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Distribution Of Phenacoccus Solenopsis Infesting Okra Plants: Evidence for Improving a Pest Scouting Method.

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Abstract

Understanding insect behavior is a prerequisite for establishing pest scouting tools for determining possible damage and implementing control measures for the cotton mealybug, *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae) on okra plants. Field trials were conducted to estimate the distribution modalities of *P. solenopsis* on plants in different cardinal directions, plant strata, leaf surfaces, and field depth (spaces from field boundaries), in a private okra field (Balady cultivar) at Esna district, Luxor Governorate during two consecutive seasons (2021 and 2022). Results revealed that *P. solenopsis* attacked okra plants, were observed from the first week of March through the end of July during each season, and occurred on all okra field directions in all plant levels and on leaf surfaces, on all the dates of weekly inspections. During the two seasons, there were highly significant differences in population, as well as infestation percentages in various cardinal directions, and very significant changes between the various stratums of plant and on leaf surfaces, as well as between the various distances from field boarders. *P. solenopsis* favors the lower leaf surface of the top stratum of the plant, in the south and east aspects, where its population was constantly abundant throughout the season, and pests more highly attacked okra plants distant from the farm borders than close plants over each season. The current information can be used to help design mealybug monitoring and control programs on okra plants.

Keywords: *Phenacoccus solenopsis*, population density, okra plants, distribution patterns and directional preference.

1. Introduction

Okra, *Abelmoschus esculentus* L. (Family: Malvaceae), is a major vegetable and economical crop in Egypt. Okra fruits are high in vitamins A, B, and C, as well as various mineral salts, and provide a wide range of nutritional and economic benefits[5]. The cotton mealybug, *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae) is among the several pests infesting okra plants[18] and a polyphagous pest[2]. Mealybugs are serious pests that damage the economies of crops worldwide[20]. *P. solenopsis* nymphs and female adults primarily attack leaves, flowers, fruits, main stems, and branches[8, 1]. This insect causes plant damage by sucking plant sap inducing plant deformation due to the pest's toxic saliva, and excreting large amounts of honeydew, which aids in the spread of sooty mould, and results

in dryness in affected plants by slowing photosynthesis, and reducing vegetative development[16]. A common sign of pest infestation is the presence and buildup of pest bodies in attacked okra areas. *P. solenopsis* is regarded as a significant vector for numerous viral diseases[17]. Mealybugs are notoriously difficult to eradicate because they congregate in protected regions, produce a waxy covering on their bodies, and most pesticides are ineffective. Mealybugs, on the other hand, have poor immobility that allows biological control to be successful[11]. Mealybugs, or Pseudo mealy bugs, are referred to as "hard to kill pests"[15].

The plant's cardinal directions influence insect flying, movement, and dispersal patterns. Most insects prefer to go along the east-west axis rather than the south-north axis[3]. This insect dispersal behaviour aids in the development of specific pest control monitoring and recommendation systems. Insects try to land on branches that match their optimum requirements for heat, sunlight, and humidity based on their habitat requirements. Monitoring from these locations aids in developing earlier pest management strategies[9].

There is no data on the spatial pattern of *P. solenopsis* in the literature. As a result, the current study was performed to define the factors influencing *P. solenopsis* distribution on okra plants. This work can be utilized to develop pest monitoring and control systems.

2. Materials And Methods

Many scientists have utilized different insect expressions to explain the pest's population size. In this study, the two manifestations, "insect numbers" and "infestation percentages," were applied**.**

2.1 Population estimates:

2.1.1- Seasonal incidence of P. solenopsis infesting okra plants:

Field studies were conducted in a private okra field during two growing seasons (2021 and 2022) at Esna district, Luxor Governorate. The okra plants were grown on a field area of one feddan (4200 m2) (Balady cultivar) in the first week of February. The planting area was split into four replicates, each divided in a randomized complete blocks pattern. Regular conventional farming procedures were followed, except for the pest management block. Okra field was divided into four main directions (east, west, north, and south); the level of infestation was counted on two strata per plant, i.e., (top and bottom parts).

All sampling was done from 6400 leaves, *i.e.* (4 replicates x 5 leaves per stratum x 2 levels x 4 directions x 40 times) over a two-season period by a random method in the field. This pest appeared on okra plants when the age of the plants reached 30 days after the agriculture date. Samples were assessed weekly and continued throughout the cultivation season. Samples were collected regularly and transported to the laboratory in plastic bags for examination under a stereo-microscope. The number of alive individuals on the upper and lower surfaces of okra leaves was counted and recorded, with each being inspected at every inspection time. To depict the pest population size, the number of total alive individuals on 10 leaves ± standard error (SE) was counted and recorded across weekly inspection dates. The pest was identified by specialists at the Department of Scale Insects and Mealybugs, Plant Protection Research Institute, Agricultural Research Center at Giza, Egypt.

2.2 - Infestation incidence percentages:

The infestation incidence percentages by *P. solenopsis* in different directions of the okra field were estimated according to the formula of Bertin *et al.*[4].

$$I = (a / A) \times 100.$$

Where, I = Percentage of infestation incidence.

a = The number of affected plants where the insect first evidenced.

A = Total number of inspected plants (Uninfested + Infested) in each inspection date.

The following formula by Mahmoud[10] was used to calculate directional preference for both the population density and infestation incidences as follows:

$F_1 = E - W$ $\qquad$ $F_2 = N - S$

$\tan.Q = F_2 / F_1$

F_1: The mean number of insects in the east minus the mean number of insects in the west, if the former is greater, and vice versa, if the latter is greater.

F_2: The mean number of insects in the north minus insect numbers in the south, if the former is higher, and vice versa if the latter is higher. The tangent is shown in the figure, with the relevant values acquired from the mathematical table.
tan.Q: The tan of the nook formed by the two powers.
The impact of okra field depth on *P. solenopsis* distribution was investigated on the Balady cultivar in a private field of about two feddans in Esna district, Luxor governorate, during two seasons (2021 and 2022). The long distances from the field boundary of okra fields are 5, 10, 15, 20, and 25 meters.
For each distance, four replicates were chosen and labeled; these replicates were almost identical in vegetative growth and received the same agricultural methods, with no chemical control methods applied before or during the experiment. To perform the study, ten leaves from each replicate, *i.e.*, 40 leaves per distance, were randomly selected from each distance at weekly intervals. The samples were collected on a regular basis from various directions and levels of the plant, and were immediately transferred to the laboratory in polyethylene bags for inspection using a stereo-microscope. The total number of alive insects on okra leaves was counted and recorded against each inspection date. To term on the population size, the mean number of total individuals per 10 leaves ± standard error (SE) was determined and recorded over weekly dates.
The amount of variation (±) of *P. solenopsis* individuals on the leaves of okra plants on the far boarders of the field in comparison to okra plants on the nearby boarders of the field at a distance of 5 m was calculated using the equation:

$$\text{Variation \%} = \frac{A - B}{A} \times 100$$

Where, A = average number of *P. solenopsis* individuals found on the leaves of okra plants in the far boarders of field

B= average number of *P. solenopsis* individuals on the leaves of okra plants in the close boarders of field at a distance (5 m).
All data was statistically analyzed using a computer (MSTATC Program software[13]).

3. Result And Discussion

To evaluate insect population and infestation incidences, leaf samples of okra plants infested with *P. solenopsis* exhibited significant changes in distribution patterns, not only on plant leaves, but also across field boarders. These unusual findings could indicate that insect distribution is influenced by factors other than wind direction and velocity, which are well-known in this regard. The variables were assessed as affecting the insect distribution and spread in okra fields:

3.1 Horizontal distribution of okra plants (cardinal directions):

3.1.1- Seasonal incidence of P. solenopsis on okra plants:

Data represented in Table-1, showed the monthly mean cardinal distribution of *P. solenopsis* (average number of individuals per 10 leaves) at Esna district, Luxor Governorate, Egypt, from March to June in two consecutive seasons (2021 and 2022). During the two years, the southern location of the field had greater population densities, as a general average (245.72 ± 16.78 and 252.47 ± 17.91 individuals per 10 leaves), followed by the eastern location (235.43 ± 16.14 and 241.50 ± 17.10 individuals per 10 leaves). On the other hand, the west direction was intermediately infested as an average (232.94 ± 15.79 and 238.92 ± 16.74 individuals per 10 leaves). But the least population was observed on the north side (229.73 ± 15.48 and 235.62 ± 16.42 individuals per 10 leaves), respectively, Table-1. As well, the highest total population density by *P. solenopsis* was reported during June month as an average (384.18 ± 11.20 and 408.71 ± 10.85 per 10 leaves), while the lowest one was observed through March month (65.45 ± 5.11 and 57.77 ± 4.41) during the two seasons, respectively.
When the comparisons were done for each month independently, there were very significant differences in mean populations between cardinal directions for the months of April and June, except for the months of March, May, and July, where there were no changes across each season. In addition, highly significant variations in the population means were detected across main cardinal trends for analyses of the pooled effect over the entire season in each of the two seasons, where the L.S.D values were (8.96 and 7.41), respectively. Also, to compare the average population numbers in the four main

directions between the two seasons, the analysis of variance displayed highly significant changes (L.S.D. value was 4.23), Table-1.
The data show that for the two seasons, leaves pooled from the south site of the okra field constituted (26.03–26.07%) of the overall total, followed by the east side (24.94–24.94%), the west direction (24.68–24.67%), and the north location (24.34–24.33%), as shown in Table-1.

3.1.2- The percentages of infestation by P. solenopsis:
As shown in Table-2, the southern side of the okra field had the highest percentages of infestation incidences by *P. solenopsis* during the two years, with an average (51.00 ± 1.40 and 51.00 ± 1.21%), followed by the eastern parts (44.38 ± 1.42 and 44.75 ± 1.31%), respectively. In contrast, infestation incidences by pest were lower in the north location (36.25 ± 1.54 and 36.50 ± 1.49 %), respectively. Furthermore, the west location had a moderate infestation with an average (41.38 ± 1.35 and 41.75 ± 1.19%), respectively. As for the highest percentages of infestation by *P. solenopsis* were recorded, on July month during the first season (2021) as an average (49.38 ± 1.59%), and through the second season (2022) in May month, as being (51.25 ± 1.17%), but the lowest percentages were observed during March month (29.38 ± 1.72 and 33.13 ± 1.68%), during the two seasons, respectively.
When the comparisons were done for each month independently, there were highly significant differences in the percentages of infestation incidences on cardinal sides in all the tested months, in each season, as well in the mutual impact in the entire season, when the L.S.D values were (3.05 and 2.86), for the two seasons, respectively. On the contrary, when the comparison between the percentages of infestation in the four main directions between the two seasons was made, the analysis of variance revealed no differences, as shown in Table-2.
Data offered those leaves compiled from the south direction of the okra field amounted to (29.48 – 29.31%) of the infestation, next by the east location (25.65 – 25.72%), west site (23.92 – 23.99%), and the north side (20.95 – 20.98%) during the two seasons, respectively, are shown in Table-2.
Based on current data for the two seasons of study and relying mostly on significant differences, the southern and eastern sides of the okra plants appear to be more preferred for infestation with *P. solenopsis* and have the highest population densities than the other sides. The variances in distribution could be explained by the combined influence of wind direction and the length of time leaves are exposed to the sun's rays. This conclusion is logical because the main wind direction in the study area was north-west, which causes more freshly emerging pest crawlers to drift southeastwards, where they can collect for feeding and growth. The combined impact of wind direction and the period of leaves exposure to the sun rays could explain these discrepancies in their distributions[7], perhaps because of the direction of the wind, which blows from north to south, carrying freshly hatched crawlers and allowing each other to land on the leaves in those orientations[6].
P. solenopsis prefers to accumulate on the east southern side of the okra plants, which is usually more exposed to the sun and relatively warmer than the other sides, with angles of 81º 9' 47.11" and 81º 17' 3.29" for total alive population, and 78º 30' 12.36" and 78º 18' 38.27" for percentages of infestation incidences during the two seasons, respectively, according to the results in Graph-1. These results were agreeable with Shehata and Moussa[18] who reported that the highest population density tends to accumulate on the plants on the east side.

3.2- Vertical distribution of P. solenopsis on the plant (Strata):
Results presented in Table-3, showed that the top stratum leaves of the plant were the most preferred strata by *P. solenopsis* as a general average (137.84 ± 9.32 and 141.42 ± 9.88 of individuals per 5 leaves) and the bottom stratum leaves were the least infestation by insects with an average (98.11 ± 6.71 and 100.71 ± 7.14 of scale per 5 leaves) during the two seasons, respectively. Furthermore, the highest average of *P. solenopsis* population occurred in the top stratum in June month with an average of (223.03 ± 12.92 and 237.25 ± 12.41 individuals per 5 leaves), but, the lowest population was observed at the bottom leaves in March, with an average of (27.38 ± 4.43 and 24.17 ± 3.83) during the two seasons, respectively, Table-3.
When the comparisons were made separately for each month, there were very significant differences in mean populations between stratums in all of the inspected months in each season, as well as in the pooled influence over the entire season, when the L.S.D values were (4.65 and 3.74, respectively) for the two seasons. In addition, the analysis of variance revealed extremely significant differences

(L.S.D. value of 3.05), when comparing the average numbers of population in different stratums of plant between the two seasons, Table-3.
Insect populations on the top regions of the plant's leaves comprised for (58.42 and 58.41%) of the total number of insects, while rates on the bottom leaves of the plant ranged between (41.58 and 41.59 %) during two seasons. The changes in the insect distribution patterns on plants in the various strata, which could be related to differences in the environmental conditions, wind direction, sunlight, and other variables. Also, the top stratum leaves provide a good refuge for insects, particularly during feeding and growth. *P. solenopsis* favours the top layer of leaves on the okra plant. These findings are consistent with those of Shehata and Moussa[18], who found that the top levels of the plant were more appealing to *P. solenopsis* than the other parts.

3.3- Leaf surface:

Results in Table-4, showed that the lower surfaces of leaves were more heavily infested by *P. solenopsis* than the upper ones. The general averages for this pest per 10 leaves on the lower surface were 141.73 ± 10.40 and 145.71 ± 11.05 for two seasons of study, respectively. While the general averages of *P. solenopsis* on the upper surfaces of leaves were 94.23 ± 5.93 and 96.41 ± 6.26 for two years, respectively. In addition, the highest average of *P. solenopsis* population was found in the lower surface leaves in June month, with averages of (238.58 ± 12.35 and 253.54 ± 11.26 individuals per 10 leaves), while the lowest population densities was found in the upper surface leaves in March, with averages of (26.62 ± 4.11 and 23.49 ± 3.54) during the two seasons, respectively (Table-4).

When the differentiations were made separately for each month, there were highly significant differences between the population means at both leaf surfaces in all of the tested months, in each season, as well as in the combined influence over the entire season, when the L.S.D values were (5.13 and 4.22), respectively. In contrast, when the population means at both leaf surfaces were compared over the two seasons, the analysis of variance revealed no differences, as shown in Table-4.

For two seasons, the insect population on the upper surface of the leaf accounted for (60.07 and 60.18%) of the total number of insects, whereas the lower surface of the leaf accounted for (39.93 and 39.82%), respectively. In general, the percentages of the pest population on leaf surfaces were similar in both seasons, which may be attributable to similar environmental conditions (Table-4).

This indicates that *P. solenopsis* is photonegative, meaning that the lower surface of the leaf receives less sunlight than the upper surface. The above findings show that *P. solenopsis* favours the lower surface of the okra leaf over the upper surface. According to Nabil[14] and Mohamed[12], they reported that the population of *P. solenopsis* was higher on the lower leaf surface than on the upper surface. This supports the theory that the distribution of mealybugs on the same plant is linked to the plant's age, the location of infestation, and the structural strength of the plant.

The distribution patterns of *P. solenopsis* on okra leaves were shown in Table-5, as aggregated counts across the two consecutive seasons. In each of the two seasons, the data revealed that the insect population occurred in various directions and on all strata of okra plants and leaf surfaces during the entire season. Furthermore, during the two seasons, the population densities and infestation incidences of pests considerably vary from one direction to the next, and from one stratum of plant to another, and also on leaf surfaces throughout each season. *P. solenopsis* population density and infestation incidences were highest on the lower surface of the top stratum of the plant on the east southern side, compared to the other directions and stratums. The temperature difference between the various features of the plants is the most likely cause of this distribution manner.

Although the plant receives the same amount of direct sunshine in east and west directions, the air temperature in the morning is cooler than in the afternoon. The combination of high air temperature and intense sunlight may result in a decrease in infestation to the west. These findings were derived from the original seasonal abundance data, which consisted of 10 leaves sampled in each of the four cardinal directions. Each direction sub-sample, and every stratum sub-sub-sample, was evaluated separately, and the results were merged to determine *P. solenopsis* seasonal incidence.

3.4- Field depth:

3.4.1- Seasonal activity of P. solenopsis on okra plants:

Results are represented in Table-6, revealed that the fluctuation of *P. solenopsis* seasonal activity in field circumstances is determined by field depth, *i.e.*, the space between the field's edge and the okra plant. *P. solenopsis* was found to be more prevalent in okra plants farther away from the field boundary than in those closer to it. Furthermore, the general average for the population per 10 leaves was higher at 25 m as mean (282.33 ± 19.10 and 287.71 ± 20.19 individuals), followed by plants positioned at 20 m (271.62 ± 18.40 and 278.54 ± 19.48 individuals), followed by plants located at 15 m (254.34 ± 17.30 and 260.95 ± 18.35 individuals). On contrast, the plants on distance 5 m closest from the field boarder were the least infested by pest (191.64 ± 12.97 and 188.72 ± 13.22 per 10 leaves). But, the distance of plants at 15 m was moderately infested by pests as mean (236.49 ± 16.12 and 242.77 ± 17.15 per 10 leaves) is represented in Table-6.

When the comparisons were done for each month separately, analysis of variance revealed that there were very significant differences in mean populations between different distances from okra field boarders in all of the tested months, in each season, as well as in the mutual impact, over the entire season, when the L.S.D values were (9.46 and 7.59), respectively. In addition, the analysis of variance revealed significant differences between the two seasons when comparing average population numbers at different distances from okra field boarders (L.S.D. value of 3.94), Table-6.

The highest average of *P. solenopsis* population was observed at a distance of 25 m from the farm boarder in June month with an averages of (464.01 ± 25.56 and 493.06 ± 23.77 individuals per 10 leaves), but, the lowest one occurred at a distance of 5 m from the boarder in March, with an average (54.35 ± 8.84 and 46.04 ± 7.31) during the two seasons, respectively, Table-6. As for the leaves gathered from the okra plants at a distance of 25 m away from the field boarder, they accounted for (24.27 – 24.38 % of the total population), followed by the plants located at 20 m (23.35 – 23.60 %), at 15 m (21.86 – 22.11%), at 10 m (20.33 – 20.57 %) and at 5 m (15.50 – 14.99 %) during the two seasons, respectively, are represented in Table-6.

As shown in Table-6, the percentage of increase in *P. solenopsis* individuals on leaves of okra plants on away boarders of field at a distance of 25 m is estimated to account for 32.12–34.41% when compared to okra plants on nearby boarders of field at a distance of 5 m, followed by plants at 20 m (29.44–32.25%), 15 m (24.65–27.68%), and 10 m ((18.96–22.27%) over the two seasons, respectively. Therefore, the percentages of *P. solenopsis* population densities for each of the two seasons were similar, which could be related to similar environmental conditions.

3.4.2- The percentages of infestation by P. solenopsis:

Data presented in Table-7, showed that the okra plants closest to the field boundary were observed to have the least percentage of infestation incidences by *P. solenopsis* than those furthest from it. Moreover, the general average for percentages of infestation incidences was higher at a space of 25 m as mean (49.88 ± 1.35 and 50.50 ± 1.14%), followed by the plants placed at 20 m (43.25 ± 1.41 and 43.63 ± 1.31%), and followed by the plants located at 15 m (41.38 ± 1.29 and 41.44 ± 1.15%). However, the plants nearest to the field on space at 5 m were the least infested by pests (35.38 ± 1.51 and 35.88 ± 1.43%). While, the distance between plants at 10 m were moderately as mean (40.25 ± 1.34 and 40.63 ± 1.20%) as shown in Table-7.

Analysis of variance revealed that there were very significant variations in infestation incidence percentages between different spaces from okra field boarders in all of the examined months, in every season, as well in the pooled influence, over the whole season, whenever the L.S.D calculations were (2.79 and 2.61) for two seasons, respectively. On the contrary, when the comparison between percentages of infestation in various spaces of okra field boarders between the two seasons was conducted, the analysis of variance revealed no variations between the both seasons, as shown in Table-7.

As for the lowest infestation incidences by *P. solenopsis*, they took place at a length of 5 m from the field boarder in March with an average of (20.63 ± 3.70 and 24.38 ± 3.53%). However, the highest one was found at a distance of 25 m from the boarder in July during the first season by (55.63 ±

3.02%) and in May over the second season by (57.50 ± 2.33) for the two seasons, respectively, Table-7.

Data in Table-7, showed that the percentage of increment in infestation incidence percentages by *P. solenopsis* at 25 m was represented by a higher percentage (29.07–28.96%), than that of the okra plants at 5 m, followed by the plants at 20 m (18.21–17.77%), at 15 m (14.50–13.42%) and at 10 m (12.11–11.69%) through the two seasons, respectively.

It is obvious that okra plants closest to field borders may be subject to the least infestation and have the lowest population density when compared to plants located further away. These variations may be attributed to variations in climatic factors between the inside and outside of the farm boundary, as well as other reasons such as wind trend, irrigation, sun rays, irrigation, and plant density.

The present study contributed to a better understanding of *P. solenopsis* dispersion behaviour on the okra plant leaves, as well as indicated the locations where *P. solenopsis* can be discovered, which aids in determining the level of infestation. Results mentioned that okra plants are subject to infestation by *P. solenopsis* were observed on all okra field sides in all strata of plant and on surfaces of leaves on all the dates of weekly examinations. For the two seasons, there were highly significant differences in population, as well as infestation percentages on various trends, as well as extremely significant differences between the various strata of plants and on leaf surfaces, as well as between various spaces on field borders. *P. solenopsis* prefers the lower leaf surface of the plant's top stratum, in the south and east parts, in which its population was consistently large across the season, and okra plants farther away from the farm boarders were more infested by pests than nearby plants over each season.

These studies could have significant value. Foremost, population censuses should be conducted on the plants that are heavily infested, saving time and effort. Second, the chemical spraying programme might be tweaked to focus on the plants' most infested areas. However, experiments should be performed to validate these suppositions.

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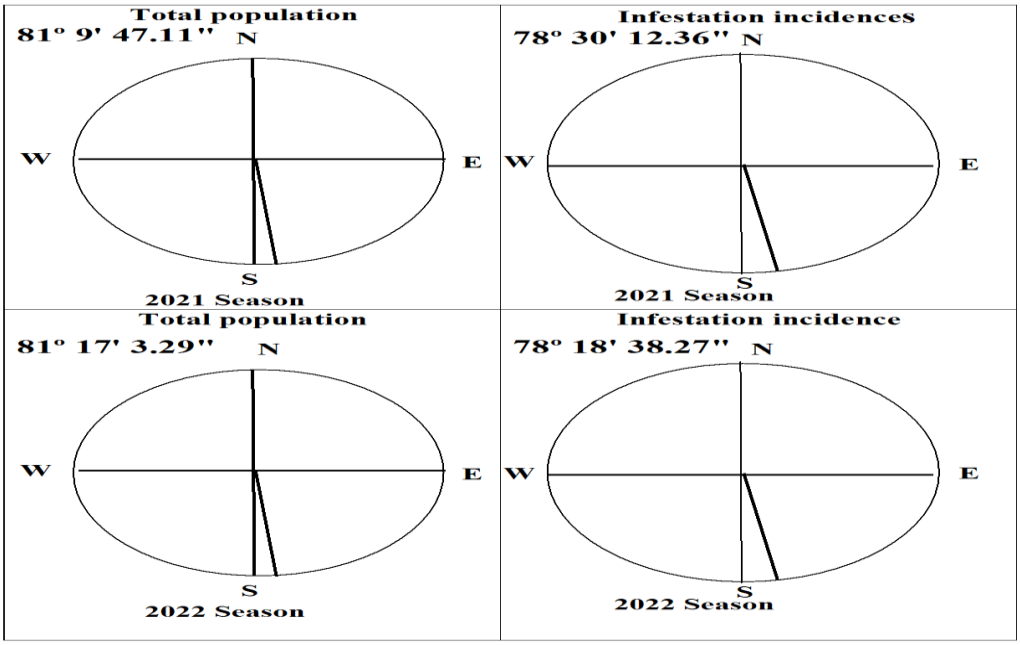
Table-1: Monthly mean numbers of P. solenopsis total population occurred in different directions of okra plants at Esna district, Luxor Governorate during the successive two seasons (2021 and 2022).

Years	Seasons	Okra plant directions				Total	Mean ± S.E.	L.S.D. %5	% From overall seasonal total			
		North	South	East	West				North	South	East	West
		Average no. of *P. solenopsis* individuals per 10 leaves ± S.E.										
2021 season	March	63.10 ± 10.15	67.76 ± 10.73	65.89 ± 10.54	65.04 ± 10.45	261.80	65.45 ± 5.11	N.S.	24.10	25.88	25.17	24.84
	April	170.04 ± 12.01	176.09 ± 11.74	166.89 ± 11.64	168.18 ± 11.94	681.20	170.30 ± 5.79	6.79 *	24.96	25.85	24.50	24.69
	May	336.27 ± 18.30	345.56 ± 17.16	338.14 ± 18.17	334.03 ± 18.56	1354.00	338.50 ± 8.83	N.S.	24.84	25.52	24.97	24.67
	June	363.41 ± 22.54	409.69 ±22.59	385.64 ± 22.83	377.98 ± 22.17	1536.72	384.18 ± 11.20	11.73 **	23.65	26.66	25.09	24.60
	July	215.83 ± 34.26	229.47 ± 38.02	220.60 ± 36.18	219.49 ± 34.94	885.40	221.35 ± 17.52	N.S.	24.38	25.92	24.91	24.79
	General average	229.73 ± 15.48	245.72 ± 16.78	235.43 ± 16.14	232.94 ± 15.79	943.82	235.96 ± 8.00	8.96 **	24.34	26.03	24.94	24.68
2022 season	March	55.68 ± 8.74	59.86 ± 9.28	58.16 ± 9.10	57.40 ± 9.01	231.09	57.77 ± 4.41	N.S.	24.09	25.90	25.17	24.84
	April	155.54 ± 7.05	161.17 ± 6.49	152.71 ± 6.86	153.63 ± 6.86	623.05	155.76 ± 3.35	4.74 **	24.96	25.87	24.51	24.66
	May	359.33 ± 16.35	369.96 ± 15.63	361.22 ± 16.09	357.17 ± 16.85	1447.68	361.92 ± 7.95	N.S.	24.82	25.56	24.95	24.67
	June	386.73 ± 21.97	436.41 ± 22.13	409.88 ± 21.77	401.82 ± 21.07	1634.84	408.71 ± 10.85	11.02 **	23.66	26.69	25.07	24.58
	July	220.81 ± 32.91	234.93 ± 36.86	225.55 ± 34.79	224.57 ± 33.52	905.87	226.47 ± 16.87	N.S.	24.38	25.93	24.90	24.79
	General average	235.62 ± 16.42	252.47 ± 17.91	241.50 ± 17.10	238.92 ± 16.74	968.50	242.13 ± 8.49	7.41**	24.33	26.07	24.94	24.67
L.S.D. between the two seasons at 0.05 level = 4.23**												

Table-2: *Monthly mean percentages of infestation incidences by P. solenopsis occurred in different directions of okra plants at Esna district, Luxor Governorate during the successive two seasons (2021 and 2022).*

Years	Seasons	Okra plant directions				Total	Mean ± S.E.	L.S.D. %5	% From overall seasonal total			
		North	South	East	West				North	South	East	West
		Average percentages of infestation incidences by *P. solenopsis* ± S.E.										
2021 season	March	21.88 ± 3.90	36.88 ± 2.70	30.63 ± 3.47	28.13 ± 2.77	117.50	29.38 ± 1.72	5.78 **	18.62	31.38	26.06	23.94
	April	35.63 ± 2.41	49.38 ± 1.93	43.13 ± 1.98	39.38 ± 1.93	167.50	41.88 ± 1.20	5.63 **	21.27	29.48	25.75	23.51
	May	40.00 ± 2.04	55.63 ± 1.82	47.50 ± 1.71	44.38 ± 1.82	187.50	46.88 ± 1.15	5.43 **	21.33	29.67	25.33	23.67
	June	41.88 ± 3.06	56.25 ± 2.72	50.00 ± 3.03	46.88 ± 2.85	195.00	48.75 ± 1.57	6.52 **	21.47	28.85	25.64	24.04
	July	41.88 ± 3.06	56.88 ± 3.26	50.63 ± 2.66	48.13 ± 2.77	197.50	49.38 ± 1.59	6.15 **	21.20	28.80	25.63	24.37
	General average	36.25 ± 1.54	51.00 ± 1.40	44.38 ± 1.42	41.38 ± 1.35	173.00	43.25 ± 0.77	3.05 **	20.95	29.48	25.65	23.92
2022 season	March	25.63 ± 3.76	40.63 ± 2.66	34.38 ± 3.29	31.88 ± 2.77	132.50	33.13 ± 1.68	6.68 **	19.34	30.66	25.94	24.06
	April	36.25 ± 2.39	50.00 ± 1.58	43.75 ± 2.02	40.00 ± 1.58	170.00	42.50 ± 1.14	4.74 **	21.32	29.41	25.74	23.53
	May	44.38 ± 1.82	58.75 ± 2.21	52.50 ± 1.71	49.38 ± 2.13	205.00	51.25 ± 1.17	5.49 **	21.65	28.66	25.61	24.09
	June	42.50 ± 3.10	56.88 ± 2.18	50.63 ± 2.66	47.50 ± 2.14	197.50	49.38 ± 1.41	4.75 **	21.52	28.80	25.63	24.05
	July	33.75 ± 3.28	48.75 ± 2.39	42.50 ± 2.50	40.00 ± 2.24	165.00	41.25 ± 1.45	6.82 **	20.45	29.55	25.76	24.24
	General average	36.50 ± 1.49	51.00 ± 1.21	44.75 ± 1.31	41.75 ± 1.19	174.00	43.50 ± 0.71	2.86 **	20.98	29.31	25.72	23.99
L.S.D. between the two seasons at 0.05 level = N.S.												



Graph-1: *Preferable cardinal directions of P. solenopsis infestation on okra plants at Esna district, Luxor Governorate during 2021 and 2022 seasons.*

Table-3: *Monthly mean numbers of P. solenopsis total population in the different strata of okra plant through the two consecutive seasons of (2021 and 2022) at Esna district, Luxor Governorate.*

Data of inspection		Okra plant strata			Mean ± S.E.	L.S.D at %5	%From overall seasonal total	
		Average no. of total population per 5 leaves ± S.E.		Total per 10 leaves				
		Top	Bottom				Top	Bottom
2021 Season	March	38.07 ± 6.02	27.38 ± 4.43	65.45	32.73 ± 3.80	3.18 **	58.16	41.84
	April	100.13 ± 6.84	70.17 ± 4.95	170.30	85.15 ± 4.95	3.83 **	58.80	41.20
	May	197.29 ± 10.30	141.21 ± 7.69	338.50	169.25 ± 8.08	6.31 **	58.29	41.71
	June	223.03 ± 12.92	161.15 ± 9.49	384.18	192.09 ± 9.65	6.92 **	58.05	41.95
	July	130.69 ± 21.17	90.66 ± 14.65	221.35	110.68 ± 13.16	12.03 **	59.04	40.96
	General average	137.84 ± 9.32	98.11 ± 6.71	235.96	117.98 ± 5.94	4.65 **	58.42	41.58
2022 Season	March	33.60 ± 5.20	24.17 ± 3.83	57.77	28.89 ± 3.28	2.15 **	58.16	41.84
	April	91.67 ± 3.93	64.09 ± 2.83	155.76	77.88 ± 3.43	2.36 **	58.85	41.15
	May	210.93 ± 9.16	150.99 ± 6.99	361.92	180.96 ± 7.82	5.66 **	58.28	41.72

	June	237.25 ± 12.41	171.46 ± 9.18	408.71	204.35 ± 9.62	5.46 **	58.05	41.95
	July	133.63 ± 20.34	92.84 ± 14.15	226.47	113.23 ± 12.73	8.86 **	59.01	40.99
	General average	141.42 ± 9.88	100.71 ± 7.14	242.13	121.06 ± 6.29	3.74 **	58.41	41.59
L.S.D. between the two seasons at 0.05 level = 3.05 **								

Table-4: *Monthly mean numbers of P. solenopsis total population occurred on the surfaces of okra leaf through the two consecutive seasons of (2021 and 2022) at Esna district, Luxor Governorate.*

Data of inspection		Okra leaf surfaces			Mean ± S.E.	L.S.D at %5	%From overall seasonal total	
		Average no. of total population per 10 leaves ± S.E.		Total				
		Lower	Upper				Lower	Upper
2021 Season	March	38.83 ± 6.36	26.62 ± 4.11	65.45	32.73 ± 3.88	3.41 **	59.33	40.67
	April	89.68 ± 7.28	80.62 ± 5.81	170.30	85.15 ± 4.65	4.37 **	52.66	47.34
	May	219.72 ± 12.38	118.78 ± 6.03	338.50	169.25 ± 11.32	11.22 **	64.91	35.09
	June	238.58 ± 12.35	145.60 ± 11.02	384.18	192.09 ± 11.66	9.61 **	62.10	37.90
	July	121.84 ± 22.43	99.51 ± 13.52	221.35	110.68 ± 13.04	12.43 **	55.05	44.95
	General average	141.73 ± 10.40	94.23 ± 5.93	235.96	117.98 ± 6.26	5.13 **	60.07	39.93
2022 Season	March	34.28 ± 5.49	23.49 ± 3.54	57.77	28.89 ± 3.36	2.37 **	59.33	40.67
	April	81.34 ± 4.41	74.43 ± 4.09	155.76	77.88 ± 3.02	3.03 **	52.22	47.78
	May	234.85 ± 11.23	127.07 ± 5.46	361.92	180.96 ± 11.46	9.75 **	64.89	35.11
	June	253.54 ± 11.26	155.17 ± 11.25	408.71	204.35 ± 11.80	8.43 **	62.04	37.96
	July	124.56 ± 21.77	101.91 ± 12.83	226.47	113.23 ± 12.60	9.46 **	55.00	45.00
	General average	145.71 ± 11.05	96.41 ± 6.26	242.13	121.06 ± 6.62	4.22 **	60.18	39.82
L.S.D. between the two seasons at 0.05 level = N.S.								

Table-5: *The distribution of P. solenopsis per 10 leaves, given as a general average count that was done during the two successive seasons of (2021-202) at Esna district, Luxor Governorate.*

Directions	Strata	Surfaces	Average no. of individuals per 10 leaves					
			First season (2021)			Second season (2022)		
North	Top	Lower	157.8	270.5	229.7	162.1	277.4	235.6
		Upper	112.8			115.3		
	Bottom	Lower	104.0	188.9		106.8	193.8	
		Upper	85.0			87.0		
South	Top	Lower	191.1	289.0	245.7	196.7	296.8	252.5

		Upper	97.9			100.1		
	Bottom	Lower	120.7	202.5		124.3	208.1	
		Upper	81.8			83.8		
East	Top	Lower	173.6	271.7	235.4	178.4	278.6	241.5
		Upper	98.0			100.2		
	Bottom	Lower	120.4	199.2		123.8	204.4	
		Upper	78.8			80.6		
West	Top	Lower	158.8	271.5	232.9	163.1	278.5	238.9
		Upper	112.7			115.4		
	Bottom	Lower	107.5	194.3		110.4	199.4	
		Upper	86.9			89.0		
General average			235.96			242.13		

Table-6: *Monthly mean numbers of P. solenopsis total population in the different distances from boarders of okra plants during consecutive seasons of (2021 and 2022) at Esna district, Luxor Governorate.*

Season	Date of sampling	Different distances from okra field					Total	Mean	L.S.D.% 5	% From overall seasonal total				
		5 m	10 m	15 m	20 m	25 m				5 m	10 m	15 m	20 m	25 m
		Average no. of *P. solenopsis* individuals per 10 plants ± S.E.												
2021	March	54.35 ± 8.84	63.84 ± 10.21	70.94 ± 11.26	75.92 ± 12.04	78.21 ± 12.32	343.25	68.65 ± 4.90	6.06 **	15.83	18.60	20.67	22.12	22.79
	April	138.18 ± 9.88	173.49 ± 12.05	182.09 ± 12.50	195.36 ± 13.50	204.01 ± 13.62	893.14	178.63 ± 5.98	5.44 **	15.47	19.42	20.39	21.87	22.84
	May	276.19 ± 15.34	343.45 ± 18.22	362.83 ± 19.05	388.16 ± 20.70	398.86 ± 20.60	1769.48	353.90 ± 9.53	10.43 **	15.61	19.41	20.50	21.94	22.54
	June	312.82 ± 18.02	378.89 ± 23.84	416.09 ± 23.93	440.93 ± 25.51	464.01 ± 25.56	2012.74	402.55 ± 11.86	12.74 **	15.54	18.82	20.67	21.91	23.05
	July	176.68 ± 27.87	222.76 ± 36.20	239.77 ± 39.07	257.71 ± 41.66	266.55 ± 43.61	1163.49	232.70 ± 16.97	22.88 **	15.19	19.15	20.61	22.15	22.91
	General average	191.64 ± 12.97	236.49 ± 16.12	254.34 ± 17.30	271.62 ± 18.40	282.33 ± 19.10	1236.42	247.28 ± 7.69	9.46 **	15.50	20.33	21.86	23.35	24.27
	* The amount of change (±) %	------	(+) 18.96	(+) 24.65	(+) 29.44	(+) 32.12								
2022	March	46.04 ± 7.31	56.35 ± 8.80	62.62 ± 9.72	66.99 ± 10.39	69.28 ± 10.67	301.29	60.26 ± 4.23	4.18 **	15.28	18.70	20.78	22.23	23.00
	April	121.19 ± 5.50	158.61 ± 6.85	166.64 ± 7.19	178.81 ± 7.85	183.74 ± 7.67	808.98	161.80 ± 3.96	4.31 **	14.98	19.61	20.60	22.10	22.71
	May	283.43 ± 13.33	367.31 ± 16.48	387.84 ± 16.92	414.82 ± 18.34	422.47 ± 17.53	1875.87	375.17 ± 9.16	9.79 **	15.11	19.58	20.68	22.11	22.52
	June	319.29 ± 16.33	403.58 ± 23.76	442.43 ± 22.79	468.62 ± 24.09	493.06 ± 23.77	2126.98	425.40 ± 11.90	12.74 **	15.01	18.97	20.80	22.03	23.18
	July	173.64 ± 25.73	228.02 ± 34.97	245.19 ± 37.56	263.43 ± 39.92	270.02 ± 41.78	1180.31	236.06 ± 16.34	16.81 **	14.71	19.32	20.77	22.32	22.88
	General average	188.72 ± 13.22	242.77 ± 17.15	260.95 ± 18.35	278.54 ± 19.48	287.71 ± 20.19	1258.69	251.74 ± 8.13	7.59 **	14.99	20.57	22.11	23.60	24.38

	* The amount of change (±) %	------	(+) 22.27	(+) 27.68	(+) 32.25	(+) 34.41	
L.S.D. between the two seasons at 0.05 level = 3.94*							

* refers to the percentage of increase (+) or decrease (-) in number of *P. solenopsis* individuals on 10 okra plants on far boarders of field as compared to okra plants nearby boarders of field at distance (5 m).

Table-7: *Monthly mean percentages of infestation incidences by P. solenopsis in the different distances from boarders of okra plants during consecutive seasons of (2021 and 2022) at Esna district, Luxor Governorate.*

Season	Date of sampling	Different distances from okra field					Total	Mean	L.S.D. %5	% From overall seasonal total				
		5 m	10 m	15 m	20 m	25 m				5 m	10 m	15 m	20 m	25 m
		Average percentages of infestation incidences by *P. solenopsis* ± S.E.												
2021	March	20.63 ± 3.70	26.88 ± 2.70	27.50 ± 2.66	29.38 ± 3.35	35.63 ± 2.41	140.00	28.00 ± 1.42	4.71 **	14.73	19.20	19.64	20.98	25.45
	April	34.38 ± 2.41	38.13 ± 2.09	40.63 ± 1.70	41.88 ± 2.09	48.13 ± 1.88	203.13	40.63 ± 1.03	4.85 **	16.92	18.77	20.00	20.62	23.69
	May	38.75 ± 2.02	43.13 ± 1.98	43.75 ± 2.02	46.25 ± 1.80	54.38 ± 1.82	226.25	45.25 ± 1.02	5.54 **	17.13	19.06	19.34	20.44	24.03
	June	41.25 ± 3.01	46.25 ± 2.72	47.50 ± 2.33	49.38 ± 2.95	55.63 ± 2.58	240.00	48.00 ± 1.30	6.20 **	17.19	19.27	19.79	20.57	23.18
	July	41.88 ± 2.62	46.88 ± 2.54	47.50 ± 2.50	49.38 ± 2.49	55.63 ± 3.02	241.25	48.25 ± 1.26	5.71 **	17.36	19.43	19.69	20.47	23.06
	General average	35.38 ± 1.51	40.25 ± 1.34	41.38 ± 1.29	43.25 ± 1.41	49.88 ± 1.35	210.13	42.03 ± 0.66	2.79 **	16.84	19.16	19.69	20.58	23.74
	* The amount of change (±) %	------	(+) 12.11	(+) 14.50	(+) 18.21	(+) 29.07								
2022	March	24.38 ± 3.53	30.63 ± 2.66	30.00 ± 2.58	33.13 ± 3.13	41.88 ± 2.45	160.00	32.00 ± 1.42	5.44 **	15.23	19.14	18.75	20.70	26.17
	April	35.00 ±	38.75 ±	42.50 ±	42.50 ±	49.38 ±	208.13	41.63 ±	4.88 **	16.82	18.62	20.42	20.42	23.72

	2.42	1.80	1.71	2.14	1.70		1.01						
May	43.13 ± 1.98	48.13 ± 2.45	47.03 ± 2.01	51.25 ± 2.02	57.50 ± 2.33	247.03	49.41 ± 1.09	5.64 **	17.46	19.48	19.04	20.75	23.28
June	41.88 ± 3.06	46.88 ± 1.98	48.13 ± 1.88	50.00 ± 2.58	56.25 ± 2.02	243.13	48.63 ± 1.15	4.26 **	17.22	19.28	19.79	20.57	23.14
July	35.00 ± 2.74	38.75 ± 2.02	39.53 ± 1.88	41.25 ± 2.39	47.50 ± 2.14	202.03	40.41 ± 1.09	6.07 **	17.32	19.18	19.57	20.42	23.51
General average	35.88 ± 1.43	40.63 ± 1.20	41.44 ± 1.15	43.63 ± 1.31	50.50 ± 1.14	212.06	42.41 ± 0.61	2.61 **	16.92	19.16	19.54	20.57	23.81
* The amount of change (±) %	------	(+) 11.69	(+) 13.42	(+) 17.77	(+) 28.96								
L.S.D. between the two seasons at 0.05 level = N.S.													

* refers to the percentage of increase (+) or decrease (-) in % infestation incidences by *P. solenopsis* on okra plants on far boarders of field as compared to okra plants nearby boarders of field at distance (5 m).

References

1. Aheer, G.M., Z. Shah and M. Saeed, 2009. Seasonal history and biology of cotton mealy bug, *Phenacoccus solenopsis* Tinsley. *J. Agric. Res.* 47: 423–431.
2. Babasaheb, B.F. and S.S. Suroshe, 2015. The invasive mealybug, *Phenacoccus solenopsis* Tinsely, a threat to tropical and subtropical agricultural and horticultural production systems- *A review*. *Crop Protection*, 69: 34-43.
3. Bancroft, J.S., 2005. Dispersal and abundance of *Lygus hesperus* in field crop. *Environ. Ent*., 34: 1517-1523.
4. Bertin, S.; V. Cavalieri; C. Grazino and D. Bosco (2010): Survey of mealybug (Hemiptera: Pseudococcidae) vectors of Ampelo virus and Viti virus in vineyards of north western Italy. Phytoparasitica, 38(4):401-409.
5. Diaz, F.A. and M.A.S. Ortegon, 1997. Fruit characteristics and yield of new okra hybrids. Subtrop. *Plant Sci*. 49: 8-11.
6. Draz, K.A.A., G.B. El-Saadany, M.A. Mansour, A.G. Hashem and A.A. E. Darwish, 2011. Ecological studies on the purple scale insect, *Lepidosaphes beckii* (Hemiptera: Diaspididae) on navel orange trees at El-Behaira Governorate, Egypt in 2009 and 2010 seasons. *J. Agric. and Environ. Sci.,* Damanhour Univ., Egypt, 10(1): 25- 40 pp.
7. Eraki, M.M., 1998. Ecological studies on some scale insects infesting date palm trees. Ph.D. Thesis, Fac. of Agric., *Al-Azhar Univ., Egypt*, 127 pp.
8. Hodgson, C., G. Abbas, M.J. Arif, S. Saeed and H. Karar, 2008. *Phenacoccus solenopsis* Tinsley (Sternorrhyncha: Coccoidea: Pseudococcidae), an invasivemealybug damaging cotton in Pakistan and India, with a discussion on seasonal morphological variation. *Zootaxa* 1913: 1-35. https://doi.org/10.1146/annurev.en.36.010191.001441
9. Karar, H., J. Arif, A. Hameed, A. Ali, M. Hussain, F.H. Shah and S. Ahmad, 2013. Effect of Cardinal Directions and Weather Factors on Population Dynamics of Mango Mealybug, *Drosicha mangiferae* (Green) (Margarodidae: Homoptera) on Chaunsa Cultivar of Mango. *Pak. J. Zool.*, vol. 45(6): 1541-1547 pp.
10. Mahmoud, S.F., 1981. Ecological studies on California red scale and purple scale insects on citrus, and the effect of some recent insecticides on them and their parasites. *M.Sc. Thesis, Fac. of Agric., Cairo Univ., Egypt*.
11. Mani, M., A. Krishnamoorthy and C. Shivaraju, 2011. Biological suppression of major mealybug species on horticultural crops in *India Journal of Horticultural Sciences*, Vol 6 (2).
12. Mohamed, G.S., 2021. Studies on Population Dynamic, Biology of The Cotton Mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) and Its Natural Enemies as A New Insect on Okra Plant, (*Abelmoschus esculentus* (L.) Moench) at Qena Governorate, Egypt. *Egypt. Acad. J. Biolog. Sci*., 14(3): 1-16.
13. MSTATC, 1980. A Microcomputer Program of the Design Management and Analysis of Agronomic Research Experiments. *Michigan State Univ., USA*.
14. Nabil, H.A., 2017. Ecological studies on cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Sternorrhyncha: Coccoidea: Pseudococcidae) on eggplant at Sharkia Governorate, Egypt. Egypt. *Acad. J. Biol. Sci*., 10(7): 195-206.
15. Saad, L.H.A., 2021. Efficacy of some insecticides against cotton mealybug *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae). Ph. D. Thesis, *Faculty of Agriculture, Mansoura University, Egypt*, 151 pp.
16. Sahayaraj, K., V. Kumar and P.B. Avery, 2014. Functional response of *Rhynocoris kumarii* (Hemiptera: Reduviidae) to different population densities of *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae) recorded in the laboratory. *Eur. J. Entomol*. 112: 69-74.
17. Shah, T.N., M.A. Agha and N. Memon, 2015. Population dynamics of cotton mealybug, *Phenacoccus solepnosis* Tinsely in three talukas of district Sanghar (Sindh). *J Entomo Zool Stu*. 3(5):162-167.
18. Shehata, I.E., 2017. On the biology and thermal developmental requirements of the cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) in Egypt. *Archives of Phytopathology and Plant Protection*, 50 (11–12): 613–628.

19. Shehata, I.E. and S.F.M. Moussa, 2018. Infestation rate and management of the cotton mealybug, *phenacoccus solenopsis* (Hemiptera: *Pseudococcidae*). *Bioscience Research*, 15(4): 4252-4266.
20. Sreedevi, G., Y.G. Prasad, M. Prabhakar, G.R. Rao, S. Vennila and B. Venkatewarlu, 2013. Bioclimatic thresholds, thermal constants and survival of mealybug, *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae) in response to constant temperatures on hibiscus. *PLoS ONE*, 8(9): e75636.