Using degree- day unit accumulation to predict potato tubeworm incidence under climate change conditions in Egypt

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Abstract: The potato tuber worm, *Phthorimaea operculella Zeller*, is a serious pest of potato, *Solanum tuberosum L*., in subtropical and tropical production systems around the world. Knowledge of the temperature-dependent population growth potential is crucial for understanding population dynamics and implementing pest control strategies in different agro-ecological zones. Potato tuber moth is considered among the most important potato insect pests in Egypt. The aim of this study was to predict degree day's unit and annual generation peaks for tuber worm 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. It is evaluated how temperature influences the annual generation in two distinct locations in Egypt using the climate change data output from the HadCM3 model for A1 scenario proposed by the Intergovernmental Panel on Climate Change. Our results indicated that population of the tuber worm at Ismailia gave the highest number of generations as compared with EL Beheira location under current climate. Generation numbers of tuber worm under climate change conditions increased especially in Ismailia location. However, the expected generation numbers of the tuber worm in 2050 and 2100 are expected to be 9-11 and 10-12 generations per year, respectively.

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1. Introduction:

Potato, *Solanum tuberosum L.* is a crop of international importance for consumers everywhere in the world. Potato tuber worm, *Phthorimaea operculella Zeller* (Lepidoptera: Gelechiide), is considered among the most impotent potato insect pests in Egypt. Temperature has a direct influence on the activity as well as on the rate of development of insects and other ectothermic organisms. 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) denominates "optimal range" the temperature going from the lower threshold 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 insecticide applications Zalom *et al*., (1983). From the practical aspect, cumulated thermal units have been used to predict the seasonal development and emergence of various insects Eckenrode *et al.,* (1975), Sevacherian *et al.,* (1977), Daoud *et.al.* (1999) and Khalil *et. al.,* (2010). 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 crops pests 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).

The objective of the present study is to predict potato tuber worm annual generation peaks under current and expected future climate changes by using the relationship between the cumulated thermal heat units expressed as degree-days (DD's) and the population fluctuations of potato tuber worm in four governorates in Egypt.

2. Materials and Methods

1- Experimental area :

This study was conducted in two locations in Egypt (EL Beheira and Ismailia); we selected these locations as thy displayed different micro climates and the highest potato yields in comparison with other locations Agriculture Statistic, (2008).

2- Estimate degree-days units :

2-1- Under current climate temperature:

For the estimation of degree day's unit, we obtained daily temperature records from Central Laboratory for Agricultural climate (CLAC) from 2004 to 2008 for These two experimental locations (EL Beheira and Ismailia) and the average were calculated and processed for abrojection on future climate consequences (2050 and 2100).

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

Climate change scenarios for locations were assessed according to prediction conditions derived from MAGICC/SCENGEN software of the university of East angle (UK). In this study the A1 scenario of climate data were used. The principle 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. In order to be able to compare a no action scenario with an action or policy scenario.

Thus in MAGICC/SCENGEN the two emission scenarios are referred to as a reference scenario and policy scenario Wigley *et al.*, (2000). The data which were generated from MAGICC/SCENGEN 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 the thermal units required for potato tuber worm development in relation with degree day's unit (DDU):

Maximum and minimum temperatures were transformed to heat units using the lower threshold temperature (t_0) 9.6˚C with 459.6 (DDU) for a generation of potato tuber the average developmental time needed for completion of the potato tuber worm was calculated according to the hereunder formula Elsaadany *et al.*, (2000) and Richmond *et al.*, (1983) formula as follows:

H= ∑ D-D

Where:

H= Number of heat unit to emergence.

D-D= (Max. t. + Min. t.)/2 – t_0, if Max. t.> t_0 < Min

D-D=(Max.t.–t_0)/2/2(Max.t-Min.t) ,if Max.t.> t_0<Min

D-D= Zero, if Max. t.> t_0< Min

t_0= threshold temperature = 9.5˚C

3. Results and Discussion

Current climate:

Under current climate conditions, generation number one gave the highest number of days and generation number six gave the lowest number of days, at EL Beheira and Ismailia (Table 1). The mean values of thermal units required for complete development of *Phthorimaea operculella* generation were 466 and 467 units in EL Beheira and Ismailia, respectively. So, the *Phthorimaea operculella* exhibited 9 and 10 generations in El Beheira and Ismailia, respectively.

Expected future climate:

Generation number of *Phthorimaea operculella* (Table 1) at El-Behaira is expected to be increased by one generation in 2050 (it will roach 10 generations) to two generations in 2100 (11 generations) in comparison with current climates (9 generations).The first generation longest period under current and future climate (2050 and 2100), being 81, 73 and 64 days, The number of days per generation in 2050 and 2100 is expected to be shortened of 8 and 17 days respectively compared to that under the current climate, respectively. The sixth generations under current climate took lowest number of days (24 days) in comparison with other generations days and the sixth and seventh generations under future climate (2050 and 2100) took the lowest number of days (23 and 22 days generations), respectively.

The mean period of generation under current climate lasted longest period, being 36 days in comparison with the expected future climate conditions in 2050 (32 days) and 2100 (31 days) (Table, 1).

Generation number of *Phthorimaea operculella* (Table 2) at Ismailia is expected to be increased from one generation per year in 2050 (11 generations) to two generations in 2100 (12 generations) in comparison with current climate (10 generations). The first generations took the highest number of days under current and future climate in 2050 and 2100, being 81, 65 and 61days, respectively. The number of days in 2050 and 2100 is expected to bee reduced of 16 and 20 days compared to that obtained an the current climate, respectively. The sixth generation under current climate took the lowest number of days (24 days) in comparison with the other generations. The sixth and the seventh generation under future climate in 2050 and 2100 took lowest number of days (22 and 21) in comparison with the other generations.

The mean period of generation under current climate lasted longest period, being 36 days in comparison with the expected future climate conditions in 2050 (30 days) and 2100 (29 days) (Table, 2).

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

Table (1): Comparison between degree days and generation numbers of *P. operculella* under current and future climate (2050 and 2100) in EL Beheira region.

No. of generation			1	2	3	4	5	6	7	8	9	10	11	Mean
Current	Climate	Day	81	44	29	27	26	24	27	29	36			**36**
		DDU	464	464	472	465	471	464	466	467	463			**466**
Future Climate	2050	Day	73	48	21	21	24	23	23	25	27	28		**32**
		DDU	460	463	468	466	466	465	460	467	474	468		**464**
	2100	Day	64	50	23	19	24	22	22	23	25	26	29	**31**
		DDU	464	465	475	466	476	462	466	469	472	462	466	**468**

Table (2): Comparison between degree days and generation numbers of *P. operculella* under current and future climate (2050 and 2100) in Ismalia region.

No. of generation			1	2	3	4	5	6	7	8	9	10	11	12	Mean
Current	Climate	Day	81	43	27	26	25	24	25	27	37	45			**36**
		DDU	461	466	472	471	464	469	470	469	465	464			**467**
Future Climate	2050	Day	65	47	24	20	24	22	22	23	26	26	34		**30**
		DDU	473	472	466	470	464	475	462	477	479	460	466		**471**
	2100	Day	61	43	26	19	23	21	21	22	23	25	25	40	**29**
		DDU	466	469	460	477	477	469	466	461	473	466	463	462	**469**

In general, these results are in accordance with Abolmaaty, *et.al* (2010), which recorded that the expected generation numbers of the *Tuta absoluta* in 2050 and 2100 should be 12-14 and 13-15 generations per year, respectively, and degree with FAO/IAEA (2000), which recorded that, the *B. zonata* had 6-10 overlapping generations per year. results similar were obtained by Tranka, *et al.*, (2007), which reported that the effect of climate change for multivoltine species such as the European corn borer ***Ostrinia nubilalis*** Hubner (Lepidoptlera: Pyralidae) will be that it may be able to produce additional generations, relative to current conditions, in a given locality, 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 were 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.

The insect may develop generations under awarmer climate. High temperature in the future may thus increase the damage on crops, by increasing the number generations Abolmaaty *et al.,* (2010).

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 for the period, 2071–2100, which imply a severe change in the pest status in the southern region of Chile.

4. References:

1. Abolmaaty, S. M.; Hassanein, M. K.; Khalil, A. A. and Abou-Hadid, A.F. (2010). Impact of Climatic Changes in Egypt on Degree Day's Units and Generation Number for Tomato Leaf miner Moth *Tuta absoluta,* (Meyrick) (Lepidoptera gelechiidae)., Nature and Science, Vol.(11): 122-129.
2. Agriculture Statistics, 2008. Ministry of Agriculture, Egypt, vol (1).
3. Andrew, P. G.; Ponti, L.; Ellis, C. K. and Thibaud, O. (2006). Analysis of climate on agricultural systems. A Report *From:*California Climate Change Center. P. 11-12.
4. Bale, J.; Masters, G.; Hodkinson I; Awmack C.; Bezemer T,;Brown V.; Butterfield J.; Buse A.; Coulson J. and Farrar J. (2002). Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. Glob. Chang, Bol. 8,1–16.
5. Barrientos, Z.R.; Apablaza, H.J.; Norero, S.A. and Estay, P.P. (1998) Threshold temperature and thermal constant for development of the South American tomato moth tuta absoluta (Meyrick) (Lepidoptera: Gelechiidae).
6. Chiang, H. 1985. Insects and their Environment. p. 128-161. In: R.E. Pfadt (ed.) Fundamentals of Applied Entomology. MacMillan Publishing Company, NY, USA.
7. CIP. (1996). Major Potato Diseases, Insects, and Nematodes, 3rd edn. entro Internacional de la Papa, Lima (PE).
8. Cannon, R. (1998). The implications of predicted climate change for insect pests in the UK, with emphasis on non-indigenous species. Glob. Chang. Biol. 4, 785–796.
9. Daoud,M.A.; El-saadny, G. B.; Mariy, F. M .A. and Ibrahim, M.Y. (1999) the thermal threshold uints for PHTORIMAEA OPERCULELIA (ZELLER). Annals Agric.Sci.Ain-Shams Univ.,Cairo 44 (1), 379-393.
10. Eckenrode, S. J.; Vea, E.V. and Stone ,K.W. (1975). Population trends of onion maggots correlated with air. Thermal unit accumulations. Environ. Entomol. 4:785-9.
11. El-Saadany, G. B.; Mariy, F. M. A.; Abdel- Wahed, M. S. and Ibrahim, M. Y. (2000). The applicability predicting the changes in the population density of *Phthorimaea operculella (Zeller).* Annals Agricultural Science, Sp., Issue 4, 1469- 1484.
12. EPPO (2005), Datasheet *Tuta absoluta* datasheet. OEPP/EPPO Bulletin 35: 434-435.
13. Estay, S. A.; Lima, M. and Labra, F. A. (2009). Predicting insect pest status under climate change scenarios: combining experimental data and population dynamics modeling. J. Appl. Entomol., Blackwell Verlag, GmbH,1-9.
14. Farag, M. M. A.; Shehata ,N.F and Mahmoud ,Y.A. (2009). Predicting the annual generation peaks of peach fruit fly, *Bactrocera zonata* (Saunders) (Diptera: Tephritidae) using heat units accumulation at Giza Governorate, Egypt. 4th Conf. on Recent Technologies in Agriculture. Egypt.
15. Garcia, M.F. and Espul, J.C. (1982). Bioecology of the tomato moth (*Scrobipalpula absoluta*) in Mendoza, Argentine Republic. Revista-de-Investigaciones-Agropecuarias 17: 135-146.
16. Khalil, A. A.; Abolmaaty, S. M.; Hassanein, M.K.; El- mtewally, M. M. and Moustafa, S. A. (2010). Degree days units and generation number of peach fruit fly *Bactrocera zonata* (Saunders) (Diptera: Tephritidae) under climate change in Egypt, Egypt.Acad.J.biolog.Sci. 3(1):11-19.

17. Kriticos, D. J.; Stephens, A. E .A. and Lerich, A. (2007). Effect of climate change on Oriental fruit fly in New Zealand and the Pacific. New Zealand Plant Protection 60:271-278.
18. Meehl ,G.; Stocker, T.; Collins, W.; Friedlingstein, P.; Gaye, A.;Solomon ,S.; Qin, D.; Manning, M.; Chen, Z. and Marquis,M. (2007). Climate Change, 2007: The Physical Science Basis. Contribution of Working group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY, USA.
19. Merrill, R.; Gutie´rrez D.; Lewis O.; Gutie´rrez, J.; Diez, S. and Wilson, R. (2008). Combined effects of climate and biotic interactions on the elevational range of a phytophagous insect. J. Anim. Ecol. 77, 145–155.
20. Moore, J.E. (1983). Control of tomato leafminer (Scrobipalpula absoluta) in Bolivia. Tropical pest Management 29: 231-238.
21. Parmesan, C. (2007). Influences of species, latitudes and methodologies on estimates of phenological response to global warming. Glob. Chang. Biol. 13, 1860–1872.
22. Pereyra, P.C. and Sanchez, N. (2006). Effect of two Solanaceous plants on developmental and population parameters of the tomato leafminer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). Neotropical Entomology 35: 671-676.
23. Povolny, D. (1975). On three neotropical species of Gnorimoschemini (Lepidoptera, Gelechiidae) mining Solanaceae. Acta Universitatis Agricultarae 23: 379-393.
24. Richmond, J. A.; Thomas, H. A. and Hattachargya, H. B. (1983). Predicting spring flight of Nantucket pine tip moth (Lepidoptera: Olethreutidae) by heat unit accumulation. J. Econ. Entomol., 76: 271-296.
25. Sevacherian ,V.;N.C.; Toscano, R.A.; van Steenwy, K .R .K. Sharma and Sanders, R.R. (1977). Forecasting pink bollworm emergence by thermal summation Environ. Entomol. 6:545-6.
26. Wigley, T. M .L.; Raper, S.C.B.; Hulme, M. and Smith, S.J. (2000). The Magicc/Scengen Climate Scenario Generator Version 2.4: Technical Manual. C.F: http://www.cru.uea.ac.uk.
27. Woiwod, I. (1997). Detecting the effects of climate change on Lepidoptera. J. Insect Conserv. 1, 149–158.
28. Zalom, F. and Wilson, T. (1982). Degree days in relation to an integrated pest management program. Division of Agricultural Sciences, University of California, Davis, CA, USA. 2 pp.
29. Zalom, F.; Goodell, P.; Wilson, L.; Barnett, W. and Bentley, W. (1983). Degree-days: the calculation and use of heat unit in pest management. Division of Agricultural and Natural Resources, University of California, Davis, CA, USA. 10 pp.

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