# Response of maize hybrids to *Spodoptera frugiperda* (J. E. Smith) infestation and the impact of insecticides under field conditions

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**Abstract**

This study was carried out to evaluate the relative susceptibility of eight maize hybrids to *Spodoptera frugiperda* (J. E. Smith) **i**nfestation under field conditions during 2023 and 2024 seasons at Nubaria district, Beheira Governorate, Egypt. The results revealed that none of the hybrids exhibited high resistantance to the pest, but SC128 and SC130 hybrids showed moderate resistance. In the first season, TW352 and TW360 hybrids received the highest number of egg masses, while SC130 and SC128 were the least attractive for oviposition. A similar trend was observed in 2024, with TW352 and TW360 being the most preferred for oviposition. The abundance of larvae was measured during both seasons, showing that TW352 hosted the highest number of larvae, while SC130 had the lowest. These findings were consistent across the two years. Additionally, the infestation percentages were highest in TW352 and lowest in SC130. In both years, infestation percentages significantly differed among the hybrids, indicating into variations in susceptibility. Insecticidal treatments revealed that Pleo and Lannate were the highest efficient, with Pleo exhibiting the best residual effect. Coragen, though effective, induced the lowest larval mortality rate in both seasons. This research highlights the importance of selecting maize hybrids resistant to S. *frugiperda*, with the application of effective insecticides to manage *S. frugiperda* infestations. These results contribute valuable insights for enhancing maize pest management programs and improving crop protection strategies.

**Keywords:** Fall armyworm**,** Maize geotypes**,** Pesticides, Open field

## Introduction

Maize (*Zea mays* L.), a vital cereal crop from Poaceae family, ranks third in global importance after wheat and rice (Cooper *et al*., 2014) [6]. In Egypt, maize is widely utilized as human food, livestock and poultry feed, and as a raw material for several industrial products such as oil and starch. In 2022, the total cultivated area of maize in Egypt reached 2.4 million feddans, yielding an annual grain production of 7.5 million metric tons with an average productivity of 23.10 ardabs per feddan (Economic Affairs Sector, 2022) [13]. Given its economic significance, increasing and maintaining maize yields is a priority.

The fall armyworm, *Spodoptera frugiperda* (J. E. Smith) is one of the most significant threats to maize production. This highly destructive pest belongs to Noctuidae (Lepidoptera) and has been widely studied, especially after its recent expansion beyond its native range from the Americas to Africa and Asia, where it has posed a substantial risk to agricultural crops (Corbett and Rosenheim, 2008; Goergen *et al*., 2016; Day, 2017; Ward and Kim, 2019) [7, 15, 11, 26]. *S. frugiperda* has a vey wide range of hostds range, feeding on over 350 plant species, including maize, rice, sugarcane, wheat, and soybean (Yang *et al*., 2021; Gui *et al*., 2022; Wu *et al*., 2021) [29, 16, 28]. However, maize is one of tha most preferred hosts, with reported yield losses ranging from 15% to 73% (Day, 2017) [11]. The pest completes its life cycle in approximately one month without undergoing diapause, and thus spreads very rapidly, and travels for long-distance migration, resulting in severe outbreaks (Sun *et al*., 2019; Zhang, 2019) [24, 31]. Compared to other noctuid pests of maize, *S. frugiperda* larvae exhibit an unusually high feeding capacity (Day *et al*., 2017) [11]**.** It actively consumes young maize leaves and frequently damages the plant's vegetative growth point. In addition, the caterpillars attack tassels, silks, and developing maize cobs, further reducing yield potential.

The extensive reliance on chemical insecticides for pest control has led to negative environmental concerns, including pesticide resistance and ecological imbalances. As a result, sustainable pest management strategies have gained increased attention. One of the most promising alternatives is host plant resistance, which provides an economical and environmentally friendly approach to pest control (Dar *et al*., 2006) [8]. However, insecticides remain an essential component of IPM, serving as an important line of defense against severe pest infestations.

The current study aimed to evaluate susceptibility of eight maize hybrids to S. frugiperda infestation, and efficacy of five chemical insecticides in managing this pest.

## Materials and Methods

### Relative susceptibility of maize hybrids to *Spodoptera frugiperda* infestation

This experiment was carried out at a private maize field located at Nubaria district, Beheira Governorate, Egypt. Maize seeds were sown in the last week of April and harvested in the first week of September in 2023, while in 2024, planting occurred on May 7, with harvesting in the last week of September. The study evaluated the susceptibility of four yellow maize hybrids; three-way cross 352, three-way cross 360, single cross 168 and single cross 173, and four white hybrids; single cross 122, single cross 128, three-way cross 321, and three-way cross 324. The experiment was conducted on an area of about one-feddan, divided into 32 equal plots (8 hybrids x 4 replicates) distributed in a completely randomized block design (RCBD). Insect inspections began 15 days after sowing and weekly continued until harvest. At inspection, five maize plants from each plot (20 plants per hybrid) were randomly selected and examined between 6:00 and 10:00 a.m. for egg masses, larvae, and symptoms of *S. frugiperda* infestation. In addition, the numbers of egg masses and larvae per ten maize plants were recorded. Standard agricultural practices were maintained throughout the study, except for insecticide applications.

The seasonal mean values of hybrids infestations were calculated as mean ± SE (standard error) and statistically analyzed using the LSD test (SAS Statistical Software, 1999) [23]. Infestation percentages were determined using Caniço *et al*. (2020) [5] formula, as follows:

Infestation percentage=(a/b)×100

Where: a = Number of infested plants (showing visual symptoms of fall armyworm damage, irrespective of the presence or absence of egg masses or larvae). b = Total number of inspected plants.

**Efficacy of five chemical insecticides against *S. frugiperda***

An area of about 2,000 m² was assigned to test the efficacy of five synthetic insecticides against *S. frugiperda*. The experimental area was divided into 24 plots (80 m² each), distributed in a completely randomized block design (RCBD); five insecticides and a control, with four replicates each. Insecticide applications were performed in mid-June during both seasons using a Knapsack sprayer (Solo, 20-liter capacity), following the manufacturers' recommended application rates. The number of live *S. frugiperda* larvae was recorded for ten maize plants per plot before treatment and 1, 4, 7, and 14 days post-application. Larval reduction was determined using Henderson and Tilton (1955) formula:

Reduction percentage ={1−(Ta×Cb)(Tb×Ca)}×10

Where:

- Cb = Average larval count in the untreated plots before application.
- Ta = Average larval count in the treated plots after application.
- Ca = Average larval count in the untreated plots after application.
- Tb = Average larval count in the treated plots before application.

**Table 1:** Tested insecticides

| Trade name | Common name | Manufacturer | Application Rate (per feddan) |
|---|---|---|---|
| Lannate® 90% SP | Methomyl | DuPont (USA) | 300 g |
| Robek® 50% WP | Acetamiprid (22.7%) + Bifenthrin (27.3%) | Shoura Co. | 50 g |
| Pleo® 50% EC | Pyridalyl | Sumitomo Chemical Co. | 100 ml |
| Coragen® 20% SC | Chlorantraniliprole | DuPont Du Nemours Co. | 100 ml |
| Match® 5% EC | Lufenuron | Syngenta Co. | 120 ml |

**Statistical analysis**

All obtained data were subjected to statistical analysis using analysis of variance (ANOVA) to assess the significance of differences among treatments. Mean comparisons were performed using the Least Significant Difference (LSD) test to distinguish variations among treatment means at a specified significance level (SAS Statistical Software, 1999) [23].

## Results and Discussion

**The relative susceptibility of eight maize hybrids under field conditions**

Data presented in Figures (1–3) illustrate the susceptibility of eight maize hybrids to *Spodoptera frugiperda*, expressed as number of egg masses (Figure 1), the number of larvae (Figure 2), and infestation percentages (Figure 3) over two consecutive growing seasons: 2023 and 2024. None of the evaluated maize hybrids exhibited high resistance to this fall armyworm. However, SC128 and SC130 demonstrated moderate levels of resistance in both seasons.

The number of egg masses deposited on each maize hybrid indicated a significant ovipositional preference for TW352 and TW360 hybrids. During the first season (2023), the mean numbers of egg masses recorded on TW352 and TW360 were 1.013 and 0.927 egg masses per plant, respectively. In contrast, SC130 and SC128 hybrids were the least attractive for oviposition, with averages of 0.24 and 0.316 egg masses per plant. In the following season (2024), the maize hybrids could be ranked in a descending order according to their attractiveness for *S. frugiperda* oviposition as follows: TW352 (1.275), TW360 (1.105), TW321 (0.636), SC168 (0.694), TW324 (0.563), SC173 (0.53), SC128 (0.42), and SC130 (0.286) egg masses per plant.

Figure 2 illustrates the seasonal abundance of *S. frugiperda* larvae on different maize hybrids during both seasons. SC130 harbored the lowest number of larvae (0.944 per plant) in the first season, followed by SC128 (1.003), SC168 (1.372), SC173 (1.53), TW321 (2.119), TW324 (2.377), TW360 (3.216), and TW352 (3.288 larvae per plant). During the following season (2024), these results were confirmed. The hybrid TW352 harbored the highest number of *S. frugiperda* larvae, with an average of 5.791 larvae per plant per season, while the hybrid SC130 had the lowest larval count (1.305 larvae per plant).

Regarding the infestation percentages of maize hybrids due to *S. frugiperda* larvae, a significant difference was observed among the hybrids across both seasons (LSD = 6.233 in 1st season and 7.823 in 2nd season, $p<0.05$). In the first season (2023), the greatest infestation rate was observed in TW352 (22.5%), whereas the lowest one was observed in SC130

(8.056%). During the second season (2024), the infestation percentages followed a similar trend, with TW352 exhibiting the highest infestation (26.94%), followed by TW360 (23.89%), TW324 (23.06%), TW321 (21.11%), SC168 (18.33%), SC173 (17.22%), SC128 (14.17%), and SC130 (12.5%).

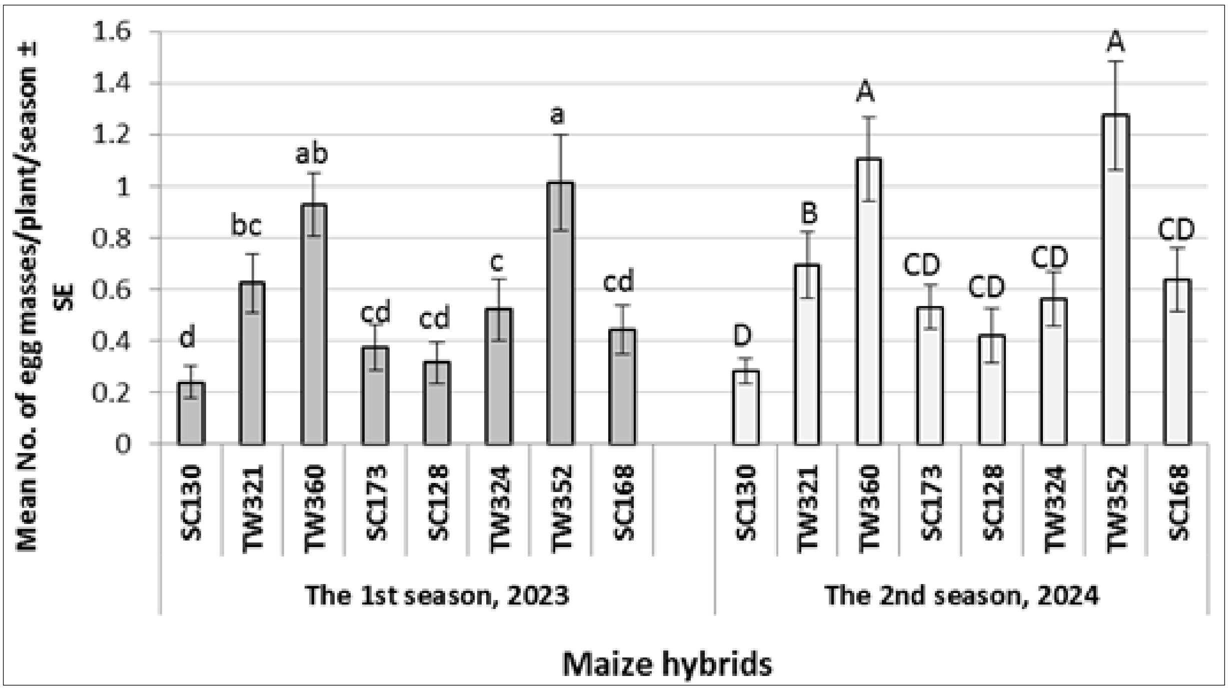


**Fig 1:** Relative susceptibility of maize hybrids to *Spodoptera frugiperda* expressed as mean number of egg masses / plant / season throughout 2023 season (F = 6.1058, LSD = 0.3186) and 2024 (F = 6.7536, LSD = 0.05 = 0.3624)

Means followed by the same letter(s) are not significantly different ($p<0.05$); Means followed by the same letter(s) are not significantly different ($p<0.05$), small letters for 2023 season and capital letters for 2024.

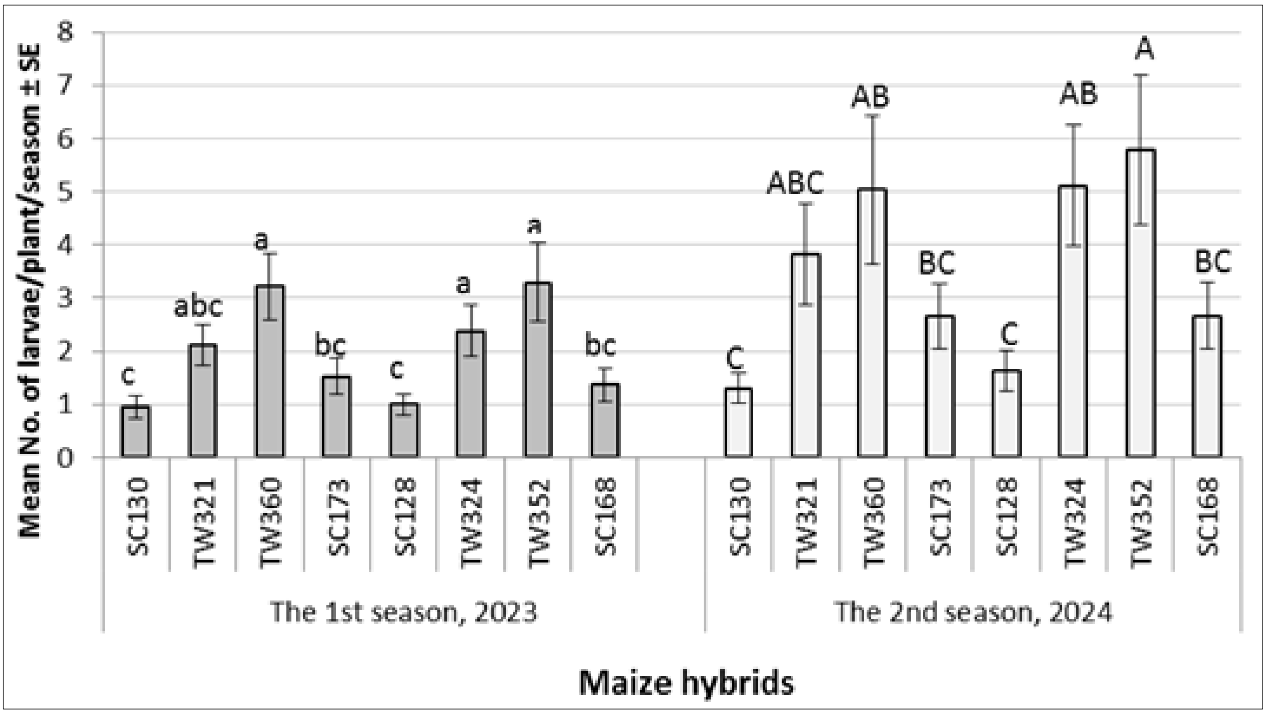


**Fig 2:** Relative susceptibility of maize hybrids to *Spodoptera frugiperda* expressed as mean number of larvae / plant / season throughout 2023 season (F = 4.209, LSD = 1.264) and 2024 (F = 3.212, LSD = 2.6398)

Means followed by the same letter(s) are not significantly different ($p<0.05$), small letters for 2023 season and capital letters for 2024.

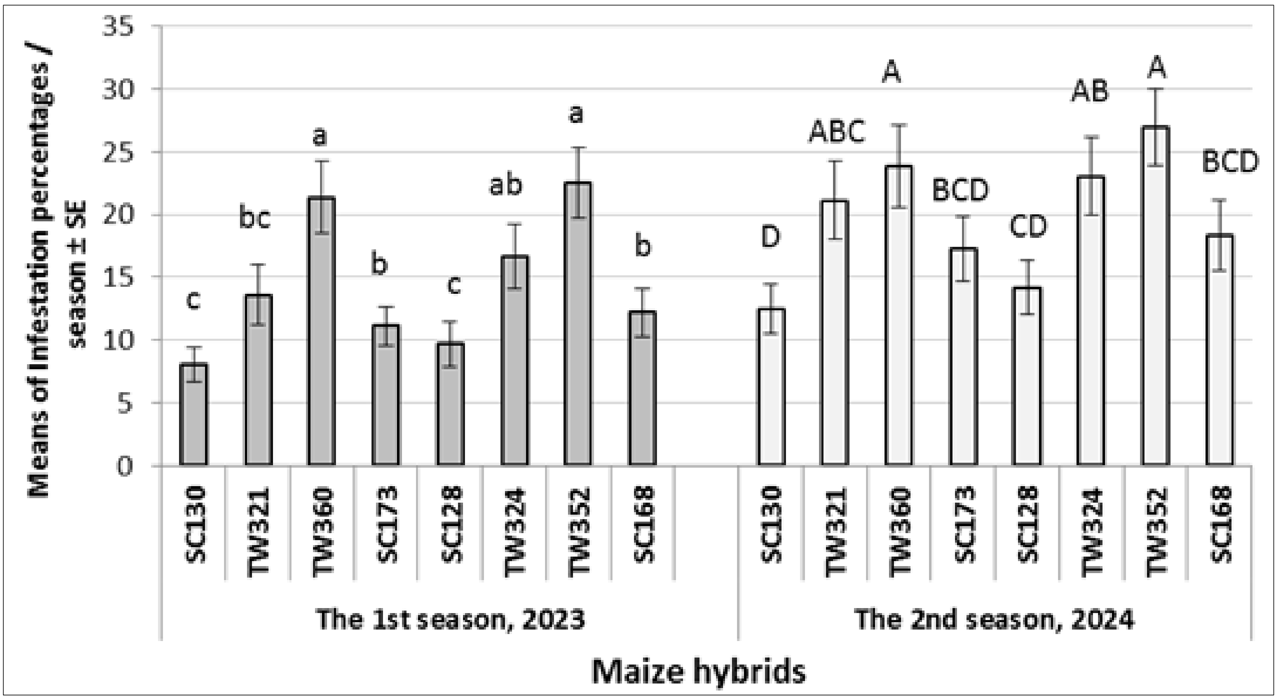


**Fig 3:** Relative susceptibility of maize hybrids to *S. frugiperda* expressed by the general means of infestation percentages / season throughout 2023 season (F = 5.6905, LSD = 7.823) and 2024 (F = 3.1716, LSD = 7.8232). Means followed by the same letter(s) are not significantly different (p<0.05); Means followed by the same letter(s) are not significantly different (p<0.05), small letters for 2023 season and capital letters for 2024

Horgan *et al*. (2020) [19] and El-Dessouki *et al*. (2022) [14] emphasized that host plant resistance plays a crucial role in pest management, and is regarded as one of the most effective control strategies. The present study underscores the necessity of thoroughly screening existing maize hybrids and genotypes to identify potential parental lines exhibiting resistance to *Spodoptera frugiperda* infestation and damage. Such resistant genotypes could be integrated into maize breeding programs to enhance pest resistance.

The results revealed significant variations in the attractiveness of maize hybrids to *S. frugiperda* moths. The hybrid T.W.C. 352 exhibited the highest attractiveness, whereas S.C. 128 was the least attractive. These findings align with Darwish *et al*. (2019) [10], who tested five maize hybrids for susceptibility to the sugarcane borer (*Sesamia cretica* Led.) and ranked them in a descending order of susceptibility as follows: T.W.C. 352, S.C. 168, S.C. 122, S.C. 10, and S.C. 128. Paul and Deole (2020) [22] reported that the maize genotype DKC-9190 exhibited minimal leaf damage (2.36), while NK-30 recorded the highest (8.21). Kasoma *et al*. (2020) [21] conducted a screening experiment for fall armyworm-resistant genotypes and found that genotype CML304-B suffered the lowest leaf damage (8.87%).

Darshan *et al*. (2024) [9] evaluated 15 maize cultivars and observed that PMH 2244 had the lowest average larval density (0.67 larvae/plant), while Kaveri Minchu displayed the highest mean leaf damage score (4.62). The hybrid PMH 224 demonstrated the lowest mean leaf damage score (0.73).

**Effectiveness of Chemical Insecticides Against *S. frugiperda***

Data shown in Tables (2 and 3) depict the number of *S. frugiperda* larvae recorded before insecticide treatment, and 1, 4, 7, and 14 days post-application of five insecticides. The highest initial mortality rate was 92.78%, observed for Pleo within 24 hours of application, followed by 87.78% for Lannate, while Coragen recorded the lowest initial mortality (71.13%).

In terms of residual efficacy, Pleo exhibited the highest residual effect (94.95%) 7 days post-treatment, followed by Lannate (85.95%) and Robek (78.43%). After 14 days, Pleo remained the most effective insecticide, with a residual efficacy of 91.8%, followed by Lannate (84.92%), while Coragen had the lowest residual effect (70.59%).

A significant variation was observed among treatments in the general means of reduction percentages ($p\leq0.05$). Pleo exhibited the highest mean reduction percentage (93.27%), followed by Lannate (86.96%), Match (80.41%), Robek (75.33%), and Coragen (72.86%). In the second season (2024), the trend remained similar, with significant differences ($p\leq0.05$) in reduction percentages: Pleo (95.16%), Lannate (84.44%), Match (82.68%), Robek (78.74%), and Coragen (73.06%).

Similar studies have supported these findings. Ahmad *et al*. (2023) [2] evaluated five synthetic insecticides against *S. frugiperda* in maize fields and reported maximum mortality (75%) with monomehypo and minimum mortality (49%) with emamectin benzoate 10 days post-treatment. Chlorpyrifos, lambda-cyhalothrin, and carbofuran resulted in mortality rates of 68%, 65%, and 58%, respectively. Deshmukh *et al*. (2020) [12] identified chlorantraniliprole as the most effective insecticide for *S. frugiperda* control, followed by emamectin benzoate, spinetoram, flubendiamide, indoxacarb, lambda-cyhalothrin, and novaluron. Karki *et al*. (2023) [20] validated the field efficacy of chlorantraniliprole, spinetoram, and emamectin benzoate, with chlorantraniliprole exhibiting the highest effectiveness, followed by spinetoram and emamectin benzoate.

The effectiveness of insecticides could be influenced by various factors, including geographic location, crop variety, and pest population dynamics. Beuzelin *et al*. (2022) [3]

observed that the efficacy of chlorantraniliprole and spinetoram varied across different regions, with chlorantraniliprole demonstrating high performance in certain areas while being less effective in others. Similarly, Tumma and Chandrika (2018) [25] identified methomyl, pyrethroids, cyfluthrin, and organophosphate insecticides, such as methyl parathion, as viable options for managing *S. frugiperda*. Additionally, Bhusal and Bhattarai (2019) [4] reported over 90% larval mortality when using spinosad, chlorantraniliprole, flubendiamide, and spinetoram, which proved to be more effective than conventional insecticides like lambda-cyhalothrin and novaluron (Hardke *et al*., 2015) [17].

**Table 2:** Reduction percentages in *Spodoptera frugiperda* population due to insecticide applications, under field conditions, during the 2023 season, mean numbers of larvae/ten plants are in brackets

| Treatment | Pre spray | Post spray (days) | | | | General mean |
|---|---|---|---|---|---|---|
| | | 1 | 4 | 7 | 14 | |
| Control | (34.25±2.06) | (40.5±2.08) | (44.75±2.22 | (58.25±3.86 | (51.75±2.36) | |
| Coragen® | (38.5±2.89) | 71.13±5.06$^{b}$ (13±0.82) | 76.94±3.36$^{c}$ (11.5±0.58) | 72.77±3.65$^{d}$ (17.75±1.89) | 70.59±3.97$^{c}$ (17±1.41) | 72.86±4.45$^{d}$ |
| Lannate® | (39.75±1.71) | 87.78±5.61$^{a}$ (5.75±2.75) | 89.19±4.74$^{ab}$ (5.5±2.08) | 85.95±2.46$^{b}$ (9.5±1.73) | 84.92±3.09$^{b}$ (9±1.41) | 86.96±4.1$^{b}$± |
| Match® | (41.5±1.73) | 86.63±3.4$^{a}$ (6.5±1.29) | 83.71±3.76$^{b}$ (8.75±1.5) | 77.65±2.58$^{c}$ (15.75±1.71) | 73.63±5.14$^{c}$ (16.5±2.89) | 80.41±6.26$^{c}$ |
| Pleo® | (41±1.83) | 92.78±1.15$^{a}$ (3.5±0.58) | 93.56±2.01$^{a}$ 3.5±1.29) | 94.95±1.94$^{a}$ (3.5±1.29) | 91.8±2.06$^{a}$ (5±0.82) | 93.27±2.02$^{a}$ |
| Robek® | (42.25±2.5) | 71.66±4.99$^{b}$ (14±0.82) | 77.15±4.6$^{c}$ (12.5±1.73) | 78.43±1.18$^{c}$ (15.5±1.29) | 74.1±2.5$^{c}$ (16.5±1.29) | 75.33±4.26$^{d}$ |
| F values | | 20.867 | 14.729 | 48.106 | 25.921 | 57.479 |
| L. S. D. | | 6.5657 | 5.75995 | 3.76515 | 5.31525 | 3.1198 |

In a column, means followed by the same letter(s) are not significantly different at the 0.05 probability.

**Table 3:** Reduction percentages in *Spodoptera frugiperda* population due to insecticide applications, under field conditions, during the 2024 season, mean numbers of larvae/ten plants are in brackets

| Treatment | Pre spray | Post spray (days) | | | | General mean |
|---|---|---|---|---|---|---|
| | | 1 | 4 | 7 | 14 | |
| Control | (42.75±2.99) | (47.75±3.77) | (56.75±2.36) | (64.5±3.7) | (62.25±2.22) | |
| Coragen® | (44.25±3.3) | 75.68±3.41$^{d}$ (12±1.83) | 76.89±3.35$^{d}$ (13.5±1.29) | 70.57±5.03$^{c}$ (19.5±2.38) | 69.09±6.35$^{d}$ (19.75±2.87) | 73.06±5.41$^{d}$ |
| Lannate® | (48.25±2.17) | 82.87±4.86$^{c}$ (9.25±2.63) | 87.47±1.81$^{b}$ (8±0.82) | 84.38±5.77$^{b}$ (11±2.45) | 83.05±4.26$^{b}$ (11.75±2.06) | 84.44±4.39$^{b}$ |
| Match® | (41.5±1.73) | 89.27±1.03$^{b}$ (5±0.82) | 86.73±2.51$^{bc}$ (7.25±0.96) | 79.3±5.38$^{b}$ (12.75±1.71) | 75.43±5.41$^{cd}$ (14.75±2.5) | 82.68±6.79$^{b}$ |
| Pleo® | (41±1.83) | 95.14±2$^{a}$ (2.25±0.96) | 96.37±1.35$^{a}$ (2±0.82) | 96.7±1.59$^{a}$ (2±0.82) | 92.45±1.14$^{a}$ (4.5±0.58) | 95.16±2.22$^{a}$ |
| Robek® | (42.25±2.5) | 74.19±5.23$^{d}$ (12±0.82) | 82.89±3.48$^{c}$ (9.5±1.29) | 80.63±2.74$^{b}$ (12.25±0.5) | 77.27±1.43$^{bc}$ (14±1.15) | 78.74±4.63$^{c}$ |
| F values | | 23.444 | 29.213 | 18.492 | 17.048 | 44.083 |
| L. S. D. | | 5.5434 | 3.97145 | 6.66015 | 6.42765 | 3.46635 |

In a column, means followed by the same letter(s) are not significantly different at the 0.05 probability

## Conclusion

This study highlights the variability in susceptibility of maize hybrids to *Spodoptera frugiperda*, with SC128 and SC130 showing relatively high resistance. Treatments with Pleo and Lannate showed significant reductions in larval populations. The current findings emphasize the importance of integrating resistant hybrids and insecticide applications in mitigating the impact of *S. frugiperda* on maize crops.

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