-
T × S × P			-	-	-	-	-	-	-	0.05	-
CD at 5% Treatment (T)			-	-	-	-	-	-	-	0.06	-
Spray (S)			-	-	-	-	-	-	-	0.03	-
Period (P)			-	-	-	-	-	-	-	0.04	-
T × S			-	-	-	-	-	-	-	N.S.	-
T × P			-	-	-	-	-	-	-	0.11	-
S × P			-	-	-	-	-	-	-	0.05	-
T × S × P			-	-	-	-	-	-	-	0.15	-
CV (%)			-	-	-	-	-	-	-	11.57	-

Note: 1. DAT: Days after spray 2. Figures in parentheses are $\sqrt{X + 0.5}$ transformed values

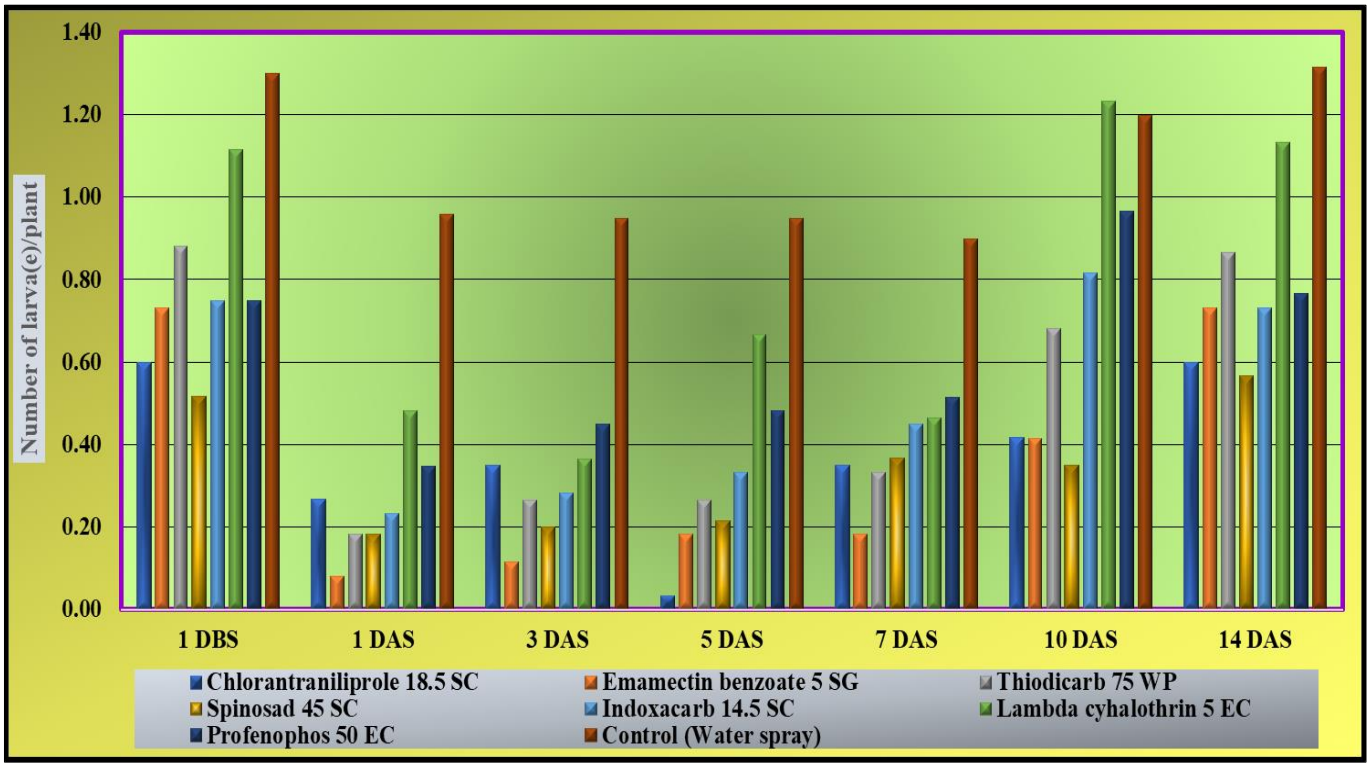

Fig 1: Efficacy of different insecticides against *S. frugiperda* infesting maize (Pooled over spray)

Conclusion

The order of effectiveness of various treatments against *S. frugiperda* was found as emamectin benzoate (0.025%) ≥ spinosad (0.018%) ≥ chlorantraniliprole (0.005%) ≥ thiodicarb (1.1%) ≥ indoxacarb (0.0094%) ≥ profenophos (0.0125%) ≥ lambda cyhalothrin (0.0038%) > control (water spray).

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