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Original Research

Detection and Monitoring of Damage Status and Infestation by *Spodoptera frugiperda* in Maize Crops in Luxor Region, Egypt

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ABSTRACT

The fall armyworm (*Spodoptera frugiperda*) is a serious crop pest that destroys maize plants in Egypt and the world, leading to reduced quality and quantity of the maize crop. We conducted this study to monitor and determine the damage status and infestation frequency of *S. frugiperda* on maize plants in Luxor Governorate, southern Egypt. The sampling date was set with the first observable occurrence of fall armyworm at the study site. Forty randomly selected corn plants (ten plants from each replicate) were evaluated and estimated weekly until harvest. The total number of plants used for sampling was 960 plants during the two seasons. The invasion and damage of maize plants by *S. frugiperda* started at the age of 16 days after sowing until the time of harvest, i.e. *S. frugiperda* larvae were detected on maize plants during the period from the third week of June until the maize harvest. In terms of number of larvae, number of plants infested with larvae, percentage of infestation, and percentage of damage intensity, three peaks were recorded in each season, occurring at 30, 58 and 86 days after sowing in 2021 and 2022, respectively. Our study shows that the number of damaged plants was higher than the number of infected plants throughout the season. Thus, the percentage of plants damaged by *S. frugiperda* increased as the timing of corn plant inspections increased during the two seasons. The results indicate that monitoring plant inspections at key times during the growing season can provide crucial data to help farmers implement timely control measures.

Keywords: Fall Armyworm, *Spodoptera frugiperda*, Maize, Plant age, Damage intensity, infestation.

INTRODUCTION

The fall armyworm [*Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae)] is one of the most serious maize pests (Anjorin et al., 2022; Bakry and Abdel-Baky, 2023 a; El-Gaby et al., 2024) and is spreading rapidly in Africa (Goergen et al., 2016). In Africa, *S. frugiperda* prefers maize to numerous other crops (Prasanna et al. 2018). It is a dangerous, mobile, and migratory insect pest (Anandhi et al., 2020; Caniço et al., 2020; Maruthadurai and Ramesh, 2020). The rapid spread of *S. frugiperda* is attributed to its migratory potential (Meagher et al. 2004) and high dispersal ability (Kumela et al. 2018). Larvae of *S. frugiperda* have multiple generations per season (Bakry and Abdel-Baky, 2023 a). One month can fly

up to 100 kilometers in one night (FAO, 2017). *S. frugiperda* is a voracious, invasive, alien, nocturnal, and damaging pest that can pose a threat to maize yield (Caniço et al., 2020; Yigezu and Wakgari, 2020; Xiao-xu et al., 2021).

S. frugiperda threatens maize plants at all stages of growth and development, resulting in severe damage, reduction in photosynthetic area, slowing of growth, dead and torn hearts, windowing of leaves, and impeded reproduction (Chimweta et al., 2020; Bakry et al., 2023), as well as a reduction in growth attributes (height, stem diameter, and number of green leaves per plant) and a reduction in grain yield, straw yield, and biological yield (Bakry and Abdel-Baky, 2023 b). This pest can cause direct and indirect damage to the corn plant (Bakry and Gad, 2023). Direct damage can result in fungal diseases and aflatoxins associated with larval consumption, while indirect damage can result in grain quality losses (Bangale, 2019).

Maize yields can be greatly impacted by FAW feeding and biological activity; annual losses in Brazil are estimated to be $400 million (Figueiredo et al., 2005). FAW reduced maize production by 73% in Latin America, costing millions of dollars in losses (Murua et al., 2006). Millions of dollars were lost as a result of FAW's 22–67% yield reduction in Ghana and Zambia (Rwomushana et al. 2018).

Severe FAW infestations can decrease crop yields by 50–80%, which lowers per capita income and increases hunger (Rwomushana et al. 2018). Fungal infection brought on by indirect damage to cobs can lower grain quality. According to Bakry and Abdel-Baky (2023b), FAW is predicted to result in a 33% annual loss in maize yield in the absence of management measures.

This pest is difficult to control due to the short duration of its life cycle and polyphagy (Rios et al., 2014; Montezano et al., 2018).

A lack of adequate knowledge on how to manage fall armyworm invasion appears to be an important problem for corn growers. In light of these challenges, this study aims to monitor the infestation patterns of *S. frugiperda* in maize fields in southern Egypt and evaluate the associated damage to aid in the development of effective management strategies."

MATERIAL AND METHODS

Experimental design

Monitoring of *S. frugiperda* populations was conducted on maize plants under field conditions during two cropping seasons in the Esna region, Luxor governorate, southern Egypt (25º21'48" N, 32º32'55" E). At the ideal cultivation date (first week of June each season). One maize variety (single hybrid 128 White) was grown on a plot of about 4200 m^2. Except for pest management, standard traditional agricultural practices (irrigation and fertilization) were applied according to the recommendations of the Egyptian Ministry of Agriculture.

S. frugiperda population estimates and infestation:

1. Sampling of pest infestation:

The sampling date was set with the first observable occurrence of fall armyworm at the study site. Pest infestation and damage began on corn plants between 16 and 93 days of age after planting (DAC). Forty randomly selected corn plants (ten plants from each replicate) were evaluated and estimated weekly until harvest. The total number of plants used for sampling was 960 plants, i.e. (10 plants × 4 replicates × 12 dates × 2 seasons). Each season included 480 plants. All samples of maize plants were randomly selected in "the early morning hours between 7 and 9 a.m. to determine, based on larval feeding behavior, the abundance of *S. frugiperda* larval populations in the different locations of the field, to estimate the number of larvae, the number of plants infested with larvae, and the number of damaged plants and the number of healthy plants (not infested), were reviewed after this Fernández (2002), Caniço et al. (2020), Vinay et al. (2022) and Sholahuddin et al. (2023).

2. Variables:

A- Based on the number of plants where *S. frugiperda* larvae were found, the number of plants infested with larvae was computed.
B- By deducting the total number of plants studied (40 plants) from the total number of plants in which *S. frugiperda* larvae were found, the number of healthy (non-infested) plants was determined.
C- Regardless of the presence or absence of larvae, the number of plants exhibiting outward indications of *S. frugiperda* infestation or attack was used to determine the total number of attacked plants.
D- Number of larvae: the average number of *S. frugiperda* larvae per 10 maize plants.

E- The number of plants on which *S. frugiperda* larvae were found was divided by the total number of plants inspected (infected and uninfested) (40 plants) on each sample day, and the result was converted to a percentage. This allowed for the calculation of the percent infestation. (Note: Plants were deemed infested whenever *S. frugiperda* larvae were found on them).

F- By dividing the number of plants on which *S. frugiperda* larvae were observed by the number of healthy, uninfested plants, and converting the results to percentages, the percentage of attack intensity was determined.

G- The number of plants that showed clear signs of infestation or assault by *S. frugiperda* was divided by the total number of plants examined (40 plants total—infested and uninfested) on each sample day, and the result was converted to a percentage. This yielded the percentage of attacked plants. (Note that regardless of the presence or absence of larvae, plants were deemed attacked or infested if there was visible evidence of *S. frugiperda* larvae feeding.).

To evaluate the linear relationship between the tested independent variables (x), i.e., plant growth, number of larvae-infested plants, number of larvae, and number of damaged plants, and the dependent variables (y), i.e., percentages of infestation, damage intensity, and damaged plants by *S. frugiperda* estimated over two seasons (2021 and 2022).

The simple regression method was used to show the variations among the studied parameters as a result of insect infestation. This method was calculated by Fisher (1950). In addition, the coefficient of determination and the percentage of variance explained were calculated to provide important information about the extent of variation among the variables studied. Microsoft Excel (2007) was used to estimate all the data, create their graphical representations, and perform the statistical analysis of the data.

RESULTS

Weekly estimates of larval numbers, numbers of plants infested with larvae, and numbers of plants damaged by *S. frugiperda* infesting maize plants under field conditions (single-hybrid 128 White cultivar) in Esna Province, Luxor Governorate, were estimated in two consecutive seasons (2021 and 2022) and are presented in Tables (1 and 2) and Fig. (1). Also shown are the weekly records of the percentage of infestation, damage intensity, and plants damaged by S. frugiperda. Our observations showed that *S. frugiperda* larvae were detected on corn plants from the third week of June until corn harvest, i.e., infestation and damage by the pest began on corn plants at 16 to 93 days after planting per season.

1. Population estimates of S. frugiperda:

1.1 Number of larvae-infested plants:

The average number of larvae-infested plants was 8.75 ± 1.66 and 7.75 ± 2.26 plants per 40 maize plants in the first and second growing seasons, respectively, and had three peaks in each season, occurring at 30, 58 and 86 days post-planting in 2021 and 2022, as shown in Tables (1 and 2) and Figure (2).

1.2 Number of plants damaged:

The number of plants damaged by *S. frugiperda* increased with increasing study duration of the corn plants in the two years (Tables 1 and 2; Fig. 2). The mean number of plants damaged by *S. frugiperda* was 25.33 ± 6.79 and 22.00 ± 7.31 plants per 40 plants in the two years, respectively. The number of damaged plants was higher than the number of infected plants throughout the season. The study also showed that corn plants were more suitable for *S. frugiperda* larvae to settle a larger number of larvae during their vegetative stage. The results show that during the two growing seasons, significant damage to maize plants during flowering and reproductive stages progressively increased the number of plants damaged by the pest.

1.3 S. frugiperda larval estimates:

Seasonal larval activity had three maximum values, 30, 58, and 86 days after cultivation in the 2021 and 2022 seasons (see Tables (1 and 2); Fig. 2). The estimated average population of *S. frugiperda* larvae was 24.60 ± 4.41 and 18.75 ± 4.85 larvae per 40 plants in 2021 and 2022, respectively (Tables 1 and 2).

1.4 Percentage of S. frugiperda infestation:

The percentage of infestation with *S. frugiperda* varied with increasing age of corn plants in the two seasons (Tables 1 and 2; Fig. 3). Three peaks per season were observed at 30, 58, and 86 days after planting (DAP) in the two years. In addition, the average infestation percentage of *S. frugiperda* was 21.88 ± 4.15 and 19.38 ± 5.65% in the two years, respectively.

1.5 Percentage of damage intensity of S. frugiperda:

The mean percentage of damage intensity was 28.34 ± 6.91 and 24.61 ± 9.09% in 2021 and 2022 seasons, respectively, and had three peaks per season that occurred at 30, 58, and 86 days of age after maize planting in the two seasons, as shown in Tables (1 and 2) and Fig. 1.

1.6 Percentage of plants damaged by S. frugiperda:

The percentage of plants damaged by *S. frugiperda* increased in both years as the date of the maize survey increased (Tables 1 and 2; Fig. 3). The mean percentages of plants damaged by *S. frugiperda* were 63.33 ± 16.97 and 55.00 ± 18.28% in the two seasons, respectively.

86 days after cultivation was the most suitable time to increase the number of *S. frugiperda* larvae, the number of plants infested by larvae, the infestation percentages, and the intensity of damage caused by larvae; however, 16 DAS was the least suitable time for infestation and damage in the two seasons.

Table 1. Weekly counts of larvae, percentage of infestation, damage intensity, and damaged plants by *S. frugiperda* on maize plants and the corresponding biotic factor in Esna Province, Luxor Governorate, in the first season (2021).

Sampling date		DAS*	No. of plants examined	No. of plants infested with larvae per 40 plants	No. of healthy plants per 40 plants	No. of damaged plants per 40 plants	No. of larvae per 40 plants	% Infestation	% Damage intensity	% Damaged plants
June, 2021	3rd	16	40.00	6	34.00	12.00	15.00	15.00	17.65	30.00
	4th	23	40.00	7	33.00	16.00	22.00	17.50	21.21	40.00
July	1st	30	40.00	9	31.00	19.00	26.00	22.50	29.03	47.50
	2nd	37	40.00	8	32.00	23.00	20.00	20.00	25.00	57.50
	3rd	44	40.00	7	33.00	24.00	22.00	17.50	21.21	60.00
	4th	51	40.00	9	31.00	26.00	26.00	22.50	29.03	65.00
Aug.	1st	58	40.00	10	30.00	28.00	28.00	25.00	33.33	70.00
	2nd	65	40.00	9	31.00	29.00	28.00	22.50	29.03	72.50
	3rd	72	40.00	8	32.00	30.00	24.00	20.00	25.00	75.00
	4th	79	40.00	10	30.00	31.00	26.00	25.00	33.33	77.50
Sept.	1st	86	40.00	12	28.00	32.00	32.00	30.00	42.86	80.00
	2nd	93	40.00	10	30.00	34.00	26.25	25.00	33.33	85.00
Average ± STD			40.00 ± 0.00	8.75 ± 1.66	31.25 ± 1.66	25.33 ± 6.79	24.60 ± 4.41	21.88 ± 4.15	28.34 ± 6.91	63.33 ± 16.97

* DAS refers to days after sowing, STD = Standard deviation

Table 2. Weekly counts of larvae, percentage of infestation, damage intensity, and damaged plants by *S. frugiperda* on maize plants and the corresponding biotic factor in Esna Province, Luxor Governorate, in the second season (2022).

Sampling date		DAS	No. of plants examined	No. of plants infested with larvae per 40 plants	No. of healthy plants per 40 plants	No. of damaged plants per 40 plants	No. of larvae per 40 plants	% Infestation	% Damage intensity	% Damaged plants
June, 2022	3rd	16	40.00	5.00	35.00	10.00	10.00	12.50	14.29	25.00
	4th	23	40.00	6.00	34.00	12.00	14.00	15.00	17.65	30.00
July	1st	30	40.00	8.00	32.00	14.00	18.00	20.00	25.00	35.00
	2nd	37	40.00	5.00	35.00	18.00	14.00	12.50	14.29	45.00
	3rd	44	40.00	6.00	34.00	19.00	20.00	15.00	17.65	47.50
	4th	51	40.00	8.00	32.00	22.00	22.00	20.00	25.00	55.00
Aug.	1st	58	40.00	11.00	29.00	25.00	24.00	27.50	37.93	62.50
	2nd	65	40.00	8.00	32.00	26.00	18.00	20.00	25.00	65.00
	3rd	72	40.00	6.00	34.00	28.00	15.00	15.00	17.65	70.00
	4th	79	40.00	9.00	31.00	29.00	20.00	22.50	29.03	72.50
Sept.	1st	86	40.00	12.00	28.00	30.00	26.00	30.00	42.86	75.00
	2nd	93	40.00	9.00	31.00	31.00	24.00	22.50	29.03	77.50
Average ± STD			40.00 ± 0.00	7.75 ± 2.26	32.25 ± 2.26	22.00 ± 7.31	18.75 ± 4.85	19.38 ± 5.65	24.61 ± 9.09	55.00 ± 18.28

Fig. 1. The devastating symptoms of infestation of maize plants by voracious *S. frugiperda* larvae and the direct and indirect damage to maize plants in the field (single-hybrid 128 White). (Source: Moustafa M.S. Bakry).

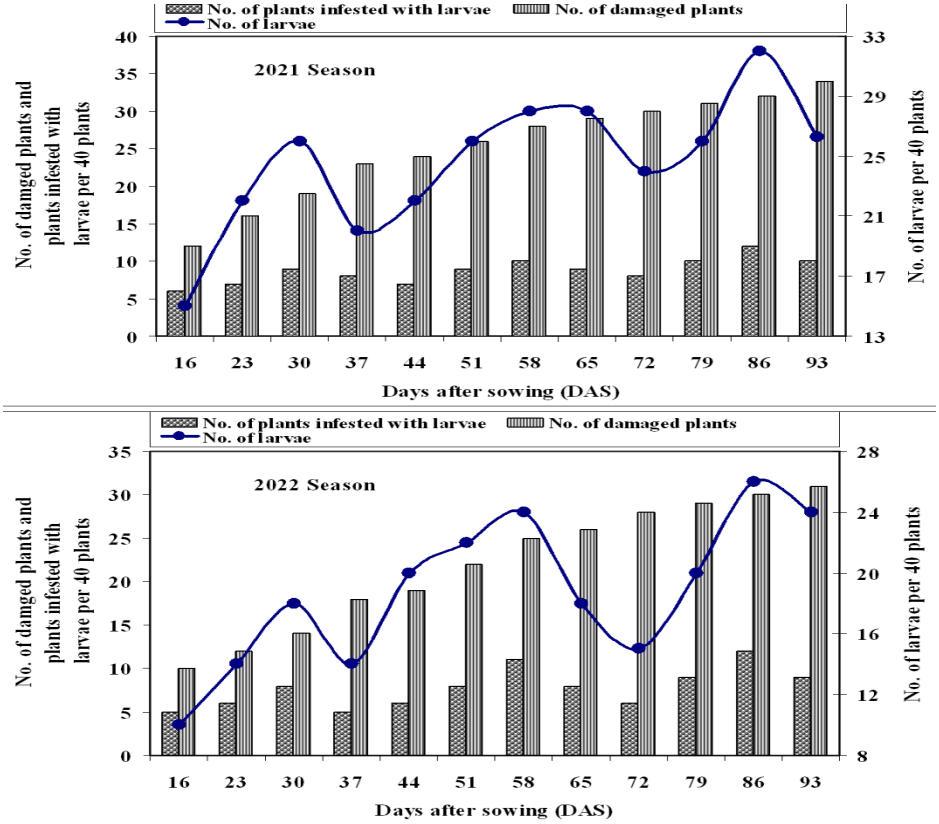

Fig. 2. Weekly counts of *S. frugiperda* larvae, plants damaged numbers on maize plants in Esna Province, Luxor Governorate, in 2021 and 2022.

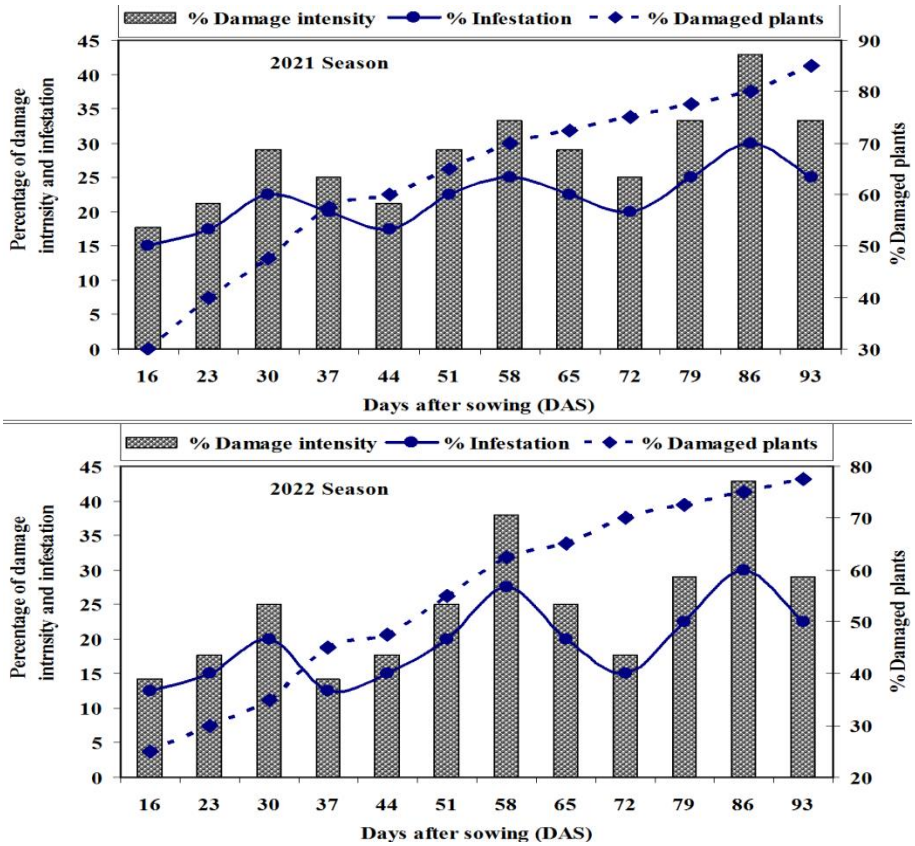

Fig. 3. Weekly percentages of damage intensity, damaged plants, and *S. frugiperda* infestation on maize plants in Esna Province, Luxor Governorate, in 2021 and 2022.

2. Evaluation of the linear relationship between the changes in the tested independent variables and the difference in the dependent parameters caused by the invasion of S. frugiperda:

The data presented in Table (3) showed the linear relationship between the tested independent variables (x), i.e. plant growth, number of larvae infested plants, number of larvae and number of damaged plants, and the dependent variables (y), i.e. percentages of infestation, damage intensity and damaged plants by *S. frugiperda* estimated over two seasons (2021 and 2022).

The data showed a highly significant positive correlation between plant development (in days) and the dependent variables, i.e. the number of larvae-infested plants, number of damaged plants, larval population, percent infestation, percent damage intensity, and percent damaged plants (r values: 0.78, 0.97, 0.73, 0.78, 0.78, and 0.97 in 2021 and 0.66, 0.99, 0.72, 0.66, 0.65, and 0.99 in 2022, respectively). At the same time, the linear regression coefficient showed that with each increase in plant age of maize, the number of larvae-infested plants (0.05 and 0.06 plants), the number of damaged plants (0.26 and 0.29 plants), larval population (0.13 and 0.14 larvae), percent infested (0.13 and 0.15%), percent damaged intensity (0.21 and 0.23%), and percent damaged plants (0.65 and 0.71%) would increase in 2021 and 2022, respectively (Table 3).

The estimated simple correlation values between the number of larvae-infested plants and the dependent variables, i.e., number of damaged plants, larval population, percent infestation, percent damage intensity, and percent damaged plants, were highly significantly positive and were (0.78, 0.91, 0.99, 0.99, and 0.78) and (0.65, 0.88, 0.99, 0.99, and 0.65), respectively, in the two seasons. In conjunction, the simple regression showed that an increase of one larvae-infested plant per 40 plants would increase the number of damaged plants by (3.17 and 2.12 plants), larval population (2.42 and 1.89 larvae), percentage of infestation (2.50 and 2.50%), percentage of damage intensity (4.16 and 4.01%), and percentage of damaged plants (7.93 and 5.29%) in 2021 and 2022, respectively (Table 3).

The statistical analysis of simple correlation (Table 3) showed highly significant positive correlations between larval population and the dependent variables, i.e., number of damaged plants, percent infestation, percent damage intensity, and percent of damaged plants (R values: 0.76, 0.78, 0.76, and 0.99) and (0.71, 0.65, 0.64, and 0.99) in 2021 and 2022, respectively. In addition, the simple regression showed that an increase of one larva per 40 plants would increase the number of damaged plants by (0.49 and 0.47 plants), the percentage of infestation (0.47 and 0.51%), the percentage of damage intensity (0.77 and 0.80%), and the percentage of damaged plants (2.50 and 2.50%) in 2021 and 2022, respectively (Table 3).

Simple correlation analysis (Table 3) also showed highly significant positive correlations between the number of damaged plants and the dependent variables, i.e., percent infestation, percent damage intensity, and percent damaged plants (R values of 0.91, 0.90, and 0.76) and (0.88, 0.87, and 0.71) in 2021 and 2022, respectively. Similarly, the linear regression indicates that an increase of one damaged plant per 40 plants would increase the percentage of infestation (0.85 and 1.03%), the percentage of damage intensity (1.41 and 1.63%), and the percentage of damaged plants (2.91 and 2.69%) in 2021 and 2022, respectively (Table 3).

The estimated simple correlation values between the number of larvae-infested plants and the dependent variables, i.e., number of damaged plants, larval population, percent infestation, percent damage intensity, and percent damaged plants, were also highly significantly positive and were (0.78, 0.91, 0.99, 0.99, and 0.78) and (0.65, 0.88, 0.99, 0.99, and 0.65) in the two seasons, respectively. In conjunction, the simple regression showed that an increase of one larvae-infested plant per 40 plants would increase the number of damaged plants by (3.17 and 2.12 plants), larval population (2.42 and 1.89 larvae), percentage of infestation (2.50 and 2.50%), percentage of damage intensity (4.16 and 4.01%), and percentage of damaged plants (7.93 and 5.29%) in 2021 and 2022, respectively (Table 3).

The statistical analysis of simple correlation (Table 3) showed highly significant positive correlations between larval population and the dependent variables, i.e., number of damaged plants, percent infestation, percent damage intensity, and percent of damaged plants (r values: 0.76, 0.78, 0.76, and 0.99) and (0.71, 0.65, 0.64, and 0.99) in 2021 and 2022, respectively. In addition, the simple regression showed that an increase of one larva per 40 plants would increase the number of damaged plants by (0.49 and 0.47 plants), the percentage of infestation (0.47 and 0.51%), the percentage of damage intensity (0.77 and 0.80%), and the percentage of damaged

plants (2.50 and 2.50%) in 2021 and 2022, respectively (Table 3).

The simple correlation analysis (Table 3) also showed highly significant positive correlations between the number of damaged plants and the dependent variables, i.e., percent infestation, percent damage intensity, and percent damaged plants (r values 0.91, 0.90, and 0.76, respectively) and (0.88, 0.87, and 0.71) in 2021 and 2022. Similarly, linear regression showed that an increase of one damaged plant per 40 plants would increase the percent infestation (0.85 and 1.03%), percent damage intensity (1.41 and 1.63%), and percent damaged plants (2.91 and 2.69%) in 2021 and 2022, respectively (Table 3).

Table 3. Describe the relationships between some weather factors and plant age on the number of egg masses of *S. frugiperda* on maize plants in 2021 and 2022, by various correlation and regression models.

Tested variables		2021 season					2022 season				
Independent (X)	Dependent (Y)	r	b	R^2	E.V.%	P.	r	b	R^2	E.V.%	P.
Days after cultivating (Develop plant)	No. of plants infested with larvae	0.78	0.05	0.61	61.31	0.003	0.66	0.06	0.44	44.01	0.019
	No. of damaged plants	0.97	0.26	0.94	94.02	0.000	0.99	0.29	0.97	97.28	0.000
	No. of larvae	0.73	0.13	0.53	52.68	0.008	0.72	0.14	0.52	51.94	0.008
	% Infestation	0.78	0.13	0.61	61.31	0.003	0.66	0.15	0.44	44.01	0.019
	% Damage intensity	0.78	0.21	0.60	60.18	0.003	0.65	0.23	0.42	42.35	0.022
	% Damaged plants	0.97	0.65	0.94	94.02	0.000	0.99	0.71	0.97	97.28	0.000
No. of plants infested with larvae	No. of damaged plants	0.78	3.17	0.60	60.13	0.000	0.65	2.12	0.43	42.81	0.021
	No. of larvae	0.91	2.42	0.83	82.58	0.000	0.88	1.89	0.78	77.71	0.000
	% Infestation	0.99	2.50	0.99	99.95	0.000	0.99	2.50	0.99	99.98	0.000
	% Damage intensity	0.99	4.16	0.99	99.58	0.000	0.99	4.01	0.99	99.52	0.000
	% Damaged plants	0.78	7.93	0.60	60.13	0.000	0.65	5.29	0.43	42.81	0.021
No. of larvae	No. of damaged plants	0.76	0.49	0.57	57.19	0.004	0.71	0.47	0.51	50.89	0.009
	% Infestation	0.78	0.47	0.60	60.13	0.003	0.65	0.51	0.43	42.81	0.021
	% Damage intensity	0.76	0.77	0.57	57.47	0.004	0.64	0.80	0.41	41.1	0.024
	%Damaged plants	0.99	2.50	0.99	99.98	0.000	0.99	2.50	0.99	99.99	0.000
No. of damaged plants	% Infestation	0.91	0.85	0.83	82.58	0.000	0.88	1.03	0.78	77.71	0.000
	% Damage intensity	0.90	1.41	0.81	80.73	0.000	0.87	1.63	0.76	75.72	0.000
	% Damaged plants	0.76	2.91	0.57	57.19	0.000	0.71	2.69	0.51	50.89	0.000

r = Simple correlation; b = Simple regression; R^2= Coefficient of determination; E.V% = Explained variance
P. refers to probability as significant at $P \leq 0.05$ or highly significant at $P \leq 0.01$.

DISCUSSION

The armyworm is a serious pest of crops that destroys corn plants in Egypt, leading to a decline in crop quality and quantity. The pest is currently a serious problem for maize growers, and the maize crop in Egypt may be at risk in the future.

One of the most important signs of pests in a crop is destructive behavior, which can be used to distinguish between different insect species. The formation of drag marks on leaves in the form of gaps, injured leaves, and an abundance of larval excretions are signs that *S. frugiperda* has attacked and devastated corn crops. The severity and activity of *S. frugiperda* are important indicators for understanding the spread of insect infestations in maize-growing areas, as this pest is new and invasive in southern Egypt (Bakry and Abdel-Baky 2023 a).

Therefore, monitoring and early detection are necessary to determine the number of larvae infesting maize, the percentage of infestation, the severity of damage, the percentage of damaged plants, the percentage severity, and the percentage prevalence of *S. frugiperda* larvae damaging maize plants. These results can help farmers and decision-makers reduce damage to corn plants and develop effective strategies to control this pest.

There is little knowledge in the scientific literature about the current status of the armyworm pest and monitoring in the Luxor region of southern Egypt. Therefore, this study is considered the first to focus on estimates of armyworm infestation, damage, and prevalence. Seven variables were used to express the behavior and activity of fall armyworm on corn plants, namely: the number of larvae, the number of plants infested with larvae, the number of healthy plants, the number of damaged plants, the percentage of infestation, the percentage of damage intensity and the percentage of damaged plants estimated weekly until harvest time, according to Fernández (2002), Caniço et al. (2020), Vinay et al. (2022), and Sholahuddin et al. (2023).

According to our findings, invasion and damage by *S. frugiperda* on maize plants started from 16 days after sowing to the time of harvest, i.e., *S. frugiperda* larvae were detected on maize plants during the period from the third week of June to maize harvest.

In terms of larval numbers, number of plants infested with larvae, percentage of infestation, and percentage of damage intensity, three peaks were detected in each season, indicated at 30, 58, and 86 days after sowing in 2021 and 2022, respectively. Sisay et al. (2019) reported that the generation time of fall armyworm ranges from 20 to 30 days, which could lead to multiple reinfestations of the pest (recurrent generations) during the maize growing season. Bakry and Abdel-Baky (2023 a) concluded that *S. frugiperda* larvae have three peaks per season on maize plants. Bakry and Gad (2024) mentioned that three peaks of *S. frugiperda* were observed in each season, occurring 29, 57 and 85 days after planting.

Our study shows that the number of damaged plants was higher than the number of infected plants throughout the season. The study also showed that maize plants were more suitable for *S. frugiperda* larvae to settle a larger number of larvae during their vegetative stage.

In our study, fewer plants were infested than damaged. Some damaged plants were not significantly infested at the time of sampling (Caniço et al. 2020; Fernández, 2002).

The reason for the decrease in the number of larvae-infested plants is due to external and internal factors such as food, climatic conditions, competitors, habitat, vital enemies, access to food resources, the ability of larvae to obtain the resources they need, and the nature of their dispersal (Yasa et al., 2020; Supartha et al. 2021). As indicated by the present results, the presence of caterpillars (larvae), increased food availability, a shorter larval life cycle, and displacement from one plant to another contributed to leaf damage and dispersal (Bakry and Abdel-Baky (2023 a)). Since the larvae may have reached the adult stage and left the damaged plants, this finding is likely due to the short duration of larval growth relative to the duration of the vegetative stage of maize (Caniço et al., 2020).

The reason for the increase in the number of damaged plants is the voracious feeding behavior of larvae caused by the use of ineffective insecticides or control at the age of larvae, as well as the availability of overlapping maize crops throughout the growing season, which is a major cause of the increased population density of larvae (Caniço et al., 2020; Supartha et al., 2021). Therefore, the percentage of plants damaged by *S. frugiperda* increased with increasing time of inspection of maize plants during the two seasons.

This indicates that during the two growing seasons, significant damage to corn plants during the flowering and reproductive seasons progressively increased the number of plants damaged by the pest. According to Gross Junior et al. (1982), the susceptibility of

different growth stages of maize to infestation by *S. frugiperda* varied depending on the growth and progress of the plant. The larvae of *S. frugiperda* usually feed on a large leaf mass during the vegetative growth stages of maize, which indirectly reduces the area of photosynthetic leaves and decreases yield.

Our study shows that plant development time (in days) played a role in the extent of infestation and damage observed in each season. At 6 days after planting, an increase in the number of *S. frugiperda* larvae, the number of plants infested by larvae, the degree of infestation, and the intensity of damage caused by larvae was observed in both seasons. Infestation and damage were lowest in 16 DACs in both seasons. The results are consistent with Murúa et al. (2009), who found that the number of *S. frugiperda* larvae correlated with the age of the maize and its growth.

Although damaged plants (leaf damage) occurred weekly in both seasons, the percentage of plants damaged by *S. frugiperda* increased with increasing date of inspection of maize plants in both seasons

As for the relationship between the changes in a particular preferred variable and the differences in the independent factors, the calculations of the simple correlation and regression coefficients showed highly significant positive relationships in all the variables studied. Caniço et al. (2020) reported that the relationship between the number of damaged plants and larval abundance during the different control dates was significant.

CONCLUSIONS

The infestation and damage of maize plants by *S. frugiperda* started at the age of 16 days after sowing until the time of harvest, i.e. *S. frugiperda* larvae were detected on maize plants during the period from the third week of June until the maize harvest. In terms of number of larvae, number of plants infested with larvae, percentage of infestation, and percentage of damage intensity, three peaks were recorded in each season, occurring at 30, 58, and 86 days after sowing in 2021 and 2022, respectively. Our study exhibits that the number of damaged plants was higher than the number of infected plants throughout the season. Thus, the percentage of plants damaged by *S. frugiperda* increased as the timing of corn plant inspections increased throughout the two seasons. These informations may help farmers and decision-makers to develop effective strategies to control this pest.

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