Impact of Climatic Changes in Egypt on Degree Day's Units and Generation Number for Tomato Leaf miner Moth *Tuta absoluta*, (Meyrick) (*Lepidoptera gelechiidae*)

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Abstract: The environmental conditions such as temperature and relative humidity are factors are influencing insect physiology and behavior; such as temperature and relative humidity. The aim of this study is predicting degree day's unit and annual generations of the tomato leaf moth Tuta *absoluta* under current and expected future climate by using the relationship between the accumulated thermal heat units expressed as degree-days unit (DDU) and the population fluctuations. Evaluated how temperature influence the annual generation in four governorates in Egypt using the climate change data output from the HadCM3 model for A1 scenario proposed by the Intergovernmental Panel on Climate Change. The obtained results indicate that population of the *Tuta absoluta* in Qena governorate gave the highest number of generation as compared to other locations (EL Beheira, Giza and Fayoum governorates) under current climate. Generation numbers of *T. absoluta* under climate change conditions increased especially in Qena governorates. However, the expected generation numbers of the pest at 2050 and 2100 are be 12-14 and 13-15 generations per year, respectively.
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1. Introduction:

Temperature has a direct influence on insect activity and rate of development. According to Zalom and Wilson (1982) the rate of development is based on the accumulation of heat measured in physiological rather than chronological time. Chiang (1985) denominated "optimal range" to the temperature going from the lower to the upper threshold, where the development is directly proportional to temperature. Outside these limits, activity decreases to almost a standstill without necessarily causing death. The thermal unit provides a valuable tool for insect pest control; in forecasting infestations monitoring and timing of insecticide applications (Zalom *et al.*, 1983). From the practical aspect, accumulated thermal units have been used to predict the seasonal development and emergence of various insects (Sevacherian *et al.*, 1977 and Farag *et al.*, 2009). The assessment report from the Intergovernmental Panel on Climate Change (IPCC) predicts an increment in mean temperature from 1.1 to 5.4 ^{o}C toward the year 2100 (Meehl *et al.* 2007). An increment of this magnitude is expected to affect global agriculture significantly (Cannon, 1998). In addition, such changes in climatic conditions could profoundly affect the population dynamics and the status of insect pests of crops (Woiwod, 1997). These effects could either be direct, through the influence that weather may have on the insects physiology and behavior (Parmesan 2007 and Merrill *et al.* 2008), or may be mediated by host plants, competitors or natural enemies (Bale *et al.* 2002).

T. absoluta (Meyrick) (*Lepidoptera Gelechiidae*) is a devastating pest of tomato (*Lycopersicon esculentum*). It is originated from South America. Recently ,this leaf miner is considered to be a serious threat to tomato production in the Mediterranean region, The newly introduced pest might find the climate at the shores of the Mediterranean a perfect new home where it can breed 10-12 generations a year. *T. absoluta* is a very challenging pest to control. The main host of *T. absoluta* is tomato, but also reported on potato (*Solanum tuberosum*), Aubergine (*S. melongena*) and several Solanaceae weeds (*e.g. S. nigrum* or black nightshade) and Datura stramonium) (EPPO, 2005 and Pereyra and Sanche, 2006). Its larvae mine in the leaves producing large galleries and burrow into the fruits, causing a substantial losses of tomato production in protected and open field cultivations.

The objective of the present study to predict *T. absoluta* annual generation peaks under current and expected future climate changeic by using the relationship between the accumulated thermal heat units expressed as degree-days (DD's) and the population fluctuations of it at four governorates in Egypt, namely Qena, Fayoum, Giza and El-Beheira.

2. Materials and Methods

1- Experimental area :

The study was conducted in four Egyptian governorates, (El-Behaira, Giza, Fayoum, and Qena), depending on different climate regions and highest tomato yield in comparison with the other governorates (Agriculture statistics 2008.

2- Estimation of degree-days units :

2-1- Under current climate temperature:

For estimating degree day's unit, the daily temperature records were obtained from Central Laboratory for Agriculture Climate (CLAC) during the period from 2004 to 2008 for the four experimental locations (El-Behaira, Giza, Fayoum, and Qena) and the average were calculated to compared with future climate (2050 and 2100).

2-2- Under future climate data (2050 and 2100):

Climate change scenarios for the four experimental locations were assessed according to forecasting conditions derived from MAGICC/SCENGEN software of the University of East Angle (UK). In this study one scenario of climate data was used A1. The principal of MAGICC/SCENGEN allows the user to explore the consequences of a medium range of future emissions scenarios. The user selects two scenarios from library of possibilities. The reason for two scenarios is, to be able to compare a no action scenario with an action or policy scenario. Thus, in MAGICC/SCENGEN the two emissions scenarios are referred to as a reference and policy scenarios (Wigley *et al.*, 2000). Data which generated are represented in one scenario A1. These scenarios are described by IPCC 2001 as follows: The A1 scenario describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies.

3- Determination of *Tuta absoluta* thermal units :

Maximum and minimum degrees of temperature were transformed to heat units using the lower threshold temperature (t_0) 8˚C with 460 (DDU) for *T.absoluta* development Barrientos *et al.*, (1998). Degree day's unit calculations were made to estimate the number of possible generations of *T. absoluta* in the field using the following formula:

DDU = (Max. Mean Temp. + Min. Mean Temp.)/2 – Min Development Temp.

For *T. absoluta* the minimum threshold for the a development from egg to adult is 8˚C and 460 DDU (Barrientos et *al.*, 1998).

3. Results and Discussion

1- Current climate:

Under current climate conditions, the mean values of thermal units required for complete development of *T. absoluta* generation were 468 units in each of El-Behaira ,Giza and Fayoum while it was 471 in Qena (Table 1). The numbers generation of *Tuta absoluta* exhibited 11, 12, and 13 at El-Behaira, Giza, Fayoum, and Qena, respectively.

2- Expected future climate :

As shown in (Figs. 1 and 2), under the future climate scenarios, the degree days increase during 2050 and 2100 in comparison with current data for the studied areas (El-Behaira, Giza, Fayoum, and Qena). The highest changes for degree days under climate change were found during summer and autumn period while the winter and spring period gave a slight change seasons in 2050 and 2100 in comparison with current data.

Generation number of *T. absoluta* (Table 2) at El-Behaira is expected to be increased from one generation during 2050 (it will be 11 generations) to two generations during 2100 per year (13 generations) in comparison with current climate (11generations).The first generation longest period under current and future climate (2050 and 2100), being 66, 60 and 50 days, respectively. The number of days during 2050 and 2100 took 6 and 16 days earlier than the current climate, respectively. The sixth generations under current climate took lowest number of days (23 days) in comparison with other generations days and the fifth generations under future climate (2050 and 2100) took the lowest number of days (22 days from the fifth generations to the ninth and 21 days from the sixth to the ninth generations), respectively .

The mean period of generation under current climate lasted longest period, being 33 days in comparison with the expected future climate conditions in 2050 (30 days) and 2100 (28 days) (Table, 2).

Generation number of *T. absoluta* (Table 2) at Giza is expected to be increased from one generation pear year during 2050 (13 generations) to two generations during 2100 (14 generations) in comparison with current climate (12 generations). The first generations took the highest number of days under current and future climate in 2050 and 2100, being 66, 49 and 45 days, respectively. The number of days during 2050 and 2100 took 17 and 21 days earlier than that obtained during the current climate, respectively. The sixth generation under current climate took lowest number of days (21 days) in comparison with the other generation and the seventh and eighth generations 18 and 17 days of future climate 2050 and 2100, respectively. The mean period of generation under current climate took the longest period (30 days) in comparison with future climate in 2050 (25 days) and in 2100 (30 days) (Table, 2).

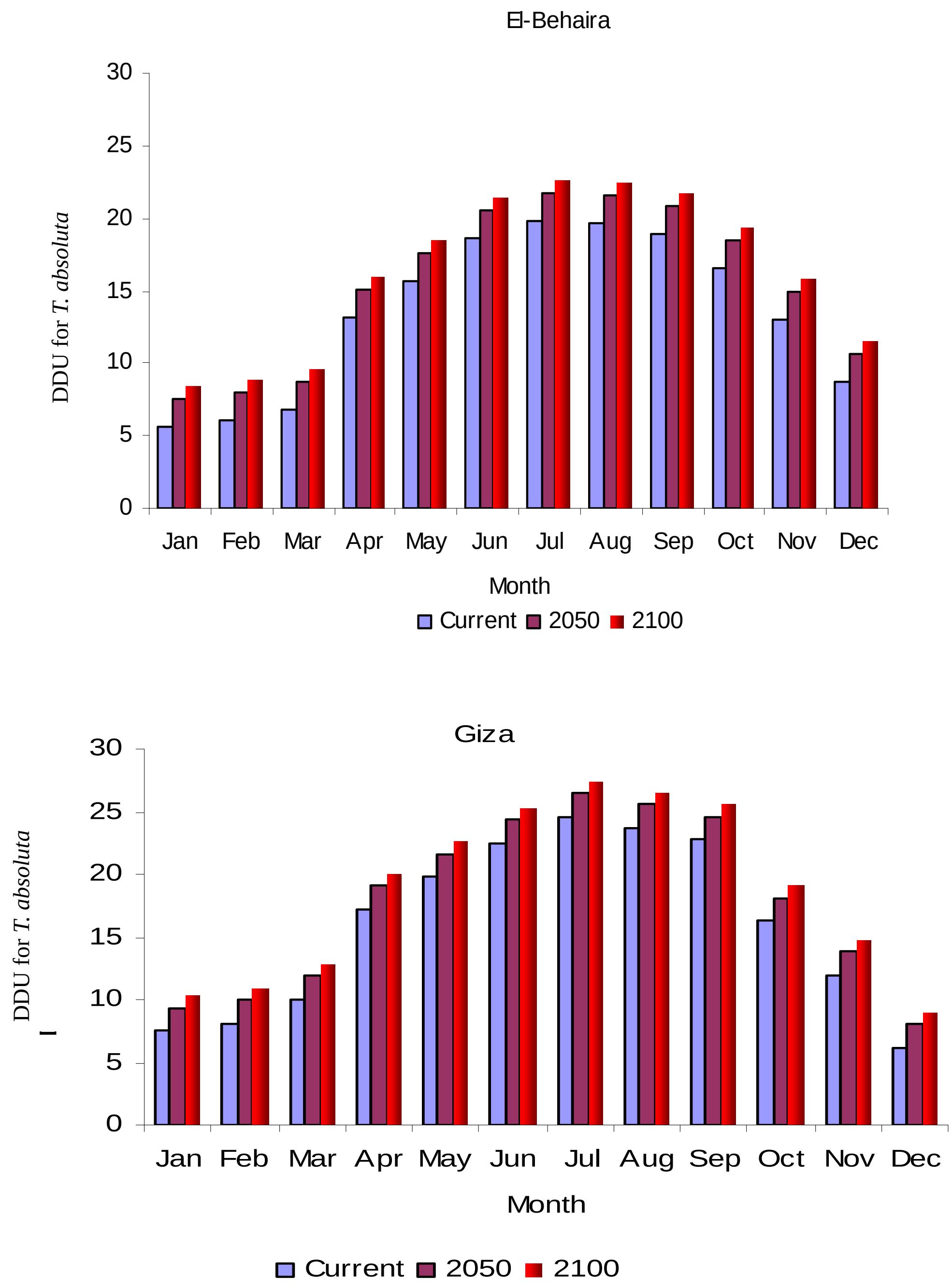
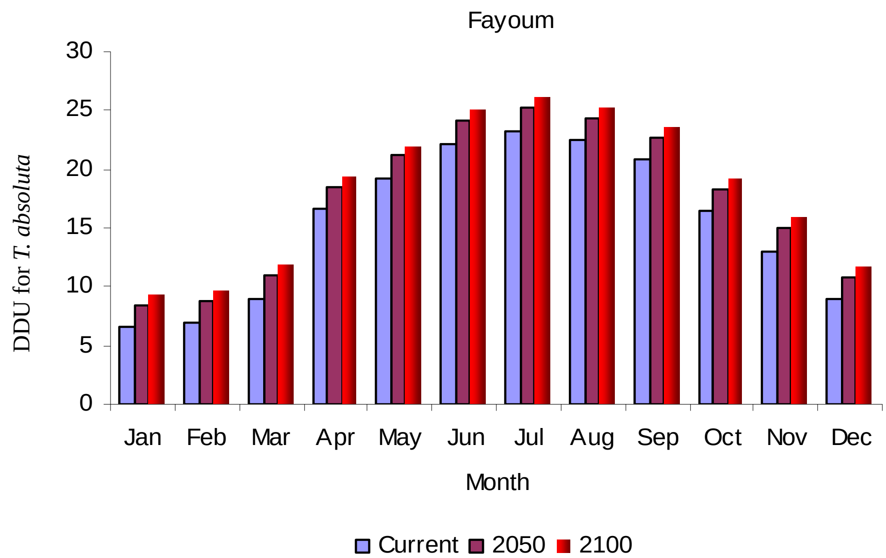


Fig.1: Comparison between degree days of *Tuta absoluta* under current and expected future climate conditions (2050 and 2100) at El-Behaira and Giza region



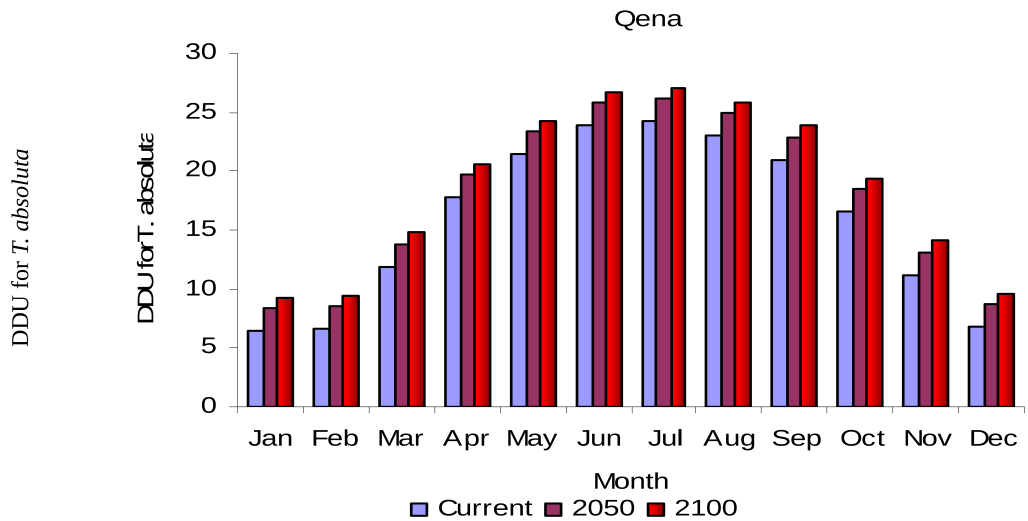


Fig.2: Comparison between degree days of *Tuta absoluta* under current and expected future climate conditions (2050 and 2100) at Fayoum and Qena region.

Generation number of *T. absoluta* (Table, 3) at Fayoum is expected to be increased from one generation during 2050 (13 generations) to two generations during 2100 (14 generations) in comparison with current climate (12 generations). The first generation took the highest number of days under current and future climate of 2050 and 2100,being 65, 54 and 49 days, respectively. The numbers of days during 2050 and 2100 lasted days earlier than the current climate (11 days in 2050 and 16 days in 2100). The sixth to eight generations under current climate lasted lowest number of days (21 days) in comparison with other generations and the sixth, seventh and ninth generations in 2050 under future climate took the number of days 19, while in 2100 it took the lowest number of days (18) in comparison with other generations.

The mean period of generation under current climate lasted the longest period (29 days) in comparison with future climate under 2050 gave (26 days) and 2100 (25 days) (Table, 3).

Generation number of *T. absoluta* (Table, 3) at Qena is expected to be increased from one generation during 2050 (14 generations) to two generations during 2100 (15 generations) in comparison with current climate (13 generations).

The first generation lasted the highest number of days under current and future climate of 2050 and 2100 being 61, 55 and 47 days, respectively. The numbers of days during 2050 and 2100 took 6 and 14 days earlier than the current climate, respectively. The two generations under current climate lasted lowest number of days (36 days) in comparison with other generations and the sixth and ten generations in 2050 under future climate lasted the number of days 20, 21 ,while 2100 lasted the lowest number of days 18,23,33 in comparison with other generation. The mean period of generation under current climate took the longest period (27 days) in comparison with future climate of 2050 (26 days) and 2100 (24 days) (Table, 3).Finally, the effect of climate change had a significant effect on the ecological parameters of *T. absoluta* number and duration of generations. These results are in accordance with CABI (2007) and EPPO (2005) who found that the average temperature in a greenhouse with tomato production is about 20 °C. Using the same DD calculation method as mentioned above, it is estimated that *T. absoluta* can have 9 generations in a greenhouse with a year round tomato production. In South America, *T. absoluta* has a neotropical distribution (Moore, 1983). *O. nubilalis* is predicted to become bivoltine – i.e. to produce two generations per season rather than one – in the Czech Republic as a result of predicted increases in temperatures during the period 2025-2050. Similar predictions were reported by Kriticos *et al.* (2007), who mentioned that, climate change scenarios for the 2080s indicate that in the central Pacific, the change in potential distribution is relatively minor for Oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae). Parts of New Zealand could become substantially more climatically suitable, increasing the likelihood of successful establishment of *Bactrocera dorsalis* after an incursion, and seriously threatening the horticultural sector. Should *Bactrocera dorsalis* become established in New Zealand, it is likely to follow any expansion of the horticultural sector into the coastal areas of the eastern part of the South Island as far south as Oamaru. In the same line Estay *et al.*, (2009) predict a change in the equilibrium density of the confused flour beetle, *Tribolium confusum* Jacquelin (Coloeoptera: Tenebrionidae) from 10 to 14% under the moderate B2 scenario and 12 to 22% under the extreme A2 scenario to the period, 2071–2100. Both results imply a severe change in the pest status in the southern region of Chile. On contrary Andrew *et al.*, (2006) predicated that, using the GFDLA2 scenario for projected weather at Davis, California, the degree-days during the seasons increase at a faster rate than using the GFDLB1 scenario, and the number of spring frosts also decrease.

Table (1): Degree days and generation numbers of *Tuta absoluta* under current climate at El-Behaira, Giza, Fayoum and Qena governorates.

No. of Generation	Current climate							
	El-Beharia		Giza		Fayoum		Qena	
	Day	DDU	Day	DDU	Day	DDU	Day	DDU
1	66	463	66	466	65	465	61	467
2	45	464	42	464	39	466	36	463
3	30	469	29	466	28	468	26	474
4	25	472	24	469	23	471	23	470
5	24	470	22	471	22	469	20	470
6	23	470	21	469	21	468	20	474
7	24	473	22	473	21	471	20	472
8	25	462	22	471	21	473	20	472
9	27	467	24	469	22	465	21	473
10	35	470	30	463	25	467	21	473
11	41	471	32	463	31	466	25	471
12			40	461	37	469	33	465
13							29	469
Mean	33	468	30	468	29	468	27	471

Table (2): Degree days and generation numbers of *Tuta absoluta* under climate change (2050 and 2100) at El-Behaira and Giza governorates.

No. of Generations	Climate change							
	El-Beharia				Giza			
	2050		2100		2050		2100	
	Day	DDU	Day	DDU	Day	DDU	Day	DDU
1	60	468	50	461	49	467	45	466
2	44	473	42	461	41	474	40	469
3	30	462	28	460	25	478	24	475
4	25	472	26	481	23	476	23	470
5	22	466	22	465	21	474	20	469
6	22	474	21	469	19	477	19	484
7	22	475	21	477	18	475	18	465
8	22	478	21	467	18	477	17	468
9	22	466	21	472	19	481	18	483
10	25	469	22	462	19	480	18	481
11	29	468	24	461	19	475	18	469
12	40	463	29	465	26	480	20	463
13			33	463	31	467	25	463
14							32	464
Mean	30	470	28	466	25	475	24	471

Table (3): Degree days and generation numbers of *Tuta absoluta* under climate change (2050 and 2100) at Fayoum and Qena governorates.

No. of Generations	Climate change							
	Fayoum				Qena			
	2050		2100		2050		2100	
	Day	DDU	Day	DDU	Day	DDU	Day	DDU
1	54	467	49	466	55	464	47	464
2	41	473	41	464	35	462	33	467
3	25	466	24	461	24	464	23	469
4	23	477	23	479	21	462	21	480
5	20	460	20	466	19	469	19	474
6	19	465	18	464	18	460	18	474
7	19	483	19	486	18	461	18	484
8	20	484	18	468	18	477	18	487
9	19	473	19	474	18	464	18	481
10	20	470	19	483	19	460	18	461
11	22	461	20	475	20	465	19	468
12	27	469	23	474	23	469	21	461
13	33	469	28	467	30	473	25	472
14			35	464	41	466	29	465
15							31	461
Mean	26	471	25	471	26	465	24	471

From the afore-mentioned results, it could be concluded that *T. absoluta*, leaf minor had a tremendous impact on major vegetable crops especially tomatoes in the experimental studied areas in (El-Behaira, Giza, Fayoum, and Qena governorates) yet despite the negative effects of *T. absoluta* and other pests. Diligent oversight is still needed in order to exclude many of the highly invasive and potentially damaging alien *T. absoluta* that are present throughout Egypt. This study is considered warning or hot line for *T. absoluta* under climate change conditions.

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