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Degree-days units and expected generation numbers of peach fruit fly *Bactrocera zonata* (Saunders) (Diptera: Tephritidae) under climate change in Egypt

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ABSTRACT

Climate change could profoundly affect the status of agricultural insect pests. This study predicts expected peach fruit fly (PFF) annual generations under current and future climate by using the accumulated thermal heat units expressed as degree-days unit (DDU). We evaluated how temperature expected to influence the annual generation numbers in three governorates of Egypt using the climate change data output from the HadCM3 model for A1 scenarios proposed by the Intergovernmental Panel on Climate Change. Results indicated that PFF in Asyout have the highest number of possible generations as compared to other locations (North Sinai and EL Beheira) under current climate to be 8 compared with 6 and 7 for other locations, respectively. Generation numbers of PFF under climate change conditions would be increased especially in Asyout governorate to 9 and 10 by 2050 and 2100, respectively. However, the expected generation numbers of PFF at 2050 and 2100 will be 8-9 and 9-10 generations per year for other two locations, respectively.

Keywords: Peach fruit fly, Climate change, Degree-days units, Generations.

INTRODUCTION

Peach fruit fly (PFF), *Bactrocera zonata* (Saunders) (Diptera: Tephritidae) is known as a most serious pest of tropical and subtropical fruits (Fletcher 1987). It was recorded on more than 50 cultivated and wild plant species, mainly those with fleshy fruits (White and Elson-Harris 1992 and EPPO 2005). It originated in South and South-East Asia (Agarwal *et al*., 1999), and spread to other parts of the world, in particular to several countries in the Near East and Egypt (El-Minshawy *et al.,* 1999). In recent years, *B. zonata* has become a widespread pest in Egypt (EPPO 2002). According to EPPO (2005) and Ghanim (2009), *B. zonata* could out compete other Tephritid fruit fly species such as *Ceratitis capitata* Wied.

Temperature is an important environmental factor affecting survival and developmental rates of fruit flies (Afia, 2007; Amin, 2008 and Ghanim, 2009). From the practical aspect, accumulated thermal units have been used to predict the seasonal development and emergence of various insects (Eckenrode *et al*., 1975, Sevacherian *et al.,* 1977 and Farag *et al*., 2009). The last assessment report from the Intergovernmental Panel on Climate Change (IPCC) predicted 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; Merrill *et al*. 2008), or may be mediated by host plants, competitors or natural enemies (Bale *et al*. 2002).

As the appearance of PFF population varies greatly from year to another, it can be predicted by the standard degree-days method. Degree-days can be defined as the units combining between time and temperature, used to measure the development of an organism from one point to another in its life cycle. (Wilson and Barnett 1983 and Zalom *et al*., 1983). The relationship between the accumulated thermal heat units [expressed as degree-days (DD's)] and the population fluctuations of PFF male indicated that there was discrepancy with an average of 3.6 days for expected and observed peaks, (Farag *et al*., 2009). The accuracy of prediction - that depends on DD's and population of *B. zonata* enable growers and pest control advisors to reduce monitoring periods to make a true decision for pest control in the proper time, which minimize costs and the hazard of chemical control (Farag *et al*., 2009). So, using degree-days allows for predicting pest occurrence, also can be an aid tool for scheduling sprays and beneficial insect releases at the optimum time to insure the best results, and helpful in monitoring pest activity. The objective of the present study to predict PFF annual generation numbers and durations under current and expected future climate changes by using the relationship between the accumulated thermal heat units expressed as degree-days (DD's) and the population fluctuations of *B. zonata* at three governorates in Egypt.

MATERIALS AND METHODS

1- Experimental area:

The study was conducted in three governorates of Egypt (*i.e.* North Sinai, El Beheira and Asyout). These are located at the East, North and South of the Egypt respectively. We selected these governorates area depended on different climate regions and highest fruit growing areas comprised with other governorates (Agriculture statistics 2008). Fig. (1) Shows the distribution map of fruit growing areas in Egypt. Degree – days for PFF from each area was estimated and presented in.

2- Estimate degree-days units :

2-1- Under current climate temperature:

For estimating degree-days unit, we obtained daily temperature records from Center Laboratory for Agriculture climate (CLAC) during the period from 2005 to 2009 for three locations (North Sinai, El Beheira and Asyout) and calculated the average from 2005 to 2009 to be compared with future climate (2050 and 2100).

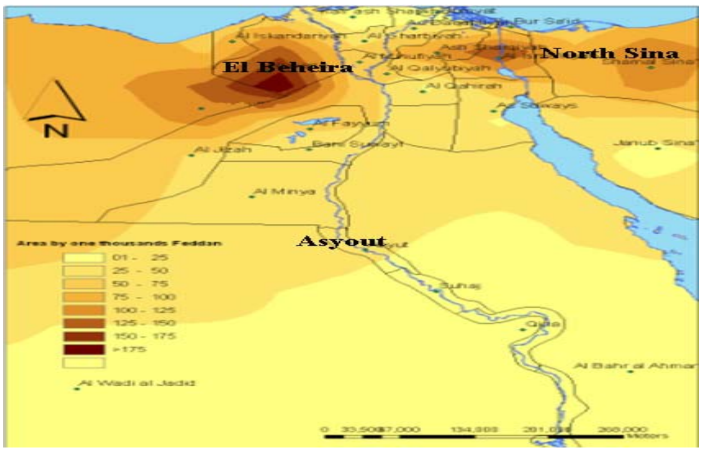

Fig. 1: Distribution map for fruit growing areas in Egypt.

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

Climate change scenarios for locations were assessed according to future conditions derived from MAGICC/SCENGEN software of the University of East Angle (UK). In this the study one scenario of climate data were used A1. The principal of MAGICC/SCENGEN is allowing the user to explore the consequences of a medium range of future emissions scenarios. The user selects two such scenarios from library of possibilities. The reason for two scenarios is to able to compare a no action scenario with an action or policy scenario. Thus, in MAGICC/SCENGEN the two emissions scenarios were referred to as a reference scenario and policy scenario (Wigley *et al.*, 2000). The data which generated from MAGICC/SCENGEN are represented in one scenario A1. These scenarios are described by IPCC 2001 as "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" (Meehl *et al.*, 2007).

3**- Determination the thermal units required for PFF development as degree-days units (DDU):**

Maximum and minimum temperatures were transformed to heat units using the lower threshold temperature (t_0) 11.84˚C with 487.92 (DDU) (for generation of peach fruit fly) (Sharaf El-Din *et al.*, 2007) by applying Richmond *et al.,* (1983) formula as follows:

$H = \sum H J$ (Where: H = number of degree-days units)

$H J = \{(max + min)/2\} – C$ (If max. > C and min. > C)

$H J = \{(max. – C)^2 /2 (max.-min.)\}$ (If max. > C and min. < C)

$H J = 0$ (If max. < C and min. < C)

$C = t_0$

RESULTS AND DISCUSSION

1- Current climate:

Under current climate conditions, the mean values of thermal units required for complete PFF generation were 491, 495 and 493 units in North Sinai, El Beheira and Asyout, respectively. So, the peach fruit fly had the capacity of six, seven and eight generations in North Sinai, El Beheira and Asyout, respectively.

2- Expected future climate:

As shown in Fig. (2), under the future climate scenarios, the degree days increase during 2050 and 2100 in comparison with current data for studied area (North Sinai, El Beheira and Asyout). Highest change for degree days under climate change shown during summer and autumn periods but the winter and spring periods expected to small change for the degree days in 2050 and 2100 in comparison with current data.

Generation number of peach fruit fly (Table 1) in North Sinai is expected to increase by two generations during 2050 (eight generations) to three generations during 2100 (nine generations) in comparison with current climate (six generations). The first generation would take the highest number of days under current and future climates (2050 and 2100) (*i.e.* 111, 92 and 80 days, respectively). The number of days during 2050 and 2100 would take days earlier than the current climate (19 days in 2050 and 31 days in 2100).

Table (1): Comparison between degree days and generation numbers of *B. zonata* under current and expected future climate (2050 and 2100) in North Sinai region.

No. of generation	Current climate		2050		2100	
	Days	DDUs	Days	DDUs	Days	DDUs
1	111	492	92	498	80	489
2	41	490	43	499	46	498
3	37	489	33	488	32	497
4	32	488	29	490	29	495
5	33	493	27	496	26	495
6	38	493	28	495	27	504
7			31	488	27	490
8			44	492	32	497
9					52	489
Mean	49	491	41	493	39	495

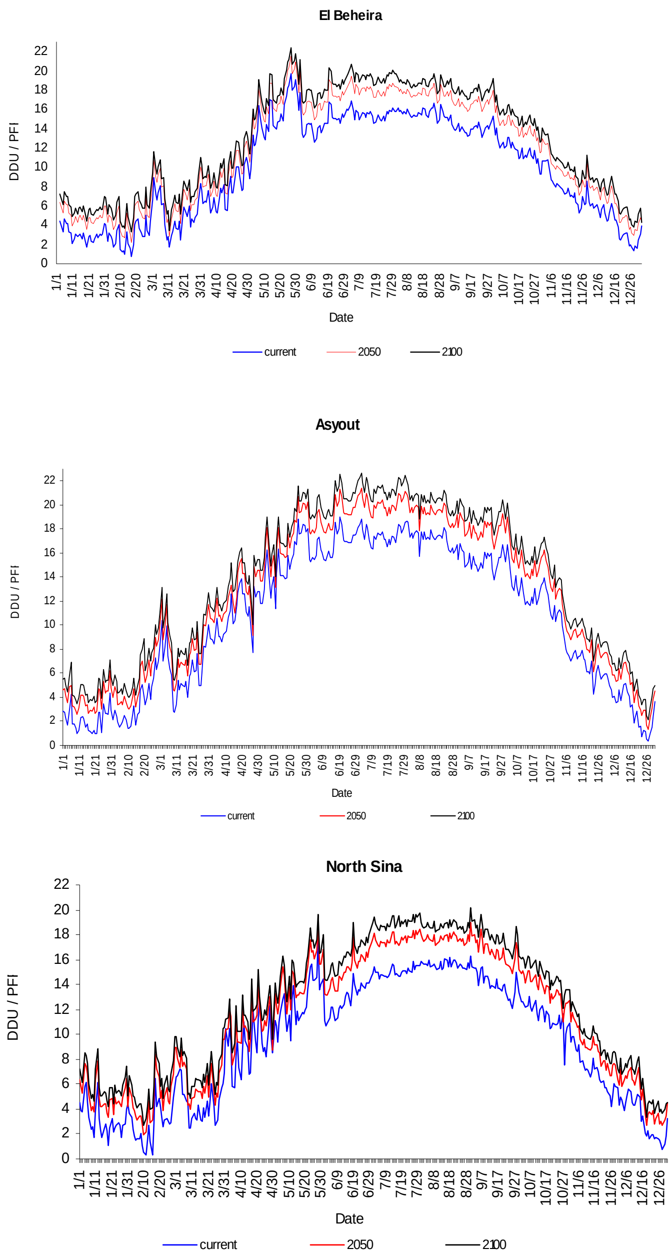

Fig. (2): Comparison between degree days usable by *B. zonata* under current and expected future climate conditions (2050 and 2100).

The fourth generation under current climate would take lowest number of days (32 days) in comparison with other generations and the fifth generation under future climate (2050 and 2100) would take the lowest number of days (27 and 26, respectively) in comparison with other generations.

The mean period of generation under current climate took the longest period of (49 days) in comparison with the expected future climate conditions in 2050 (41 days) and 2100 (39 days) (Table 1).

Generation number of peach fruit fly (Table 2) in El Beheira is expected to increase by one generation during 2050 (eight generations) to two generations during 2100 (nine generations) in comparison with current climate (seven generations). The first generation would take the highest number of days under current and future climate (2050 and 2100) (112, 89 and 79 days, respectively). The number of days during 2050 and 2100 would take days earlier than the current climate (23 days in 2050 and 33 days in 2100). The fourth generation under current climate would take lowest number of days (32 days) in comparison with other generations and the fifth generation under future climate (2050 and 2100) would take the lowest number of days (27 and 26) respectively in comparison with other generations.

The mean period of generation under current climate took the longest period (48 days) in comparison with future climate under 2050 gave (39 days) and under 2100 gave (37) (Table 2).

Table (2): Comparison between degree days and generation numbers of *B. zonata* under current and expected future climate (2050 and 2100) in El Beheira region.

No. of generation	Current climate		2050		2100	
	Days	DDUs	Days	DDUs	Days	DDUs
1	112	490	89	490	79	493
2	36	499	44	490	47	491
3	33	492	29	495	27	504
4	32	497	28	491	28	506
5	33	498	27	504	26	503
6	36	496	28	495	27	492
7	53	491	30	499	28	492
8			37	492	30	502
9					42	493
Mean	**48**	**495**	**39**	**495**	**37**	**497**

Generation number of peach fruit fly (Table 3) in Asyout is expected to increase by one generation during 2050 (nine generations) to two generation during 2100 (ten generations) in comparison with current climate (eight generations).The first generation would take the highest number of days under current and future climate (2050 and 2100) (105, 88 and 79 days, respectively). The number of days during 2050 and 2100 would take days earlier than the current climate 17 days in 2050 and 26 days in 2100. The fourth generation under current climate would take lowest number of days (28 days) in comparison with other generations and the fifth generation under future climate (2050 and 2100) would take the lowest number of days (25 and 23, respectively) in comparison with other generations.

The mean period of generation under current climate took the longest period (42 days) in comparison with future climate under 2050 gave (37 days) and under 2100 gave (35) (Table 3).

As conclusion, the effect of climate change is expected to have a significant effect on the ecological parameters of PFF (*i.e.* generations).

Table (3): Comparison between degree days and generation numbers of *B. zonata* under current and expected future climate (2050 and 2100) in Asyout region.

No	Current climate		2050		2100	
	Days	DDUs	Days	DDUs	Days	DDUs
1	105	496	88	488	79	492
2	38	494	39	493	41	501
3	29	488	29	504	29	505
4	28	489	26	499	25	503
5	30	490	25	500	23	488
6	31	502	26	495	24	488
7	35	492	27	498	25	504
8	42	493	29	491	26	497
9			43	489	29	488
10					52	493
Mean	42	493	37	495	35	496

In general, theses results are in accordance with FAO/IAEA (2000), which recorded that the *B. zonata* in general had 6-10 overlapping generations per year. Also similar results obtained by Tranka, *et al.*, (2007), who reported that the effect of climate change for multivoltine species such as the European corn borer, *Ostrinia nubilalis* Hubner (Lepidoptera: Pyralidae) will be that it may be able to produce additional generations, relative to current conditions, in a given locale, with a potentially greater impact on their host plants. For example, *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 2025-50. Similar predictions was reported by Kriticos (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 (OFF), *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae). Parts of New Zealand could become substantially more climatically suitable, increasing the likelihood of successful establishment of OFF after an incursion, and seriously threatening the horticultural sector. Should OFF 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. Tradeoffs between these two variables slow the time to bloom date (*i.e.* 0.086 days per year) because vernalization of olive is delayed. Yields decrease in the absence of olive fly due to increasing respiration costs. With uncontrolled olive fly infestations, yields are severely depressed but increase to near normal levels after year 125 (i.e., year 2075) but with greatly increased variability. Yield increases are due to decreased favorableness for olive fly due to high temperatures close to its climatic limits.

CONCLUSIONS

Peach fruit fly had a tremendous impact on fruit tree in the studied area (North Sinai, El Beheira and Asyout) yet despite the negative effects of fruit flies and other pests. Diligent oversight is still needed in order to exclude many of the highly invasive and potentially damaging alien peach fruit fly that are present throughout Egypt. These study conceder warning or hot line for fruit trees under climate change conditions.

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ARABIC SUMMARY

الوحدات الحرارية المتجمعه وعدد الأجيال المحتملة لذبابة ثمار الخوخ تحت ظروف تغير المناخ فى مصر

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١- المعمل المركزي للمناخ الزراعى
٢- معهد بحوث وقاية النباتات – مركز البحوث الزراعية

يعتبر تغير المناخ من العوامل التى تؤثر على حالة الافات الحشرية بصفه عامه ، وفى هذه الدراسة تم حساب الوحدات الحراريه المتجمعة لذبابة ثمار الخوخ وكذلك عدد الأجيال المحتملة تحت الظروف الحالية وتحت ظروف تغير المناخ .حيث استخدم احد مخرجات نماذج حسابات تغير المناخ للمحافظات التي تحت الدراسة (البحيرة،شمال سيناء،أسيوط)،حيث اشارت النتائج الى ان عدد الأجيال المحتملة تحت الظروف الحالية يتراوح من ٦ إلى ٨ اجيال بينما يزداد الى ١٠ اجيال تحت ظروف تغير المناخ .كما اوضحت النتائج فى محافظة البحيرة ان عدد الأجيال فى الظروف الحالية ٧ وتحت ظروف تغير المناخ ٩ ومحافظة شمال سيناء في الظروف الحالية عدد الأجيال ٦ وتحت ظروف تغير المناخ ٩ اجيال بينما فى محافظة أسيوط يكون عدد الأجيال فى الظروف الحالية ٨ وتحت ظروف تغير المناخ ١٠ أجيال. وتعتبر هذه الدراسة من الدراسات الاولية فى مصر لمعرفة تاثير تغير المناخ على الآفات.