وزارة الزراعة واستصلاح الأراضي
Ministry of Agriculture and Land Reclamation
مركز البحوث الزراعية
Agricultural Research Center

Egyptian Journal of Plant Protection Research Institute

www.ejppri.eg.net

PLANT PROTECTION RESEARCH INSTITUTE
PPRI

Influence of different maize planting dates on *Spodoptera frugiperda* (Lepidoptera: Noctuidae) and yield losses

Kandil, R.S. and Abd El Kader, M.A.

Plant Protection Research Institute, Agricultural Research Center, Dokki, Giza, Egypt.

ARTICLE INFO

Article History

Received: 8/7 /2023

Accepted:20 /9/2023

Keywords

Fall armyworm, population fluctuation, *Zea mays* and grain yield.

Abstract

Two field experiments were conducted in Nubaria region, Behaira Governorate, Egypt, to investigate the influence of planting dates of maize crop on *S. frugiperda* infestation and assess both final yield and yield qualitative losses in 2022 and 2023 seasons. Results showed that *S. frugiperda* population increased with increasing the plant age and a highly significant *S. frugiperda* infestation reduces maize yields and causes yield quantitative losses. The three different planting dates (mid-April, mid-May, and mid-June) influenced the population of *S. frugiperda* throughout the two seasons. The mid-April plantation date achieved the lowest *S. frugiperda* population than the mid-May and mid-June plantation dates. The mid-June plantation achieved the annual highest average number with 15.97 and 18.89 larvae/25 plants, followed by the mid-May plantation with 11.75 and 15.36 larvae/25 plants in the first and second seasons, respectively with significant variations. However, in both seasons, the mid-April planting produced the annual least average numbers of 10.86 and 12.83 larvae/25 plants, respectively, in both seasons. The effects of maximum and minimum temperature and relative humidity differed from factor to factor and season to season. The mid-April plantation produced the highest yields 2.809 and 2.721 tons/fed with the lowest quantitative loss of 65.12 and 67.58%, followed by the mid-May plantation with yields of 2.797 and 2.548 tons/fed and quantitative loss of 65.12 and 67.58%, with significant differences in the first and second seasons, respectively. In addition, mid-June plantation gave yields of 2.511 and 2.469 tons/fed with the lowest quantitative losses of 80.41 and 81.85%.

Introduction

Fall armyworm (FAW), *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae), was discovered for the first time in Egypt in May 2019 in Aswan Governorate, Upper Egypt (Dahi *et al.*, 2020 and Mohamed *et al.*, 2022). It is a major insect pest that attacks maize and other crops all over the world (Casmuz et *al.*, 2010; Rwomushana, 2019 and Montezano *et al.*, 2018). Its larvae eat the epidermis from the underside of the leaves in the early stages causing direct damage by feeding on both vegetative and reproductive parts (Makgoba *et al.*, 2021). Polyphagous insects feed on a variety of plant species, however, they may prefer or perform better on a single host plant or a small number of plant species (Clark *et al*., 2007). Because maize plant age significantly influences the development and damage of FAW, the plant age of maize can be used to predict infestation levels and explain why damage rates are affected as maize plant development changes (Williams and Dixon, 2007).

S. frugiperda recorded the highest population on yellow maize hybrid 368 in mid-June plantation and recorded the lowest population in mid-May (Olyme *et al.*, 2022). It causes high economic yield losses ranging from 20 up to 100% in the world (Hardke *et al.*, 2015 and Mallapur *et al.*, 2018) and under natural infestation without control methods, it can cause yield losses on maize crop from 20-53% (Baudron *et al.*, 2019 and De Groote, 2020). In Egypt, it causes damage to maize crop by about 78.89% so, the maize farmers should spray trinary spray sequence to control this insect and reduce the yield losses (Kandil *et al.*, 2023).

This study aimed to investigate the effect of planting dates of maize crop on *S. frugiperda* infestation, and to estimate maize yield and quantitative yield losses throughout the seasons of 2022 and 2023.

Materials and methods

Two field experiments were conducted in Saad Zaghloul village, West Nubaria, Behaira Governorate, Egypt during the 2022 and 2023 seasons to study the effect of *S. frugiperda* larvae on yellow maize hybrid 368 and to estimate maize yield and quantitative yield losses% under three planting dates, i.e., 15th April, 15th May, and 15th June. The experiment was divided into two equal parts, the first under natural infestation (Without spraying insecticides) and the second sprayed with quaternary sequences to prevent the infestation as following: methomyl (Goldben 90%® SP) at a rate of 300 g/feddan 15 days after planting, emamectin benzoate (Speedo 5.7%® WG) at a rate of 80 g/feddan 25 days after planting, methomyl at a rate of 300 g/feddan 35 days after planting and emamectin benzoate (Speedo 5.7%® WG) at a rate of 80 g/feddan 45 days after planting. The Randomized Complete Block Design with three replicates was used. The plot area was 80 m^2 (8 ×10 m), each plot consisted of 13 rows of 60 cm width, and seeding was done in the hills with 30 cm spacing between hills. In both seasons, all agricultural normal operations were carried out in accordance with the Egyptian Ministry of Agriculture's recommendations. Average of climate data in Nubaria region, Alexandria at Latitude 30:90, longitude 29:96 and elevation 3.4 during 2022 and 2023 seasons are shown in Table (1).

Table (1): Average weekly of climate data in Nubaria region, Alexandria at Latitude 30:90, longitude 29:96 and elevation 3.4 during 2022 and 2023 seasons.

Weekly inspection		1st season			2nd season		
		Temperature (°C)		Relative humidity (%)	Temperature (°C)		Relative humidity (%)
		Maximum	Minimum		Maximum	Minimum	
May	1st	26.31	16.00	63.96	28.33	15.85	56.99
	2nd	28.31	16.64	61.21	28.41	16.42	64.37
	3rd	29.35	17.27	59.20	29.53	17.57	60.80
	4th	33.27	18.78	60.66	31.44	19.24	56.33
June	1st	32.07	20.33	64.71	32.28	19.87	58.95
	2nd	34.11	21.96	55.80	31.69	20.51	65.24
	3rd	31.73	21.02	63.95	31.76	21.12	63.05
	4th	33.04	22.20	62.67	33.37	21.79	62.94
July	1st	33.50	22.21	62.86	33.69	22.86	64.29
	2nd	32.32	22.41	61.16	34.73	23.02	61.70
	3rd	34.54	23.17	61.40	37.28	23.84	62.55
	4th	35.64	22.75	60.34	36.81	24.96	59.30
August	1st	33.96	23.36	62.00	37.08	24.37	53.53
	2nd	34.07	23.95	61.40	32.94	24.42	61.83
	3rd	34.79	23.91	63.72	33.56	24.13	61.72
	4th	35.10	24.37	59.27	35.62	24.67	63.92
September	1st	33.14	24.04	64.52	35.65	24.72	54.78
	2nd	33.28	23.10	61.64	34.46	25.46	56.36
	3rd	32.20	22.09	59.58	32.70	23.24	62.88
	4th	35.65	22.91	56.63	35.22	22.92	63.41

1. Data recorded:

1.1. Mean number of *Spodoptera frugiperda* larvae/25 plants:

From the third week of planting date, twenty-five labeled maize plants were randomly selected weekly from each plot to estimate the number of *S. frugiperda* larvae per 25 maize plants, and the monthly and seasonal means were calculated.

1.2. Maize grain yield (Ton/Fadden):

At the end of the season, the maize grain yield of 25 plants was weighted at random, and the maize grain yield (Ton/Fadden) was calculated.

1.3. Yield losses and quantitative losses %

Losses in maize grain yield and percentage of quantitative losses were calculated using the following equations: (Savary and Willocquet, 2014 and Nutter *et al.*, 1993)

Yield losses (ton/feddan) = Treated yield – Untreated yield

Quantitative losses (%) = (Yield losses / Treated yield) × 100.

2. Statistical analysis:

Data were subjected to analysis of variance (ANOVA) using the ″F″ Test, and to compare means, the least significant differences (L.S.D) at the 0.05 level were determined using a computer program (Costat software, 1988).

Results and discussion

1. Population fluctuation of *Spodoptera frugiperda:*

Results listed in Tables (2 and 3) and Figures (1 and 2) show the weekly, monthly, and annual average numbers of *S. frugiperda* larvae/ 25 plants in the three planting dates during seasons (2022 and 2023). *S. frugiperda* larvae were gradually increased by increasing the plant age, so the average number of *S. frugiperda* larvae was highest in the final season.

During the first season of 2022, the highest population was noticed on the fourth week of July in the mid-April plantation and the fourth week of August in the mid-May plantation with numbers 20.67 and 17.67 larvae/ 25, respectively. In the mid-June plantation, the highest peak was recorded in the first week of September with 20.67 larvae/ 25 plants. At the same time, the annual average number of *S frugiperda* was highest in mid-June followed by mid-May and mid-April with values, of 15.97, 11.75, and 10.86 larvae/25 plants (Table, 2 and Figure, 1).

During the second season of 2023, the highest population was noticed on the fourth week of June in the mid-April plantation and the fourth week of August in mid-May plantation with numbers 15.33 and 14.67 19.00 and 17.67 larvae/ 25, respectively. In mid-June plantation, the highest peak was recorded in the first week of September with 21.67 and 20.67 larvae/ 25 plants. At the same time, the annual average number of *S. frugiperda* was highest in Mid-June followed by Mid-May and Mid-April with values of 18.89, 15.36 and 12.83 larvae/25 plants (Table, 3 and Figure, 2).

Generally, *S. frugiperda* infestation increased in late plantation of Mid-June followed by mid-May and mid-April on yellow maize hybrid 368 during the 2022 and 2023 seasons.

These findings could be attributed to the effect of temperature on the insect population of *S. frugiperda*. The findings agree with those of Abd Elmageed *et al.* (2022), who found that early May planting gave the lowest *S. frugiperda* population, and Olyme *et al.* (2022), who noticed that planting dates affected *S. frugiperda* population and mid-May planting produced a lower infestation rate on yellow maize hybrid 368 than early June and mid-June during the 2022 and 2022 seasons. The plant age of maize between 20 and 40 days old was found to have high damage, and the devastating feeding effect became even more severe when the maize plant was exposed to prolonged drought, as agreed (Ayala *et al.*, 2013; Hruska, 2019; Niassy *et al.*, 2021 and Anjorin *et al.*, 2022). From the third week of June until the harvest, the *S. frugiperda* population began to infest maize plants. *S. frugiperda* had three seasonal peaks regarding the larval population numbers/season (Bakry and Abdel-Baky, 2023).

Table (2): Population fluctuation *Spodoptera frugiperda* larvae for three plantation dates on yellow maize hybrid 368 during 2022 season.

Weekly inspection		Number of *Spodoptera frugiperda* larvae/ 25 plants					
		Plantation date					
		Mid-April	Mean	Mid-May	Mean	Mid-June	Mean
May	1st	3.33	6.50		-	-	-
	2nd	5.67		-		-	
	3rd	8.33		-		-	
	4th	8.67		-		-	
June	1st	9.33	11.17	2.67	4.83	-	-
	2nd	10.33		3.33		-	
	3rd	11.67		5.33		-	
	4th	13.33		8.00		-	
July	1st	12.33	14.92	10.67	12.33	6.33	11.17
	2nd	14.33		11.67		10.33	
	3rd	15.33		13.00		13.00	
	4th	17.67		14.00		15.00	
August	1st	-	-	15.67	18.08	16.00	18.08
	2nd	-		17.33		17.33	
	3rd	-		18.67		19.00	
	4th	-		20.67		20.00	
September	1st	-	-	-	-	20.67	18.67
	2nd	-		-		18.33	
	3rd	-		-		19.33	
	4th	-		-		16.33	
General mean/25 plants		10.86		11.75		15.97	
LSD0.05		2.24					

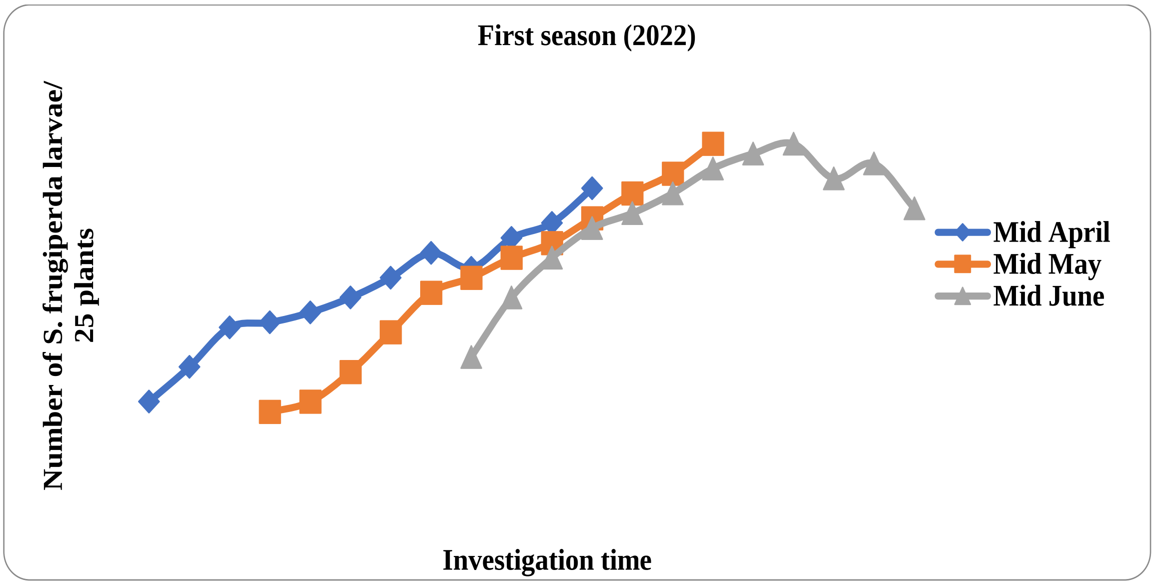

Figure (1): Population fluctuation of *Spodoptera frugiperda* larvae for three plantation dates on yellow maize hybrid 368 during 2022 season.

Table (3): Population fluctuation *Spodoptera frugiperda* larvae for three plantation dates on yellow maize hybrid 368 during 2023 season.

Weekly inspection		Number of *Spodoptera frugiperda* larvae/ 25 plants					
		Plantation date					
		Mid-April	Mean	Mid-May	Mean	Mid-June	Mean
May	1st	4.33	6.50				
	2nd	5.67		-		-	
	3rd	7.00		-		-	
	4th	9.00		-		-	
June	1st	11.33	13.75	5.67	10.67	-	
	2nd	13.33		9.00		-	
	3rd	15.00		12.00		-	
	4th	15.33		16.00		-	
July	1st	15.67	18.25	17.00	17.67	7.33	14.17
	2nd	17.67		17.33		14.67	
	3rd	18.67		17.33		15.33	
	4th	21.00		19.00		19.33	
August	1st	-		19.33	17.75	20.00	20.50
	2nd	-		18.67		21.00	
	3rd	-		18.33		20.67	
	4th	-		14.67		20.33	
September	1st	-		-		21.67	22.00
	2nd	-		-		21.33	
	3rd	-		-		22.67	
	4th	-		-		22.33	
General mean/25 plants		12.83		15.36		18.89	
LSD 0.05		2.25					

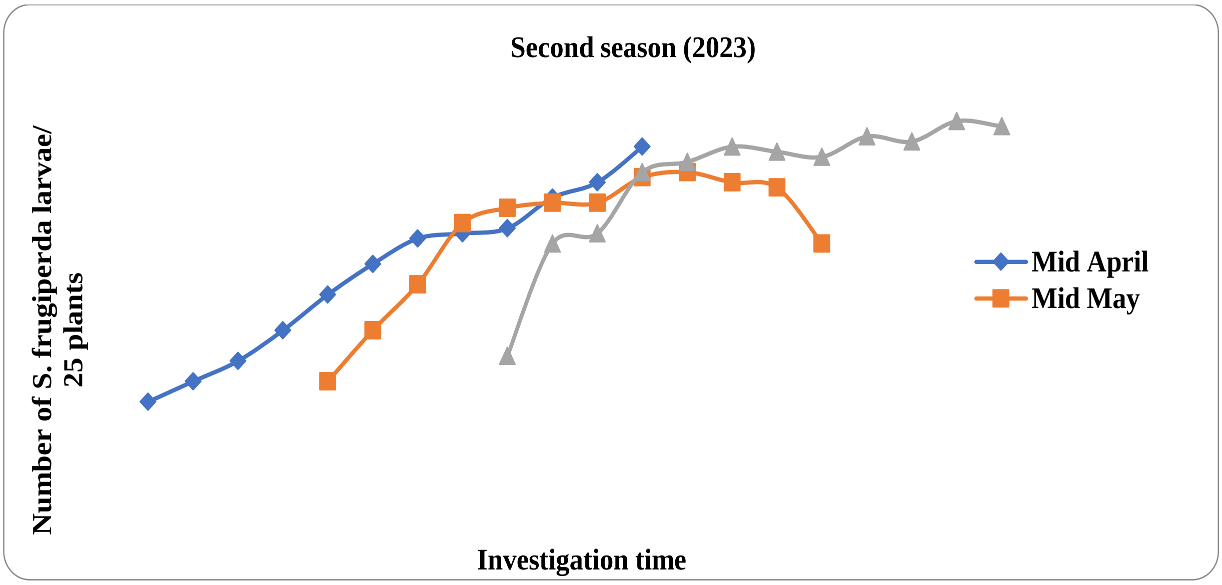

Figure (2): Population fluctuation of *Spodoptera frugiperda* larvae for three plantation dates on yellow maize hybrid 368 during 2023 season.

2. Climatic factors and *Spodoptera frugiperda* population:

The data in Table (4) demonstrated the simultaneous effect of the three selected weather factors maximum and minimum temperature and percentage of relative humidity on *S. frugiperda* population on yellow maize hybrid 368 during the 2022 and 2023 seasons in mid-April, mid-May, and mid-June. The relationship between maximum and minimum temperatures showed a significant positive effect on this insect except for maximum temperature in mid-June in the second season. Relative humidity had insignificant negative correlation effects, on the insect population except mid-April had significant positive correlation effects in the second season.

The results agree with those of Plessis *et al.* (2020), who noticed that the development rate of *S. frugiperda* increased linearly with increasing temperatures between 18 and 30 °C, with the highest larval survival occurring between 26 and 30 °C. The optimal temperature range for egg, larval, and egg-to-adult development was 26 to 30 °C. According to Sabra *et al.* (2022), as temperature rose, all developmental times from eggs to adults declined linearly.

Table (4): Correlation coefficient between *Spodoptera frugiperda* population and planning dates on yellow maize hybrid 368 during 2022 and 2023 seasons.

Planting date	1st season			2nd season		
	Temperature (°C)		Relative humidity (%)	Temperature (°C)		Relative humidity (%)
	Maximum	Minimum		Maximum	Minimum	
Mid-April	**0.86**	**0.92**	**-0.13**	**0.95**	**0.99**	**0.30**
Mid-May	**0.68**	**0.94**	**-0.05**	**0.64**	**0.87**	**-0.24**
Mid-June	**0.12**	**0.63**	**-0.06**	**-0.03**	**0.47**	**-0.34**

3. Maize yield and quantitative loss %:

Results listed in Table (5) showed that the mid-April plantation produced the highest maize grain yields 2.809 and 2.721 tons/fed with the least quantitative loss of 65.12 and 67.58%, followed by mid-May plantations with maize grain yields of 2.797 and 2.548 tons/fed and quantitative loss 77.3 and76.19% 65.12 and 67.58%, in 1st and 2nd seasons, respectively with significant differences. Also, the mid-June plantation gave maize grain yields of 2.511 and 2.469 tons/fed with the least quantitative loss 80.41 and 81.85%. In a comparison with mid-May and mid-June planting, mid-April planting of maize had the best yield and the lowest percentage of yield quantitative loss. The above findings are in agreement with those of Baudron *et al.* (2019) and De Groote (2020), who stated that the fall armyworm with high monthly and annual averages caused harm to the production of maize and can cause yield losses on maize crops from 20-53%. At the same time, Kandil *et al.* (2023) found a negative relationship between the population of *S. frugiperda* larvae and maize grain production. The highest maize yield was obtained by using methomyl and emamectin benzoate in a trinary sequence; 4.249 and 3.416 t/fed in the first and second seasons, respectively but untreated check plots had the biggest quantitative yield losses, with 77.76% and 78.89% in the first and second seasons, respectively.

Table (5.): Maize grain yield, yield loss and percentage of quantitative loss due to *Spodoptera frugiperda* infestation for three plantation dates during 2021 and 2022 seasons.

Plantation date	1st season				2nd season			
	Maize grain yield (t./f.)		Yield loss (t./f.)	Q. loss %	Maize grain yield (t./f.)		Yield loss (t./f.)	Q. loss %
	Treated	Untreated			Treated	Untreated		
Mid-April	2.809	0.980	1.829	65.12	2.721	0.882	1.839	67.58
Mid-May	2.797	0.635	2.163	77.31	2.548	0.607	1.941	76.19
Mid-June	2.511	0.492	2.019	80.41	2.469	0.448	2.021	81.85
LSD 0.05	0.021	0.033	0.027	1.053	0.031	0.027	0.050	1.201

Q. =Quantitative (t./f.) = (Ton / feddan)

As a result of the present findings, a highly significant *S. frugiperda* infestation reduces maize yields and causes yield quantitative losses %. The early plantation in mid-April gave the best maize yield and the lowest yield quantitative losses %, followed by mid-May and mid-June plantations with significant differences. So, the farmers should control *S. frugiperda* insect with spraying sequence recommendations pesticides to get the maximum maize grain yield and lowest quantitative yield losses %.

References

Abd Elmageed, A.E.; Soliman, M.H.A.; Afifi, H.A. and Ayad, E.L. (2022): Impact of Seedling deadlines and some insecticides against *Spodoptera frugiperda* (Smith) infesting maize at Qalyobia Governorate, Egypt. Egyptian Academic Journal of Biological Sciences, F. Toxicology & Pest Control, 14(1): 109-116. https://journals.ekb.eg/article_232273_f0c173855c01c3b55be57be8b77e8949.

Anjorin, F.B.; Odeyemi, O.O.; Akinbode, O.A. and Kareem, K.T. (2022): Fall armyworm (*Spodoptera frugiperda*) (J. E. Smith) (Lepidoptera: Noctuidae) infestation: maize yield depression and physiological basis of tolerance. Journal of Plant Protection Research, 62(1): 12–21. https://doi.org/10.24425/jppr.2022.140294.

Ayala O.R.; Navarro, F.R. and Virla, E.G. (2013): Evaluation of the attack rates and level of damages by the fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae), affecting corn-crops in the northeast of Argentina. Revista de la Facultad de Ciencias Agrarias. Universidad Nacional de Cuyo, 45(2): 1-12. https://www.redalyc.org/pdf/3828/382837655027.

Bakry, M.M.S. and Abdel-Baky, N.F. (2023): Population density of the fall armyworm, *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae) and its response to some ecological phenomena in maize crop. Brazilian Journal of Biology, 83: e271354. https://doi.org/10.1590/1519-6984.271354

Baudron, F.; Abdou Zaman-Allah, M.; Chaipa, I. and Chari, N. and Chinwada, P. (2019): Understanding the factors influencing fall armyworm (*Spodoptera frugiperda* J.E. Smith) damage in African smallholder maize fields and quantifying its impact on yield. A case study in Eastern Zimbabwe. Crop Protection,120:141-150.

Casmuz, A.S..; Juarez, L.; Socias, M.G.; Murúa, M.G.; Prieto, S. and Medina, S. (2010): Revisión de los hospederos del gusano cogollero del maíz, *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Rev. Soc. Entomol. Argent, 69: 209–231. https://www.researchgate.net/publication/262658952_Revision_de_los_hospederos_del_gusano_cogollero_del_maiz_Spodoptera_frugiperda_Lepidoptera_Noctuidae

Clark, P.L.; Molina-Ochoa, J.; Martinelli, S.; Skoda, S.R.; Isenhour, D.J.; Lee, D.J.; Krumm, J.T. and Foster, J.E. (2007): Population variation of the fall armyworm *Spodoptera frugiperda* in the Western Hemisphere. Journal of Insect Science, 7(1): 1-10. https://doi.org/10.1673/031.007.0501.

Costat software (1988): Microcomputer Program Analysis. Co-Hort Software, Berkely, CA, USA.

Dahi, H.F.; Salem, S.A.R.; Gamil, W.E. and Mohamed, H.O. (2020): Heat Requirements for the fall armyworm *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) as a New Invasive Pest in Egypt. Egypt. Acad. J. Biolog. Sci., 13(4): 73-85. https://doi.org/10.21608/eajbsa.2020.120603.

De Groote, H.; Kimenju, S.C.; Munyua, B.; Palmas, S.; Kassie, M. and Bruce, A. (2020): Spread and impact of fall armyworm (*Spodoptera frugiperda* J.E. Smith) in maize production areas of Kenya. Agriculture, Eecosystems & Eenvironment, 292,106804. https://www.sciencedirect.com/science/article/pii/S0167880919304219.

Hardke, J T.; Lorenz, G.M. and Leonard, B. R. (2015): Fall Armyworm (Lepidoptera: Noctuidae) Ecology in Southeastern Cotton. Journal of Integrated Pest Management, 6(1): 10. https://doi.org/10.1093/jipm/pmv009.

Hruska, A. (2019): Fall armyworm (Spodoptera frugiperda) management by smallholders.CAB Reviews, 14(043): 1-11. https://www.researchgate.net/publication/335834915_Fall_armyworm_Spodoptera_frugiperda_management_by_smallholders.

Kandil, R.S.; Mansour, M.R.K.; Abdelrahem, F.M. and Dabour, N.A. (2023): Impact of fall armyworm *Spodoptera frugiperda* on maize yield and economic assessment of losses under different insecticidal sequences. Env. Biodiv. Soil Security, 7: 133 – 140. https://jenvbs.journals.ekb.eg/article_302708.

Makgoba, M.C.; Tshikhudo, P.P. and Makhado R.A. (2021): Impact of fall armyworm (*Spodoptera frugiperda*) (J.E. Smith) on small-scale maize farmers and its control strategies in the Limpopo province, South Africa. Jamba, 13(1): 1016. https://doi.org/10.4102%2Fjamba.v13i1.1016.

Mallapur, C.P.; Naik, A.K.; Hagari, S.; Prabhu, S.T. and Patil, R.K. (2018): Status of alien pest fall armyworm, *Spodoptera frugiperda* (J E Smith) on maize in Northern Karnataka. J. Entomol. Zool. Stud., 6(6): 432-436. https://www.entomoljournal.com/archives/2018/vol6issue6/PartH/6-5-295-112.

Mohamed, H.O.; El-Heneidy, A.H.; Dahi H.F. and Awad A.A. (2022): First record of the fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) on sorghum plants, a new invasive pest in Upper Egypt. Egyp t. Acad. J. Biolog. Sci., 15(1): 15-23. https://doi.org/10.21608/eajbsa.2022.214719.

Montezano, D.G.; Specht, A.; Sosa-Gómez, A.; RoqueSpecht, D.R.; Sousa-Silva, V.F.; Paula-Moraes, J.C.; Peterson, S.V. and Hunt, T.E. (2018): Host plants of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in the Americas. African Entomology, 26: 286–300. https://bioone.org/journals/African-Entomology/volume-26/issue-2/003.026.0286/Host-Plants-of-Spodoptera-frugiperda-Lepidoptera--Noctuidae-in-the/10.4001/003.026.0286.short.

Niassy, S.; Agbodzavu, M.K.; Kimathi, E.; Mutune, B.; Abdel-Rahman, E.F.M. and Salifu, D. and *et al.* (2021); Bioecology of fall armyworm Spodoptera frugiperda (J. E. Smith), its management and potential patterns of seasonal spread in Africa. PLoS ONE, 16(6): e0249042. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0249042.

Nutter, F.W.; Teng, P.P.S. and Royer, M.H. (1993): Terms and concepts for yield, crop loss, and disease thresholds. Plant disease, 77:211–215. https://www.researchgate.net/publication/284239679.

Olyme, M.F.; Samy; M.A.; Kassem, S.A. and Fetoh B.A. (2022): Effect of maize planting dates and maize hybrids on the fall armyworm *Spodoptera frugiperda* populations. J. of Plant Protection and Pathology, Mansoura Univ., 13(12): 289 -293. https://jppp.journals.ekb.eg/article_273966_f711cc66680de72f9c68434905c22168.pdf

Plessis, H.D. ; Schlemmer, M. and Berg, J.V. (2020): The Effect of temperature on the development of *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Insects, 11(228): 1-11. DOI:10.3390/insects11040228.

Rwomushana, I. (2019): *Spodoptera frugiperda* (fall armyworm). CABI Compendium https://www.cabidigitallibrary.org/doi/10.1079/cabicompendium.29810.

Sabra, I.M.; Kandil, M. A. A. and EL-Shennawy, R.M. (2022): Effect of Temperature on development and life table parameters of fall armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae).. J. of Plant Protection and Pathology, Mansoura Univ., 13 (11):267-271. DOI: 10.21608/JPPP.2022.169253.1107.

Savary, S. and Willocquet L. (2014): Simulation modeling in botanical epidemiology and crop loss analysis. The Plant Health Instructor, pp. 174. https://hal.inrae.fr/hal02636693/document.

Williams, I.S. and Dixon, A.F.G. (2007): Life cycles and polymorphism. In: H.F. VAN EMDEN and R. HARRINGTON, eds. Aphids as crop pests Wallingford: CAB International, pp. 69-85. http://dx.doi.org/10.1079/9780851998190.0069.