Egyptian Journal of Plant
Protection Research Institute
www.ejppri.eg.net

Simulation model to determine the effect of climate change on the population density of the cotton mealybug *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae) infested cucumber

Mona, I. Ammar[1]; Hassan, H. A.[2] and Rahouma, A.K. [1]

[1]*Plant Protection Research Institute, Agricultural Research Center, Dokki, Giza, Egypt.*

[2] *Central Laboratory for Agriculture Climate (CLAC), Agricultural Research Center (ARC), Dokki, Giza, Egypt.*

ARTICLE INFO

Article History
Received:24 /1 /2024
Accepted: 20/3/2024

Keywords

Climatic change, DDUs, generation, *Phenacoccus solenopsis*, and global changes.

Abstract

Climate change and sustainable development have become among the most important global changes that have attracted the attention of the scientific community around the world. We aimed to remodel a simulation model to study the potential effect of rising temperatures because of the climatic change on the generation's number of cotton mealybug *Phenacoccus solenopsis* (Tinsley) (Hemiptera: Pseudococcidae). Firstly, generation numbers among three periods including reference period (2021 and 2022), current temperature effect, nearby future (2021–2040), and a far-future (2041–2060), were studied using the future climatic data obtained based on GHG-emissions scenarios (SSP-4.5). Our result highlights that there is a statistically significant difference in the mean quantities among the various levels of climate and generation in the Qalubiya, Beheira and El-Fayoum governorates, respectively. Moreover, there is significant differentiation in the data distribution among DDUs-values in the future than those during the current climatic state compared to 2021,2040 and 2060 in different locations. These results show great differentiation of needed DDUs for each generation in 2021-2040 and 2041-2060 compared with the current climatic state and among each other. This is mostly related to the expected temperature rise with mention to the significant differentiation from DDUs needed for the first generation compared to the consecutive following generation. The value of DDUs in the future compared to those under the current climatic state differs in the data distribution. These findings offer knowledge that will influence how future modifications to the pest will be controlled.

Introduction

One of the most significant vegetable crops grown worldwide is cucumber (*Cucumis sativus*). Among Egypt's vegetable crops, it holds a prominent place by Abdelatef *et al*. (2022). The plants of cucumber are infected with many pests, cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Sternorrhyncha: Coccoidea: Pseudococcidae) was recorded recently for the first time in Egypt infesting *Hibiscus* sp.

in September 2009 by Abd-Rabou *et al*. (2010). Since 2005, this new world species (*P. solenopsis*) has emerged as a serious pest of Cotton in Pakistan and India, and now it is a serious threat to Cotton in China, it has been reported from 173 species in 45 plant families and 26 countries in different ecological zones by Abbas *et al*. (2010). It was first recorded as a new pest on tomato, pepper, eggplant, and maize plants at Fayoum by Abd El-Wareth (2016) on soybean plants by El-Sarand (2017) and Ata (2019). A total of forty-three plant species from twenty different plant families—including ornamentals, weeds, shrubs, and trees—as well as field crops and vegetables were gathered throughout Southern Iran. Furthermore, Culik and Gullan (2005) suggest that cotton mealy bug insects are carriers of plant diseases. Its damage increases in the hot regions due to the increase in the insect population, because of the presence of a positive correlation between the mealybug population with temperature Kumar *et al*. (2013). The temperature represents an important environmental factor that affects the development, survival, and abundance of mealybugs (Amarasekare *et al*., 2008 and Shah *et al.,* 2015). Zalom *et al.* (1983) reported that thermal units provide a valuable tool for insect pest control, in forecasting infestations monitoring, and timing of insecticide applications. 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). Therefore, the present study was conducted to simulate model to investigate how climate change affects cotton mealybug (*P. solenopsis*) population density on cucumber plants.

Materials and methods

1. Field experiment:

The experiment was conducted in three different ecosystems (Experimental Farm of the Plant Protection Research Institute, Qaha, Qalubiya Governorate; Nubaria, Beheira Governorate and Tama, El-Fayoum Governorate). Cucumber plants were examined during the spring season sampling taken (March-April-May), summer season, sampling taken (June - July – August) the autumn season, sampling taken (September-October-November), and winter season, sampling taken (December- January- February) during two different seasons 2021 and 2022 and 2022 and 2023. Population counts of mealybugs (Crawler, nymph, and adult stages) were recorded from ten tagged plants from five spots starting from 18 days after sowing till the crop maturity at the weekly interval and expressed as the average number of mealybugs from 5 cm shoot/twig. The cultivated area was about 300 m^2 three different ecosystems. All agricultural practices were applied except for pest control.

2. Determination of degree-days units (DDU):

Determination of degree-days units (DDU) Daily maximum and minimum temperatures recorded and obtained from the Center Laboratory for Agriculture Climate (CLAC) were transformed to heat units using the lower threshold temperature of cotton mealy bug (Where, t0 was 8.2 °C with 774.1 units for generation according to Shehata (2017) and the lower degree-days units (DDU) were calculated by applying the Richmond *et al*., (1983) formula as follows:

$H = \Sigma H J$

(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 = t0

3. Influence of current climatic change on *Phenacoccus solenopsis*:

These experiments were performed on *P. solenopsis*, at the Experimental Farm of the Plant Protection Research Institute, Qaha, Qalubiya, Nubaria, Beheira and Tama, El-Fayoum Governorates - Egypt, from January to December for successive seasons 2022 and 2023. Average temperatures (Daily maximum and minimum) were calculated according to the data recorded and obtained from CLAC, Egypt.

4. Effect of expected future climatic change on *Phenacoccus solenopsis*:

This study was performed to predicate the numbers and durations of generations and DDU (Accumulated thermal heat units) in expected future climatic changes in 2040s and 2060s. The future climatic data have been obtained based on the GHG emissions scenarios (SSP-4.5), increase the temperature (1.5 °C) near term 2021-2040 (2.0 °C) med term 2041-2060 (IPCC 2021).

5. Data analysis:

The statistical analyses of the present data were carried out using SAS program computer including F-test and L.S.D. value (SAS Institute, 1999).

Results and discussion

Data in Table (1) and Figures (1,2,3 and 4) showed the effect of four different plantations on the infestation of the population densities. *P. solenopsis* was more abundant on summer and autumn plantations (206.3 and 201.3 individual/plant) after spring plantation (127 individual/plant) and the smallest number was found on winter plantation (75.5 individual/leaves) (Irrespective of Governorates and seasons). The statistical analysis of the total mean number of pests showed significant differentiations (F-value=15.59, L.S. D=47.9) for four plantations. We also find that the general mean number of *P. solenopsis* was more abundant at El-Fayoum Governorate (208.0 individual /plant) comes after Qalubiya Governorate with means (147.9 individual /plant) and where we find the lowest numbers of the population, Beheira Governorate with a mean (101.9 individual /plant) throughout two successive seasons 2021 and 2022 and 2022 and 2023. The statistical analysis of the total mean number of pests showed a significant difference at <0.0001 for three different locations (F value between Governorate= 27.83 and L.S.D =28.3).

Table (1): Rate of season variation in the mean number of infestations *Phenacoccus solenopsis* on cucumber plants at different Governorates through two years.

Plantation	Qalyubia Governorate		Beheira Governorate		El-Fayoum Governorate		Mean
	2021 and 2022	2022 and 2023	2021 and 2022	2022 and 2023	2021 and 2022	2022 and 2023	
Spring	123	136	105	98	146	155	**127.b**
Summer	216	198	165	148	248	263	**206.3a**
Autumn	185	179	93	101	319	331	**201.3a**
Winter	77	69	56	49	98	104	**75.5c**
Mean	**147.9b**		**101.9c**		**208.0a**		-----

F value between Governorate= 27.83* L.S.D=28.3**

F value between plantation =15.59 * L.S.D=47.9**

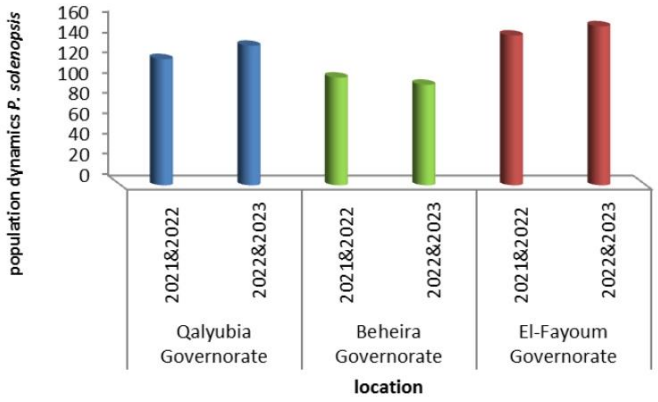

Figure (1): Population density of *Phenacoccus solenopsis* on cucumber at different Governorates in spring during 2021 and 2022 and 2022 and 2023 seasons.

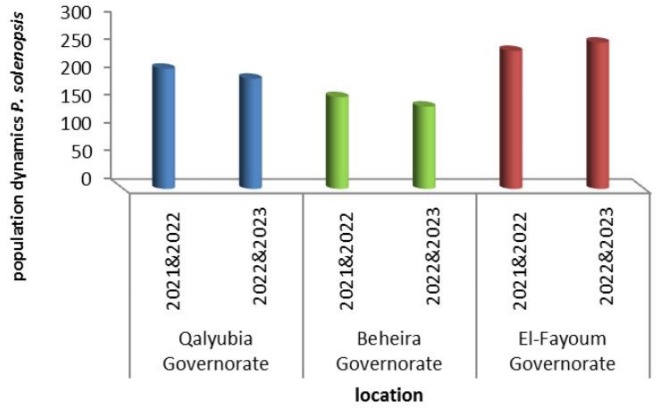

Figure (2): Population density of *Phenacoccus solenopsis* on cucumber at different Governorates in summer during 2021 and 2022 and 2022 and 2023 seasons.

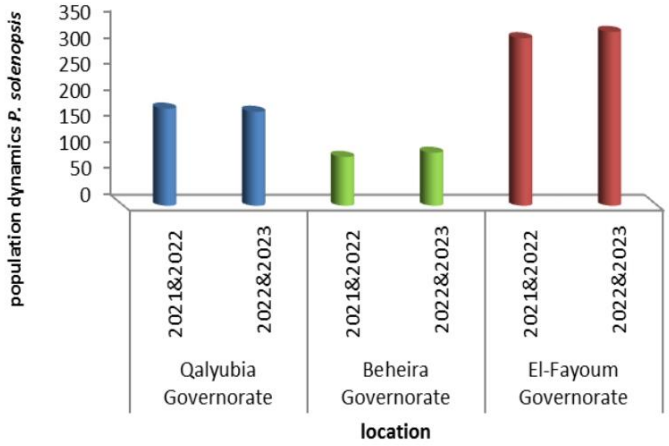

Figure (3): Population density of *Phenacoccus solenopsis* on cucumber at different Governorates in autumn during 2021 and 2022 and 2022 and 2023 seasons.

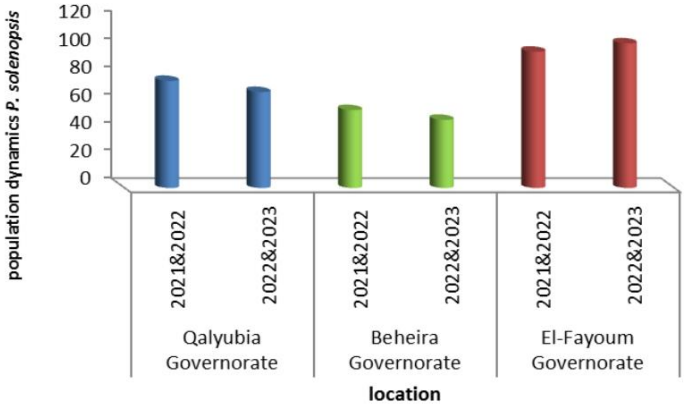

Figure (4): population density of *Phenacoccus solenopsis* on cucumber at different Governorates in winter during 2021 and 2022 and 2022 and 2023 seasons.

These results were in line with those obtained by (Ben-Dov *et al*., 2009). Also, the pest has been recorded on 183 plants in 52 families especially Malavaceae, Solanaceaeand Amaranthaceae families (Prishanthini and Vinobaba, 2014). The first record of *P. solenopsis* infestation in all of Egypt was recorded only on weed plants by Abd-Rabou *et al.* (2010). Abd El-Wareth (2016) recorded the first published record of tomato eggplant, pepper, and Maize plants as a new host for *P. solenopsis* in Egypt, especially in Fayoum Governorate. Badran *et al*. (2018) studied and evaluated some pest control methods on the Population density of *P. solenopsis* determined on cucumber plants in the greenhouse at Qaha, Qalubiya governorate. Amer *et al*. (2023) recorded that *P. solenopsis* has three peaks of abundance in both seasons (2019-2020 and 2020-2021) in the selected goldenberry orchards with a very low effective of the recorded parasitoid, *Dicrodiplosis manihoti* Harris at Qalubiya Governorate.

1. Influence of current climatic change on *Phenacoccus solenopsis* :

It has been projected that with a 2 °C temperature rise, insects might occur one to 5 extra life sequences per season (Yamamura and Kiritani, 1998). The expanded populace model ran efficaciously for different locations without combatting crashes. For the three geographical regions Qalubiya, Beheira, and El-Fayoum Governorates, the estimated climatic changes by GHG emissions scenarios (SSP-4.5) for the nearby and far future caused in a rise of the yearly temperature mean between the reference period (2022) and the nearby (2022-2040) or afar future (2040–2060) of 1.0, 2.0, and 2.7 °C, separately.

There is a statistically significant variation in the mean rates among the various levels of climate which is superior to what would be assumed by possibility after admitting for impact of differences in generation (F= 40.32, P <0.0001), (f=140.47, P <0.0001), (F= 181.19, P <0.0001), and (F= 76.00, P <0.0001), (f=10.21, P <0.001), (F= 4.15, P <0.01) in Qalubiya, Beheira and El-Fayoum Governorates, respectively. The expected temperature fluctuations manipulated the generation's number of *P. solenopsis* during the year. Related to the reference period, *P. solenopsis* consumed 773 DDU, 775 DDU to complete one generation under the current conditions on average of 41.0 and 51 d in Qalubiya, Beheira, and El-Fayoum Governorates, respectively. However, there is a statistically significant difference in the current, near, and remote future between climatic factors, the Generations number in the El-Fayoum governorate, and the near future 2022-2060 (Table 2).

Table (2): Mean of days and DDUs for *Phenacoccus solenopsis* under studied seasons and Governorates.

Years	Qalyubia Governorate		Beheira Governorate		El-Fayoum Governorate	
	Days	**DDUs**	**Days**	**DDUs**	**Days**	**DDUs**
2021	43a	775b	51a	775a	41a	773a
2040	41b	776a	46b	772c	31b	773a
2060	40b	773c	40c	774b	29c	771b
F value	40.32***	76.0***	140.47***	10.21**	181.19***	4.15*
L.S.D.	1.14	0.67	1.37	1.16	1.42	1.57

2. Degree-days and generation numbers of *Phenacoccus solenopsis* under climate season 2022 and future climate 2040 and 2060 at different Governorates:

Data in Table (3) showed that the *P. solenopsis* completed 6 to 7 generations/year on cucumber plants in Qalyubia Governorate with an average of 43.3 d/generation with 774.5 DDU in current but in 2040-2060 indicated 37.6 and 36 d/generation with 775.8 and 773.5 DDU, respectively. In the current (2022), the first generation took the longest period (From 1/3 to 8/5) with durations of 69 days. On the other hand, the shortest generation was the fourth one (From 9/7 to 6/8) with a duration of 34 days. the same results in 2040-2060, but one generation more in the period from (12/11to 4/1).

As temperature rises, the generation's number of pests will increase, so this could be explained by the fact that the low temperature contributed to less pest infestation and damage. Knowing the beginning and duration of the generation may help in early controlling to reduce the number of pests.

Table (3): Degree-days and generation numbers of *Phenacoccus solenopsis* under climate season 2022 and future climate 2040 and 2060 at Qalyubia Governorate.

No. Gen.	Qalyubia											
	2022				2040				2060			
	Days	Start	End	DDUs	Days	Start	End	DDUs	Days	Start	End	DDUs
1	69	1/3	8/5	772	63	1/3	2/5	776	61	1/3	2/5	772
2	39	9/5	17/6	778	38	3/5	10/6	770	38	3/5	10/6	770
3	35	18/6	8/7	773	32	11/6	16/7	776	32	11/6	16/7	774
4	34	9/7	6/8	778	32	17/7	19/8	778	31	17/7	19/8	774
5	37	7/8	14/9	773	32	20/8	26/9	777	31	20/8	26/9	774
6	46	15/9	30/10	773	37	27/9	11/11	775	35	27/9	11/11	770
7					55	12/11	4/1	779	49	12/11	4/1	779
8												
9												
10												

Data in Table (4) showed that the *P. solenopsis* completed 6 to 8 generations/year on cucumber plants in Beheira Governorate with an average of 50.8 d/generation with 775 DDU in current 2022, and found in 2040-2060, 42.6 and 36.8 d/generation with 771.7 and 774.2 DDU, respectively. In the current (2022), the first generation took the longest period (from 1/3 to 16/5) with durations of 77 days. On the other hand, the shortest generation was the fourth one (from 6/8 to 11/9) with a duration of 37 days. the same results in 2040-2060, increase one or two generations more in the period from (23/11 to 8/1 and 19/12 to 14/2) for 2040 and 2060, respectively.

Table (4): Degree-days and generation numbers of *Phenacoccus solenopsis* under climate season 2022 and future climate 2040, 2060 at Beheira Governorate.

No. Gen.	Beheira											
	2022				2040				2060			
	Days	Start	End	DDUs	Days	Start	End	DDUs	Days	Start	End	DDUs
1	77	1/3	16/5	773	65	1/3	4/5	773	63	1/3	2/5	775
2	41	17/5	27/6	773	41	5/5	15/6	770	39	3/5	12/6	772
3	38	28/6	5/8	773	40	16/6	26/7	775	33	13/6	19/7	774
4	37	6/8	11/9	775	34	27/7	29/8	773	27	20/7	21/8	776
5	42	12/9	23/10	777	35	30/8	4/10	770	31	22/8	1/10	770
6	70	24/10	2/1	779	49	5/10	22/11	770	34	2/10	6/11	773
7					57	23/11	18/1	772	41	7/11	18/12	776
8									55	19/12	14/2	776
9												
10												

Data in Table (5) showed that the *P. solenopsis* completed 6 to 10 generations/year on cucumber plants in El-Fayoum Governorate with an average of 40 d/generation with 773.3 DDU in current but in 2040-2060 indicated 28.5 and 26.3 d/generation with 773.3 and 770.8 DDU, respectively. In the current (2022), the first generation took the longest period (From 1/3 to 8/5) with durations of 65 days. On the other hand, the shortest generation was the third one (From 16/ 6 to 18/7) with a duration of 32 days. the same results in 2040-2060, increasing generation reach to 10 in the period (From 7/11 to 18/1).

Table (5): Degree-days and generation numbers of *Phenacoccus solenopsis* under climate season 2022 and Future climate 2040, 2060 at El-Fayoum Governorate.

No. Gen.	El-Fayoum											
	2022				2040				2060			
	Days	Start	End	DDUs	Days	Start	End	DDUs	Days	Start	End	DDUs
1	65	1/3	8/5	773	53	1/3	26/4	776	48	1/3	21/4	770
2	37	9/5	15/6	772	33	27/4	30/5	775	33	22/4	25/5	771
3	32	16/6	18/7	775	25	1/6	25/6	770	25	26/5	21/6	770
4	35	19/7	24/8	773	23	26/6	19/7	770	25	22/6	17/7	774
5	33	25/8	28/9	770	24	20/7	14/8	770	24	18/7	12/8	770
6	39	29/9	7/11	777	24	15/8	9/9	779	23	13/8	6/9	770
7	64	8/11	11/1	773	26	10/9	5/10	774	24	7/9	1/10	772
8					30	6/10	6/11	773	25	11/10	14/11	770
9					44	7/11	21/12	774	26	15/11	11/12	771
10									36	12/12	18/1	772

This result ties in well with previous studies wherein Shehata (2017). This study evaluated the thermal requirements for the development of the cotton mealybug *P. solenopsis* depending on different biological parameters on Okra leaves *Abelmoschus esculentus* at under two constant temperatures (20ºC and 30ºC). The thermal requirements to complete the insect development for one generation were 8.2ºC for the developmental zero and 774.1 DDs for the thermal constant. Based on the thermal requirements values, the average life cycle duration from January to December 2016 was 61.78 days and the number of annual generations was 7.143 when the average annual temperature was 23.29ºC.

Climate change may have an impact on pests via both intrinsic and extrinsic causes. To investigate the possible effects of increased temperatures brought on by climate change on the number of generations of *P. solenopsis*, we constructed a simulation model for our study. The mean values at different locations varied statistically significantly depending on the number of generations and the varying climatic conditions. The value of DDUs in the future compared to those under the current climatic state differs in the data distribution. These findings offer knowledge that will influence how future modifications to the pest will be controlled.

References

Abbas, G.; Arif, M.J.; Ashfaq, M.; Aslam, M. and Saeed, S. (2010): Host plants distribution and overwintering of cotton mealybug (*Phenacoccus solenopsis*, Hemiptera: Pseudococcidae). International Journal of Agriculture and Biology, 12(3): 421–425.

Abd El-Wareth, H. M. (2016): The First Record of the Cotton Mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) as a new insect pest on tomato, pepper, eggplant, maize plants and population density at Fayoum Governorate in Egypt. Egypt. Acad. J. Biolog. Sci., 9(3): 41–48 Doi: 10.21608/EAJBSA.2016.12773.

Abdelatef, G. M.; Selim, N. M.M. and Abd EL-Wanis, M. M. (2022):

Thiamethoxam Efficiency Applied with Two Spray Techniques against *Bemisia tabaci* (Genn.) on cucumber plants production under greenhouse conditions and it is residues in soil, Leaves, and Fruits. Egypt. Acad. J. Biolog. Sci., 14(1):91-98. DOI:10.21608/eajbsf.2022.226725

Abd-Rabou, S.; Germain, J.F. and Malausa, T. (2010): *Phenacoccus parvus* Morrison et *P. solenopsis* Tinsley, deux Cochenilles nouvelles pour l'Egypte (Hemiptera: Pseudococcidae). Bulletin de la Société Entomologique de France, 115(4): 509–510. DOI:10.3406/bsef.2010.2861

Amarasekare, K.G.; Chong, J.H.; Epsky, N.D. and Mannion, C.M. (2008): Effect of Temperature on the Life History of the Mealybug *Paracoccus marginatus* (Hemiptera: Pseudococcidae). J. Econ. Entomol., 101(6):1798-1804. DOI:10.1603/0022-0493-101.6.1798

Amer, M. E. S.; Abd El-Mageed, S. A.M. and Abdel-Razak, S. I. (2023): Coccoidea infesting goldenberry, Physalis peruviana L. with ecological and control studies of the cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera, Coccomorpha, Pseudocccidae) from Egypt. Journal of Entomology and Zoology Studies, 11(2): 42-51. DOI:10.22271/j.ento.2023.v11.i2a.9179

Ata, T. E. (2019): Biological Studies on the Cotton Mealybug *Phenacoccus solenopsis* Tinsley, (Hemiptera: Pseudococcidae) under the Laboratory Condition. J. Plant Prot. and Path., Mansoura Univ., 10 (3): 195-198. DOI:10.21608/jppp.2019.40926

Badran, A. B.; Ammar, M. I. and Mousa, E. A. M. (2018): Efficiency of colored sticky traps on the population of certain sap-sucking insects on cucumber plants in greenhouses. J. Plant Prot. and Path., Mansoura Univ., 9 (7): 411– 415. DOI:10.21608/jppp.2018.42807.

Ben-Dov, Y.; Miller, D.R. and Gibson, G.A.P. (2009): Scale Net: A Searchable Information System on Scale Insects. Available on-line. http://www.sel.barc.usda.gov/scalenet/scalenet.htm. Accessed 8 August 2009.

Culik, M.P. and Gullan, P.J. (2005): A new pest of tomato and other records of mealybugs (Hemiptera: Pseudococcidae) from Esperito Santo, Brazil. Zootaxa, 964(1): 1–8. DOI:10.11646/zootaxa.964.1.1

El-Sarand, E. A. (2017): The cotton mealybug, *Phenacoccus solenopsis* Tinsley (Homoptera :Pseudococcidae) as a new insect on soybean plants in Egypt and its population dynamic. J. Plant Prot. and Path., Mansoura Univ., 8 (11): 545 – 548. DOI:10.21608/jppp.2017.46603

Farag, M.M.A.; Shehata, N.F. and Mahmoud, Y.A. (2009): The 4th Conference on Recent Technologies in Agriculture, Cairo University.

Kumar, S.; Kular, J.S.; Mahal, M.S. and Dhawan, A.K. (2013): Life table of *Phenacoccus solenopsis* Tinsley (Pseudococcidae: Hemiptera) on various phonological stages of cotton. African Journal of Agricultural Research, 8 (17): 1669–1676. DOI: 10.5897/AJAR12.772.

Miller, D.R.; Ben-Dov, Y. and Gibson, G.A.P. (2016): Scale net: A Searchable Information System on Scale Insects. Biology, Environmental Science.,3(1999). DOI:10.15162/0425-1016/808

Prishanthini, M. and Vinobaba, M. (2014): Efficacy of some selected botanical extracts against the Cotton mealybug *Phenacoccus solenopsis* (Tinsley) (Hemiptera: Pseudococcidae). International Journal of Scientific and Research Publications, 4 (3): 1–6.

Richmond, V. P.; Wagner, J. P. and McCroskey, J. C. (1983): The impact of perceptions of leadership style, use of power, and conflict management style on organizational outcomes. Communication Quarterly, 31: 27-36.

SAS Institute (1999): SAS User's guide: Statistics SAS Inst., Cary, N.

Sevacherian, V.; Toscano, N.C.; Steenwy, R.A.; Sharma, K.R.K. and Sanders, R.R. (1977): Forecasting pink bollworm emergence by thermal summation. Environ. Entomol., 6:545-556.

Shah, T.N.; Agha, M.A. and Memon, N. (2015): Population dynamics of cotton mealybug, *Phenacoccus solepnosis* Tinsely in three talukas of district Sanghar (Sindh). J. Entomol. Zool. Studies., 3(5): 162-167.

Shehata, I. (2017): On the biology and thermal developmental requirements of the cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) in Egypt. Der Pharma Chemica, 9(10):39-46. https://doi.org/10.1080/03235408.2017.1357377

Yamamura, K. and Kiritani, K. (1998): A simple method to estimate the potential increase in the number of generations under global warming in temperate zones. Appl. Entomol. Zool., 33(2): 289-298. DOI:10.1303/aez.33.289

Zalom, F.; Goodell, P.; Wilson, L.; Barnett, W. and Bentley, W. (1983): Degree-Days, the calculation, and use of heat units in pest management: University of California Division of Agriculture and Natural Resources Leaflet 21373 CA, USA, 10.