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Effect of climate change on Spodoptera frugiperda (J.E. Smith) (Lepidoptera: Noctuidae), the new pest has been detected in Egypt

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Abstract: The fall armyworm (FAW) is of tropical–subtropical origin and defined as one of the most destructive agricultural pests globally, including Egypt. This study aims to effect of temperature factor on the biological cycle and generations of Spodoptera frugiperda under laboratory conditions. The highest mortality occurred when the caterpillars were kept at 32°C in the F2 generation. In general, among the temperatures tested, 24 °C and 28 °C promoted the greatest number of days in incubation. The average duration of insect development in days was inversely proportional to the increase in temperature. Understanding the climate factors are necessary to clarify the possible influences of global climate change, including warming on this species, in addition to evaluating the adaptation of insects over generations.

Keywords: Spodoptera frugiperda; climate change; global worming

1. Introduction

The fall armyworm (FAW), Spodoptera frugiperda (J. E. Smith, 1797), known as an important agricultural pest around the world, including Egypt. It is indigenous to the tropical–subtropical regions in the Western Hemisphere, although its distribution has expanded over large parts of America, Africa, Asia and Oceania in the last few years. Global climate change may significantly impact the geographic distribution of biodiversity, alter biodiversity, and affect interactions between species and ecosystems [1]. Temperature is one of the abiotic factors that exerts great influence on insect biology and this factor can affect the duration of the life cycle, population density, size and genetic composition, the extent of host plant exploitation, as well as local and geographic distribution linked to colonization and extinction [2].

insects are ectotherms, exhibiting a high degree of sensitivity to ambient temperature in their physiological processes. Several pieces of evidence indicate that not only higher temperatures, but also greater climate variability can have a significant effect on organisms and ecosystems [3]. Species present individual responses to temperature, carbon dioxide concentration, and other environmental factors, thus, climate change may affect the temporal and spatial association between species that interact at different trophic levels [4].

Several efforts have reported that temperature directly or indirectly influences the geographic distribution, phenology and natural enemies of the FAW, and thus may affect the damage to crops, e.g., the increased developmental rate accelerates the intake of crops at higher temperatures. Under some extreme temperatures, the FAW is likely to regulate various genes expression in response to environmental changes, which causes a wider viability and possibility of invasion threat. Therefore, this paper seeks to review and critically consider the variations of developmental indicators, the relationships between the FAW and its natural enemies and the temperature tolerance throughout its developmental stage at varying levels of heat/cold stress.

Based on this, the study of adaptation to certain thermal conditions is relevant to discussions about the effect of global warming on the distribution and abundance of ectothermic animals [5]. Climate change can affect herbivorous insects directly, through impacts on their physiology and behavior, or indirectly, where insects respond to climate-induced changes mediated by other factors, such as the host plant [2]. Thus, considering the importance of temperature for insect development and the possible increase in the occurrence of S. frugiperda in soybeans, this study aimed to evaluate the influence of different temperatures on the biological aspects of this insect over four generations.

2. Material and methods

The experiments were carried out in the laboratory of Entomology, Plant Protection Department, Faculty of Agriculture, Sohag University, Egypt. The maize plants offered to the insects were sown in five-liter pots, with five plants per pot putted in a growth room with a 14-hour photoperiod, temperature of 28 °C and relative humidity of 65 %.

Insect biology was performed in a B.O.D. rearing chamber at different temperatures (24°C, 28°C, 32°C and 36°C), throughout the insect biology period, to represent the

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daily oscillation, with humidity of 70 ± 10% and a 14-h photophase. Second-instar S. frugiperda larvae from the mass rearing in the laboratory, reared from hatching on maize leaves and at their respective temperatures, were individualized in paraffin cups with plastic lids. The larvae were evaluated daily, observing mortality and development time of each stage. The food was replaced daily.

After reaching the pupal stage, these were separated by sex and, immediately after emergence, the adults were placed in individual cages made of PVC tubes, 20 cm high by 10 cm in diameter [6]. For oviposition and egg collection, the cage was lined internally with A4 paper, which was removed whenever egg laying was observed. The individualized couples were kept at the same temperature to ensure continuity of generations. The cages with the adult couples were observed daily, replacing the food and recording mortality in each replicate.

For the biology of the insects, considering the larval stage to the pupal stage, and for the evaluation of adult longevity, a completely randomized design with 60 replicates was used. The response variables considered in this study were: caterpillar mortality (%) and development time (days).

Statistical analysis

Mortality and development time were analyzed using analysis of variance (ANOVA) with Tukey mean tests at a 5% probability level using the SAS-Statistical Analysis System, version 9.2 (2009) statistical program [7].

3. Results and discussions

Under the conditions of global climate change, including warming, the distribution range of S. frugiperda is expected to significantly increase [8-9]. In general, the different temperatures affected the biological aspects of S. frugiperda. The analysis of variance (ANOVA) (p>0.05) indicated differences in the percentage of mortality according to the treatments (Table 1). The highest mortality occurred when the caterpillars were kept at 32°C in the F2 generation.

At this same temperature, when the generations were compared, an increase in mortality was observed. In the F0 generation, significant difference was observed in mortality in insects kept at the different temperatures adopted. At a temperature of 24°C, the highest mortality was also observed in the F1 and F2 generation.

Table 2 shows the incubation and development period of insects at different temperatures, from the egg to hatching, which did not present variability between the data for the application of the average test. In general, among the temperatures tested, 24 °C and 28 °C promoted the greatest number of days in incubation.

The larval development time of the insects were influenced by the temperatures (Table 2). The average duration of insect development in days was inversely proportional to the increase in temperature, with the longest duration observed at 24°C and the shortest duration at 36°C (F0). This fact was also observed in the F1, F2 and F3 generations at temperatures of 24°C and 33°C. At a temperature of 33°C, a difference was observed between the generations, with the longest development time in the F0 generation. Ali et al. [10] reported the development rate of larvae at temperatures ranging between 21 and 33 oC to increase linearly and, therefore, regarded the temperature range between 21 and 33 °C to be suitable for S. frugiperda development.

In the pupal stage, the average duration, in days, within the F0 and F1 generations was longer at the temperature of 24°C, with no difference in the F2 and F3 generations at the temperatures of 25°C, 28°C and 32°C. Within the temperatures of 24°C, 28°C and 32°C in (F0) a greater number of days in the pupal stage, with no significant difference, was observed when compared to the other generations. The S. frugiperda pupal development time 8.25 days (32 oC), which is in a similar range (6.6 days at 32 oC) to that reported by Busato et al. [11]. Under future climate scenarios, it is observed a reduction in the time to complete the life cycle, as representative scenarios become stronger relative to reference period [12].

Table 1: Percentage of mortality (±S.E.) of Spodoptera frugiperda reared on maize leaves subjected to different temperatures, for four generations, there were no survivors.

Generation	**Temperature**				**F value**	***P* value**	**L.S.D**
	24 ºC	**28 ºC**	**32 ºC**	**36 ºC**			
F0	20.91±0.32	16.38±0.05	24.14±0.29	29.29±0.02	603.25	<.0001	1.0026
F1	31.63±0.61	26.45±0.28	32.13±0.40	-	48.87	0.0002	1.954
F2	31.46±0.02	28.18±0.64	50.79±1.28	-	219.55	<.0001	3.578
F3	28.26±0.91	24.90±0.57	43.49±1.14	-	119.67	<.0001	3.9298
F value	64.84	410.01	175.84				
***P* value**	<.0001	<.0001	<.0001				
L.S.D	2.8204	1.1865	4.04				

Table 2.: The mean development time (days ±S.E.) of different life stages of Spodoptera frugiperda subjected to different temperatures, for four generations The different among averages in a row or column by the Tukey test at a 5% probability level, there were no survivors.

Generation	**Temperature**				**F value**	***P* value**	**L.S.D**
	24 ºC	**28 ºC**	**32 ºC**	**36 ºC**			
Egg							
F0	2.33±0.33	2.00±0	1.67± 0.33	1.33±0.33	2.22	0.16	1.3074
F1	2.33±0.33	2.00±0	1.67±0.33	-	1.50	0.30	1.1809
F2	2.67±0.33	2.00±0	1.67±0.33	-	3.50	0.1	1.1809
F3	3.00±0.58	2.67±0.33	2.00±0.58	-	1.00	0.42	2.2093
F value	0.61	4.00	0.17				
***P* value**	0.6265	0.0519	0.9159				
L.S.D	1.8489	0.7548	1.8489				
Larva							
F0	20.22±0.45	18.67±0.66	16.19±0.48	12.71±0.27	45.48	<.0001	2.1992
F1	18.63±0.31	16.46±0.12	12.88±0.35	-	107.72	<.0001	1.2154
F2	17.47±0.22	15.26±0.27	14.97±0	-	45.81	0.0002	0.8748
F3	19.73±0.17	16.33±0.31	14.99±0.53	-	43.87	0.0003	1.6005
F value	16.21	13.00	11.90				
***P* value**	0.0009	0.002	0.003				
L.S.D	1.3779	1.7946	1.8058				
Pupa							
F0	9.25±0.12	8.26±0.20	8.25±0.11	7.48±0.08	27.91	0.0001	0.6218
F1	9.13±0.22	8.14±0.15	8.21±0.21	-	8.22	0.019	0.8392
F2	8.76±0.30	7.99±0.07	8.07±0.07	-	5.45	0.04	0.7836
F3	8.83±0.09	7.76±0.22	7.96±0.25	-	8.06	0.02	0.8723
F value	1.39	1.57	0.57				
***P* value**	0.3144	0.2711	0.6511				
L.S.D	0.9017	0.7749	0.7989				

4. Conclusion

The fall armyworm is an important agricultural pest of various crops; therefore, areliable method is needed to predict its occurrence in the field. Temperature-dependent development and thermal biology parameters are commonly used methods for simulating insect phenology. Considering the results obtained, it can be suggested that changes in temperature may cause negative effects on populations of S. frugiperda, which may reduce its incidence in the field. However, additional studies on the temperature-insect/plant interaction are necessary to clarify the possible influences of global climate change, including warming on this species, in addition to evaluating the adaptation of insects over generations.

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