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Population Ecology of the Cotton Mealybug, *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae) on Okra Plants in Luxor Region, Egypt

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ABSTRACT

Among several pests infesting okra plants, the cotton mealybug, *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae) is considered one of the most destructive pests. Field trials were conducted in a private field in Esna District, Luxor Governorate, Egypt, during two successive growing seasons (2021 and 2022) with the aim to study the seasonal fluctuation of *P. solenopsis* population infesting okra plants (Balady cultivar). Furthermore, the impacts of both climatic conditions and plant age on the seasonal variation of the tested insect pest were determined. The results indicated that *P. solenopsis* infested okra plants from the first week of March until the end of July, and had three peaks of activity per season, which were recorded in the first week of April, third week of May, and fourth week of June. The mean total population density of *P. solenopsis* per 10 leaves over the whole first season was 235.96±16.05 individuals and for the second season, it was 242.13±17.01 individuals. June was the most favourable month for *P. solenopsis* population increase (as measured during weekly inspections), while March was the least favorable in both growing seasons. Pooled effects of environmental conditions and plant ages had a strong relationship with *P. solenopsis* population density, with an Explained Variance (EV) of 93.26% in the first season and 95.09% in the second season, during the two seasons. Daily mean relative humidity was the most effective variable in explaining changes in the population density of *P. solenopsis* for the 1st season (2021), while the it was the major element influencing the changes in population in the 2nd season. On the other hand, the daily maximum temperature was clearly the least effective factor in population changes during both seasons. The data presented here can aid to monitor the oscillations in the population density of this pest.

Keywords: *Abelmoschus esculentus* L., Environmental conditions, Plant age Population density.

INTRODUCTION

Okra, *Abelmoschus esculentus* L. (Family: Malvaceae) is an important vegetable crop as well as an economic crop in Egypt. Okra fruits are a major source of vitamins A, B, and C, as well as some minerals, which has a lot of nutritional and economic value (Diaz and Ortegon, 1997). Okra plants at different growth stages are attacked by serious insect pest species. Among these pests, the cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) is a polyphagous and economically important pest (Babasaheb and Suroshe, 2015; Shehata, 2017). Mealybugs are major pests that cause economic damage to many crops around the world (Sreedevi *et al*., 2013; Ricupero *et al*., 2021). Nymphs and female

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adults of *P. solenopsis* mainly attack leaves and also infest flowers, fruits, main stems, and branches (Hodgson *et al*., 2008; Aheer *et al*., 2009). This pest impacts infested plants by sucking the sap with its mouth parts, causing plant deformation due to the pest's toxic saliva and excreting vast amounts of honeydew, which encourages the spread of sooty mould. This slows photosynthesis and reduces vegetative growth of afflicted plants, resulting in chlorosis, stunting, deformation, dryness, and death of plants (Sahayaraj *et al*., 2014). *Phenacoccus solenopsis* is also regarded as an essential vector for many viral diseases (Saeed *et al*., 2007; Shah *et al*., 2015).

Mealybugs are classified as "hard to kill insects" (Saad, 2021). Controlling their population using foliar insecticides becomes extremely difficult due to their capacity to cluster on plant buds and apexes and produce a waxy covering on their bodies (Joshi *et al*., 2010). In order to plan an effective control programme against *P. solenopsis*, it is necessary to know its bio-ecology, including population fluctuation under several climatic conditions that affect the different phenological stages. Abiotic factors also profoundly affect the population fluctuation of insect pests of crops (Woiwod, 1997), and temperature impacts insect activity and growth rate (Lamb, 1992). Relative humidity and temperature, as well as the mealybug's life span and development, all influence its fecundity (Kumar *et al*., 2013).

Mealybug infestation can also be influenced by plant phenology (plant age). Phenology, for example, indicates when a crop is most likely to be infested by mealybugs and which crops would be the most severely affected (Williams and Dixon, 2007). As well, Mohamed (2021) mentioned that the distribution of *P. solenopsis* on the okra plant is related to the age of the plant, the place of infestation, and the vigour of the plant's structure.

The present study was conducted in order to assess the influence of weather conditions and plant phenology on the seasonal incidences of *P. solenopsis* infesting okra plants in Luxor Region, Egypt, conditions over two growing seasons of 2021 and 2022. The findings can be used in designing the appropriate pest control programs.

MATERIALS AND METHODS

Seasonal Abundance of *P. solenopsis* Infesting Okra Plants

Field experiments were carried out in a private okra field at Esna District, Luxor Governorate, during two successive growing seasons of 2021 and 2022. Luxor is 99 m above sea level, with latitude 25.67º N and longitude 32.71º E. A field area of about 4,200 m^2 was cultivated with okra plants (Balady cultivar). The planting area was divided into four replicates, each of 5×5 m that were sampled. Okra was sown on the designated date (first week of February every season). Regular conventional agricultural practices are normally conducted, without using pesticides.

This pest infested okra plants 30 days after sowing. Random samples of 40 okra leaves (10 leaves from each replicate) were taken weekly and continued throughout the cultivation season. Samples were collected from the different stages of the pest from the different parts of the infested okra plants in order to be identified at the Department of Scale Insects and Mealybugs, Plant Protection Research Institute, Agricultural Research Center at Giza, Egypt.

Samples of leaves were collected randomly from different directions and strata of the plant in the experimental area. Samples were collected on a regular basis and transported to the laboratory in plastic bags for examination under a stereo-microscope. The numbers of alive insects on the upper and lower surfaces of okra leaves were counted and recorded next to each other on every examination date. The numbers of alive individuals on 10 leaves

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were counted and recorded to represent every inspection date ±Standard Error (SE), to express the population size of the pest.

We collected a total of 40 samples on 40 dates over a two-season period. All sampling was conducted from 1,600 leaves, i.e. (10 leaves×4 replicates×40 dates) across the two seasons, i.e. 800 leaves per season.

Estimation of the Mealybug-Days, Cumulative Mealybug-Days, and Accumulated Numbers

Mealybug-days are an estimate of the total number of mealybugs counted if sampling had occurred every day, and these counts had been added together. It assumes a linear trend between the first sample and the subsequent sample. This technique was estimated according to the equation provided by Ruppel (1983):

$$D= t\times[(a_1 + a_2)/2] \quad (1)$$

Where, D= Mealybug-days??, a_1= Mealybug count per 10 leaves on the previous examination date, a_2= Mealybug count per 10 leaves on the next examination date, and t= the number of days separating the two examination dates.

With more than two sampling periods, cumulative mealybug-days can be calculated. This is the cumulative addition of all the mealybug-days, allowing a cumulative trend to be produced, *i.e.*, $t\times[(a_1+a_2)/2]+ t\times[(a_2+a_3)/2]+t\times [(a_3+a_4)/2]$... This method has been used by El-Fatih (2006) on cereal aphids on barely.

To make comparisons between two seasons of the study easier, the seasonal incidence of *P. solenopsis* was estimated. This was done by adding together the *P. solenopsis* mealybug counts from the 10 leaves sampled each week, over the whole season, to produce the "total accumulated mealybug population". Throughout two seasons, this was carried out. The percentage of the accumulated mealybug population was also calculated on each sample date as the sum of mealybugs counted up to that date, divided by the total accumulated mealybug population. According to Bakry (2018), these percentages were used to reflect the general trend of population density.

The weekly variation rate in the population was determined according to the mode of Bakry *et al*. (2020) as follows:

$$R= (w/W) \quad (2)$$

Where, R= Rate of weekly variation, w= Mean mealybug count across samples current week, and W= Mean mealybug count across samples previous week.

Influences of Climatic Factors (Abiotic) and Plant Ages (Biotic) on the Seasonal Activity of *P. solenopsis* on Okra Plants

The mean daily maximum temperature (X_1), minimum temperature (X_2), mean percentage relative humidity (X_3) and dew point (X_4) of Luxor Governorate during two successive growing seasons (2021 and 2022) were acquired from the Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center (ARC), Ministry of Agriculture, at Giza. Correlations were assessed between mealybug counts on the sample date and the mean of the climate factor over the 7 days prior to the mealybug count. The biotic factor examined was associated with plant phenology, *i.e.*, the plant's age in days (X_5) at the time of mealybug counts. Correlations of these factors with mealybug population density were modelled using a third degree polynomial function, as follows:

$$Y = a+ b_1X_5+ b_2X_5^2+ b_3X_5^3 \quad (3)$$

Where, Y is mealybug population density, and a, b_1, b_2 and b_3 are constants. This method was applied by Mohamed *et al*. (2021).

Both correlation and regression analyses were used to relate each of the independent variables (abiotic or biotic factors) to the dependent variable (*P. solenopsis* population density) according to the method of Fisher (1950). The percentage Explained Variance

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(EV%) in *P. solenopsis* population density explained by each independent variable was calculated using MSTATC Program software (1980) and SPSS (1999), and the data was presented graphically using Microsoft Excel 2010.

RESULTS AND DISCUSSION

The mealybug, *P. solenopsis* infested all parts of the okra plants and caused many plant abnormalities, as illustrated in Figure 1.

Seasonal Abundance of *P. solenopsis* Population on Okra Plants

Data presented in Tables 1 and 2 and illustrated in Figures 2 and 3 showed that three peaks of activity were exhibited in the first week of April, third week of May, and fourth week of June, when the mean population densities were 198.40±20.25, 382.00±38.99 and 432.80±44.17 individuals per 10 leaves during the first season, respectively. Also, the mean population density during the second season was 172.33±12.51, 412.90±29.97 and 477.00±34.62 individuals per 10 leaves, respectively. The same findings were noticed by Nabil (2017) in Sharkia Governorate, Egypt, who mentioned that *P. solenopsis* had three or four peaks on eggplant per season. In Egypt, Abd-El-Razzik (2018) demonstrated that *P. solenopsis* had two peaks and three overlapping generations on mulberry trees in both years under field conditions. Nabil and Hegab (2019) revealed that *P. solenopsis* had two to three generations on okra plants during the two seasons, respectively. Mohamed (2021) in Qena, Egypt, reported that *P. solenop*sis had three generations per season on okra under field conditions.

Results offered that the total alive population density at different inspected dates during each season displayed statistically highly significant variances, where the LSD values were 40.00 and 31.11 throughout both seasons, respectively (Tables 1 and 2). The mean total live population density of *P. solenopsis* through the whole first growing season was smaller (235.96±16.05 individuals per 10 leaves) than in the second one (242.13±17.01 individuals per 10 leaves). The statistical analysis of the data revealed that there were highly significant differences in the numbers of total live population between the two growing seasons (F-value was 205.41 and the LSD value was 28.01). This could be due to the influence of climatic parameters and okra plant phenology, as shown in Tables 1 and 2 and Figures 2 and 3. According to Dent (1991), the rate of insect population abundance at any given location is influenced by environmental variables.

The lowest population density at different stages and total alive population of *P. solenopsis* were recorded during March in both seasons. This may be attributed to the high relative humidity and decrease in temperature (maximum and minimum) in this month, which are expected to dramatically affect the activity and behaviour of the insect and on the rate of growth and infestation. This period coincided with vegetative growth and branching. In contrast, the maximum values of insect population were observed in June, during the two seasons of study, which may be due to the influence of favourable factors (such as environmental conditions and plant phenology, etc.). Accordingly, Elbahrawy ***et al***. (2020) in Giza, Egypt, recorded that the highest *P. solenopsis* population on tomato plants (*Solanum lycopersicum* L.) occurred in the second week of June, after which the population decreased gradually.

Weekly Abundance of Accumulated Numbers of *P. solenopsis*

To make comparisons over the season and growth period easier, the population density

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Figure 1. Regular photographs of *Phenacoccus solenopsis* infesting okra plants: (A) Infestation symptoms and damages of *P. solenopsis* on leaves; (B) *P. solenopsis* nymphs and adults attacking stem, (C and D) Damage symptoms caused by *P. solenopsis* nymphs and adults on fruits at late stage.

was reported as a percentage of counted numbers in each inspected week compared to the total for the whole growing season. The percentage of mealybugs accumulated for each successive week was also linked to the season's progress and hence okra development (Tables 1 and 2; Figures 2 and 3).

These indicate that the highest percentages of *P. solenopsis* numbers were observed in the first week of April, third week of May, and fourth week of June over the season. During the first growing season, it was 4.20, 8.09, and 9.17% of the total, respectively. Over the second growing season, 3.56, 8.53, and 9.85% (as a percentage of the total cumulative numbers) were found, respectively. This could be because of the

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Table 1. Weekly mean numbers, mealybug days, % cumulative no., cumulative mealybug-days and rate of weekly variation of *Phenacoccus solenopsis* on okra plants in relation to climatic factors at Esna District, Luxor Governorate during the first growing season (2021).

Sampling date (2021)		Plant age (in days)	Mealybugs count per 10 leaves±SE[a]	% No mealybugs from overall seasonal total	Cumulative numbers per 10 leaves	% Cumulative	Mealybug -Days	Cumulative mealybug-days	Rate of weekly variation	Max temp	Min temp	% RH	Dew point
March,	1st	30	15.80 ± 1.61	0.33	15.80	0.33	55.30	55.30	—	23.75	10.35	50.06	6.03
	2nd	37	48.40 ± 4.94	1.03	64.20	1.36	338.80	394.10	3.06	28.33	12.14	38.59	4.60
	3rd	44	77.60 ± 7.92	1.64	141.80	3.00	441.00	835.10	1.60	29.05	14.44	43.70	8.70
	4th	51	120.00 ± 12.25	2.54	261.80	5.55	691.60	1526.70	1.55	26.43	8.73	47.50	7.55
April	1st	61	198.40 ± 20.25	4.20	460.20	9.75	1114.40	2641.10	1.65	30.89	17.33	36.71	7.06
	2nd	68	167.60 ± 167.60	3.55	627.80	13.30	1281.00	3922.10	0.84	33.57	17.70	31.54	7.48
	3rd	75	115.20 ± 11.76	2.44	743.00	15.74	989.80	4911.90	0.69	28.41	16.83	36.04	6.12
	4th	82	200.00 ± 20.41	4.24	943.00	19.98	1103.20	6015.10	1.74	32.46	19.21	37.03	9.75
May	1st	91	284.00 ± 28.99	6.02	1227.00	26.00	1694.00	7709.10	1.42	35.43	20.74	30.12	8.18
	2nd	98	358.00 ± 36.54	7.59	1585.00	33.59	2247.00	9956.10	1.26	36.35	21.75	27.67	8.75
	3rd	105	382.00 ± 38.99	8.09	1967.00	41.68	2590.00	12546.10	1.07	37.54	21.90	28.96	9.02
	4th	112	330.00 ± 33.68	6.99	2297.00	48.67	2492.00	15038.10	0.86	40.62	26.98	31.24	12.01
June	1st	122	296.40 ± 30.25	6.28	2593.40	54.96	2192.40	17230.50	0.90	37.22	23.72	27.95	9.42
	2nd	129	377.52 ± 38.53	8.00	2970.92	62.95	2358.72	19589.22	1.27	40.63	25.40	27.07	11.56
	3rd	136	430.00 ± 43.89	9.11	3400.92	72.07	2826.32	22415.54	1.14	42.30	27.30	23.84	11.71
	4th	143	432.80 ± 44.17	9.17	3833.72	81.24	3019.80	25435.34	1.01	40.16	25.87	28.19	12.72
July	1st	152	420.00 ± 42.87	8.90	4253.72	90.14	2984.80	28420.14	0.97	41.05	25.25	27.40	12.12
	2nd	159	253.40 ± 25.86	5.37	4507.12	95.51	2356.90	30777.04	0.60	40.63	26.43	24.11	10.09
	3rd	166	134.40 ± 13.72	2.85	4641.52	98.36	1357.30	32134.34	0.53	40.00	27.70	30.33	11.85
	4th	173	77.60 ± 7.92	1.64	4719.12	100.00	742.00	32876.34	0.58	40.87	27.62	28.79	11.31
	Total		4719.12	100			32876.34						
General average			235.96 ± 16.05							35.29	20.87	32.84	9.30

[a] The differences in the number of mealybug individuals between inspected dates and the F-value was 96.00 and the LSD value at 0.05 level was 40.00**.

Table 2. Weekly mean numbers, mealybug days, % cumulative no., cumulative mealybug-days and rate of weekly variation of *Phenacoccus solenopsis* on okra plants in relation to climatic factors at Esna District, Luxor Governorate during the second growing season (2022).

Sampling date (2022)		Plant age (in days)	Mealybugs count per 10 leaves±SE[a]	% No mealybugs from overall seasonal total	Cumulative numbers per 10 leaves	% Cumulative	Mealybug -Days	Cumulative mealybug-days	Rate of weekly variation	Max temp	Min temp	% RH	Dew point
March	1st	30	12.92 ± 0.94	0.27	12.92	0.27	45.21	45.21	—	24.13	10.71	44.29	4.29
	2nd	37	42.41 ± 3.08	0.88	55.33	1.14	296.88	342.09	3.28	25.87	10.48	42.13	3.66
	3rd	44	71.82 ± 5.21	1.48	127.15	2.63	399.80	741.90	1.69	31.90	13.65	30.86	3.77
	4th	51	103.94 ± 7.54	2.15	231.09	4.77	615.15	1357.05	1.45	33.10	16.43	32.86	5.87
April	1st	61	172.33 ± 12.51	3.56	403.42	8.33	966.94	2323.99	1.66	29.56	15.54	31.74	3.99
	2nd	68	139.73 ± 10.14	2.89	543.15	11.22	1092.22	3416.21	0.81	31.03	13.49	28.49	2.03
	3rd	75	138.00 ± 10.02	2.85	681.15	14.07	972.07	4388.27	0.99	31.43	14.92	25.30	2.45
	4th	82	172.98 ± 12.55	3.57	854.13	17.64	1088.44	5476.72	1.25	39.37	19.13	22.61	6.61
May	1st	91	300.18 ± 21.79	6.20	1154.31	23.84	1656.05	7132.77	1.74	38.33	22.16	22.59	5.38
	2nd	98	383.40 ± 27.83	7.92	1537.71	31.75	2392.51	9525.28	1.28	42.30	24.21	16.93	5.46
	3rd	105	412.90 ± 29.97	8.53	1950.61	40.28	2787.05	12312.33	1.08	40.00	25.63	21.47	7.45
	4th	112	351.20 ± 25.49	7.25	2301.81	47.53	2674.35	14986.68	0.85	40.16	23.49	25.14	9.46
June	1st	122	308.06 ± 22.36	6.36	2609.86	53.89	2307.40	17294.08	0.88	38.78	28.17	25.82	10.19
	2nd	129	393.22 ± 28.54	8.12	3003.08	62.01	2454.45	19748.53	1.28	39.52	25.16	24.47	9.30
	3rd	136	456.57 ± 33.14	9.43	3459.65	71.44	2974.25	22722.78	1.16	42.30	26.59	18.94	7.02
	4th	143	477.00 ± 34.62	9.85	3936.64	81.29	3267.47	25990.25	1.04	39.60	24.68	22.46	6.87
July	1st	152	416.38 ± 30.22	8.60	4353.02	89.89	3126.80	29117.05	0.87	41.11	27.53	23.14	8.22
	2nd	159	270.48 ± 19.63	5.59	4623.50	95.48	2404.01	31521.06	0.65	42.38	27.70	21.53	9.56
	3rd	166	136.72 ± 9.92	2.82	4760.22	98.30	1425.20	32946.26	0.51	40.32	27.14	24.67	10.76
	4th	173	82.30 ± 5.97	1.70	4842.51	100.00	766.54	33712.79	0.60	41.70	26.98	21.51	9.92
Total			4842.51	100			33712.79						
General average			242.13 ± 17.01							36.64	21.19	26.35	6.61

[a] The differences in the number of mealybug individuals between inspected dates, where the F-value was 189.83 and the LSD value at 0.05 level was 31.11**.

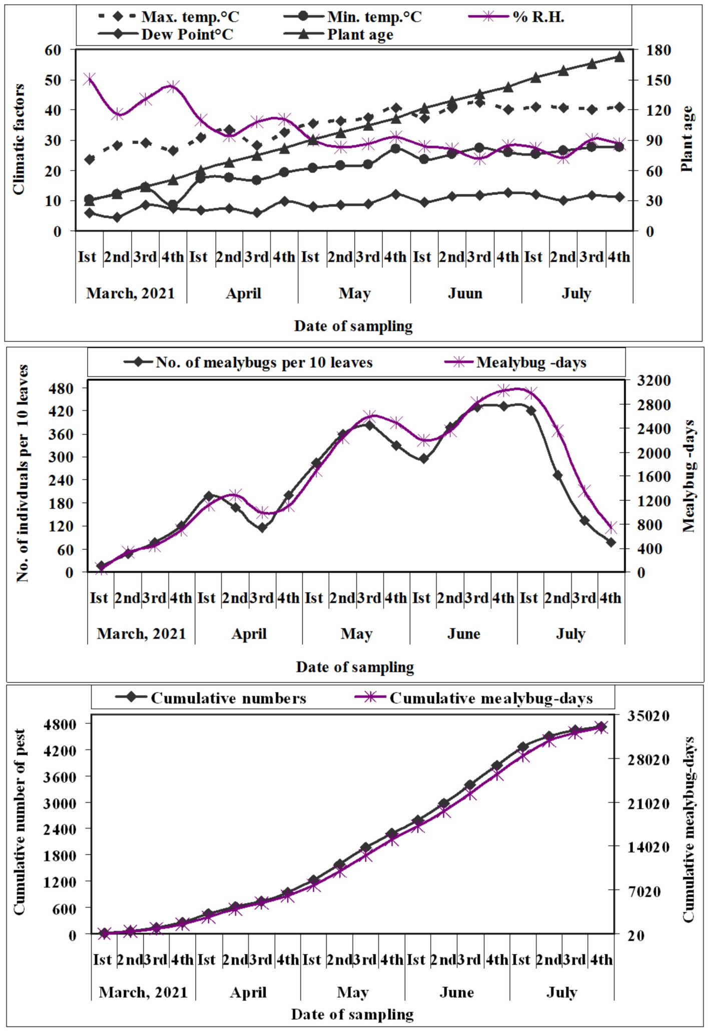

Figure 2. Weekly mean numbers of *Phenacoccus solenopsis* and the percentages of infestation on okra plants, with climatic factors, at Esna District, Luxor Governorate during the first season (2021).

appropriate climate factors at these times. The lowest percentages of *P. solenopsis* were 0.27 and 0.33%, on the first week of March in the two seasons, respectively.

According to the data, the cumulative numbers of *P. solenopsis* were 4,719.12 and 4,842.51 individuals for the two seasons, respectively (Table 3). The present results agree with those of Mohamed (2021) in Qena, Egypt, who reported that the highest percentages of *P. solenopsis* of the total monthly mean count were found to be 37.87 and 39.56% in June during the two seasons, respectively.

Cumulative Mealybug-Days

The mealybug-days and cumulative mealybug-days for *P. solenopsis* on okra leaves are presented in Tables 1 and 2 and illustrated in Figures 2 and 3 to express the cumulative impact of the changing environment on the mealybug population, as

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well as the cumulative impact of mealybugs on the phenology and development of okra plants. In the first growing season, the cumulative mealybug-days for *P. solenopsis* were lower (32,876.34) than in the second (33,712.79 mealybugs per season). In the second season, the higher number of mealybug-days had a greater impact on plant growth than in the first one.

Phenacoccus solenopsis Population Weekly Variation Rate

The weekly change rate in population is being used to determine the best week for insect activity, which is defined as the week with the highest growth in the insect population over the course of the season. When this parameter was greater than one, it indicated increased activity, smaller than one indicated decreased activity, and equal to 1 indicated no change in activity of the insect (Bakry *et al*., 2020).

As shown in Tables 1 and 2, the appropriate periods for weekly increase for the total live population appeared to be in the second, third and fourth weeks of March, the first and fourth weeks of April, the first, second, and third weeks of May, and the second, third, and fourth weeks of June, across each season (Tables 1 and 2).

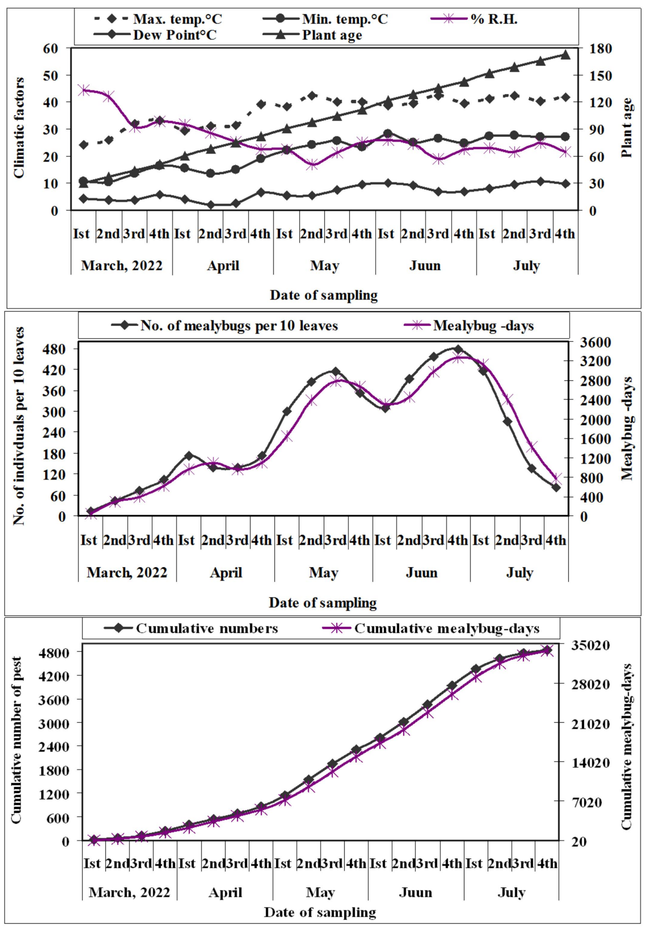

Figure 3. Weekly mean numbers of *Phenacoccus solenopsis* and the percentages of infestation on okra plants, with climatic factors, at Esna District, Luxor Governorate during the second season (2022).

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It was clear that the rate of weekly variation in population density of total *P. solenopsis* across weekly examination dates were larger than 1, suggesting climatic conditions were more appropriate for insect reproduction and growth. Furthermore, the best times for insect activity were similar across the two seasons.

Effect of the Weather Factors and Plant Ages on the Seasonal Activity of *P. solenopsis* Infesting Okra Plants

Influence of the Daily Mean Maximum Temperature

The simple correlation between the total live population of *P. solenopsis* and the daily mean maximum temperature was Significant and was positive (r values; +0.73 and +0.72) throughout the two seasons, respectively, as presented in Table 3. Likewise, the simple regression coefficient indicated that a 1˚C increment in the daily mean maximum temperature would increase the population by 17.46 and 18.83 individuals per 10 leaves for the two growing seasons, respectively (Table 3). According to Dhawan *et al*. (2009), there is a positive correlation between temperature and *P. solenopsis* development and spread, and hot weather encourages pest development and spread.

Our data revealed that the effect of daily mean maximum temperature had an insignificant negative impact and was weak with the total *P. solenopsis* population using the partial regression method (P. reg. value was -8.31) through the first growing season and had an insignificant positive effect (P. reg. value; 21.20) for the second one, as shown in Table 3.

The results indicated that the daily mean maximum temperature was the least effective variable in explaining total *P. solenopsis* population changes, with an EV of 0.24% during the first growing season and 1.73% in the second growing season (Table 3).

Influence of the Daily Mean Minimum Temperature

The simple correlation between the total insect population of *P. solenopsis* and the daily mean minimum temperature was very considerable and positive (+0.65 and +0.72) over the two seasons, respectively, as shown in Table 3. Likewise, the regression revealed that an increment of 1 ˚C in the daily mean minimum temperature would increase the population by 14.83 and 17.41 individuals per 10 leaves over the two seasons, respectively (Table 3).

The true influences of this weather variable on the total insect population of *P. solenopsis* are determined in Table 3. This showed an insignificant relationship (partial regression method value was -21.55) in the first season and a very important positive influence of 49.18 in the second one.

Minimum temperature accounted for 3.86% of the variance in the total *P. solenopsis* population during the first season, but it was the most effective variable in the second season, accounting for 18.82% of the variance (Table 3).

Effect of the Mean Relative Humidity

Data presented in Table 3 indicated that the correlation between relative humidity and the total population of *P. solenopsis* was highly significantly negative (r values; -0.74 and -0.71) during the two growing seasons, respectively. At the same time, the simple regression coefficient indicated that an increase of 1% in the mean relative humidity, would decrease the population by 13.75 and 15.09 individuals per 10 leaves during the first and second seasons, respectively (Table 3).

Partial regression showed that the influence of relative humidity on the total

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population activity of *P. solenopsis* was very significant and negative (P. reg. value; -31.22) across the first growing season and was unimportant and positive (P. reg. value; 15.93) for the second one. The mean relative humidity was the most effective on variance in total population, at 14.47% across the first season, but was responsible for certain changes in the second season, only explaining 2.33% of the variance (Table 3). Daily mean minimum temperature and relative humidity were thus shown to have a larger effect on the total population of *P. solenopsis* than daily mean maximum temperature. Zia and Haseeb (2019) stated that relative humidity plays an important factor in the population buildup of mealybug, *P. solenopsis*.

Effect of Dew Point

As seen in Table 3, the correlation between the dew point and total population activity was highly significantly positive with the total *P. solenopsis* population activity in the first growing season (r-value: 0.48), and an insignificant positive correlation (r-value: 0.25) during the second season. The regression coefficient indicated that every 1˚C increase in dew point would increase the population by 37.79 and 22.99 individuals per 10 leaves, for each of the two seasons, respectively.

Partial regression model (P. reg.) values in Table 3 show that dew point had a highly significant but positive effect (P. reg. value: 78.16) across the first season, while it had an important negative influence (P. reg. value: -65.97) throughout the second one. The dew point explained 13.51 and 10.50% of the variance in the total population of *P. solenopsis* for each season, respectively.

Effect of the Plant Age

The correlation between the total *P. solenopsis* population and plant age was significantly positive during the two growing seasons (r-values: 0.44 and 0.43, respectively). In addition, the estimated regression for the influence of this variable indicated that for every additional day of okra plant age, the total *P. solenopsis* population would increase by, respectively, 1.65 and 1.87 individuals per 10 leaves, as seen in Table 3.

The relationship between the okra plant age and the total *P. solenopsis* population was evaluated by partial regression (Table 3), which was significantly negative (P. reg. value: -2.38) for the first season and was unimportant and negative (P. reg. value: -1.63) across the second season. Plant age was the biotic variable that was responsible for the variance in the total population of *P. solenopsis* as 7.03 and 3.16% across each season, respectively.

Combined Effect of Four Climatic Factors and Plant Ages on the *P. solenopsis* Total Population

As shown in Table 3, the collective effect of these tested factors on the *P. solenopsis* total population was highly important with the F-values being 12.86 and 8.15 in the first and second growing seasons, respectively. The amounts of variance were 82.12 and 74.44% for the two growing seasons, respectively.

Effect of plant age

Plant age (X_5), when modelled using a three-degree polynomial ($Y= a+b_1X_5+b_2X_5^2+b_3X_5^3$), showed a high correlation with the log of *P. solenopsis* total population. As shown in Figure 4, the E.V. was 86.42 and 88.35% for the two growing seasons, respectively. The plant age model is the most effective in predicting the population density of *P. solenopsis* on okra plants. The nonlinear regression equations are as follows:

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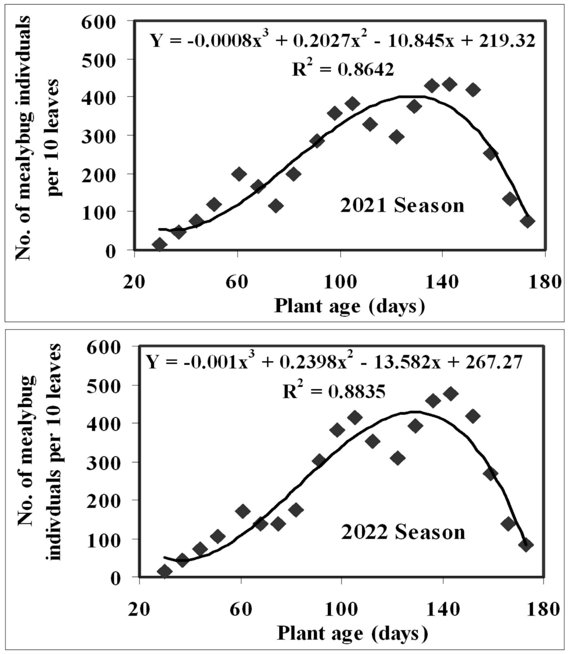

Figure 4. The polynomial relationship between plant age (X_5) and the insect population of *Phenacoccus solenopsis* during the two growing seasons (2021 and 2022).

First growing season (2021)

$Y= -0.0008\ X_5^3+0.2027\ X_5^2-10.845\ X_5+219.32$, $R^2 = 0.8642$ (4)

Second growing season (2022)

$Y= -0.001\ X_5^3\ +0.2398\ X_5^2-13.582\ X_5+267.27$, $R^2 = 0.8835$ (5)

(X5) refers to the Plant age, (Y) refers to P. Solenopsis total population.

The F-values were 33.95 and 40.43 in this regression for the two seasons, respectively (Table 3). When the plant age reached 143 days, the population of *P. solenopsis* recorded the maximum peak in the fourth week of June, being 432.80±44.17 per 10 leaves in the first season and 477.00±34.62 per 10 leaves in the second growing season.

Combined Effect of All Abiotic and Biotic Factors on the *P. solenopsis* Population

The combined effect of the abiotic factors (four climatic factors) and the biotic factor (phenology) was used to model *P. solenopsis* total population density in a multiple regression analysis. The explained variance was 93.26 and 95.09% in the two growing seasons. The model was highly significant, with F-values of 23.74 for the first growing season and 33.22 for the second (Table 3).

The results of the ecological study showed that, during the first season, the daily mean relative humidity was the most effective variable in explaining variations in the total *P. solenopsis* population, whereas the daily mean minimum temperature was the major element influencing the changes in population across the second season. Throughout both seasons, the daily mean maximum temperature was the least effective parameter influencing the pest population changes.

Most authors studied several experiments to investigate the impact of temperature and relative humidity on mealybugs. Abiotic factors exert a great influence on the growth, development, distribution, and population dynamics of insect pests (Clark, 2003). Other climatic factors beyond those

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of temperature and humidity could have also affected the mealybug population growth. Williams and Dixon (2007) mentioned that plant phenology can have considerable impact on the state of mealybug species infestation. Kumar *et al*. (2013) mentioned that there was a positive relationship among the mealybug population with temperature. Also, the optimum temperature and relative humidity combination for *P. solenopsis* growth was 35±1°C and 65% R.H. El-Zahi and Farag (2017) showed that the relative humidity had the largest effect on the population of *P. solenopsis*. Nabil (2017) stated that the maximum temperature, minimum temperature, and relative humidity exhibited positive relations with the *P. solenopsis* population. Abd El-Razzik (2018) mentioned that the simple correlation between the *P. solenopsis* mealybug population and maximum and minimum temperatures was positive and very significant, but that the air RH% had a negative and unimportant impact. Nabil and Hegab (2019) stated that there is a significant positive correlation between maximum temperature and the population of *P. solenopsis* females. The relative humidity appeared an important negative impact on the female's population. Zia and Haseeb (2019) recorded that the *P. solenopsis* population exhibited a negative correlation with maximum temperature and a positive correlation with relative humidity. In Egypt, Elbahrawy *et al.* (2020) found significantly positive relationships between maximum temperature and *P. solenopsis* populations during the summer seasons in Giza. The first fall season in Qalyubia had a highly significant relationship with air relative humidity, while the second summer and nili seasons had a significant relationship with relative humidity. The findings of the study will be applied as an indicator for monitoring the pest population in terms of pest behavior and recording of abiotic elements to establish the ideal time for carrying out pest control.

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بوم شناسی جمعیت شپشک آردآلود پنبه، Phenacoccus solenopsis (Hemiptera: Pseudococcidae) روی گیاهان بامیه در منطقه الاقصر، مصر

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چکیده

در میان چندین آفات آلوده به گیاه بامیه، شپشک آردآلود پنبه Phenacoccus solenopsis (Hemiptera: Pseudococcidae) یکی از مخرب ترین آفات به حساب می آید. آزمایشات مزرعه ای در یک مزرعه خصوصی در منطقه اسنا، استان الاقصر، مصر، طی دو فصل رشد متوالی (۲۰۲۱ و ۲۰۲۲) با هدف بررسی نوسانات فصلی جمعیت P. solenopsis آلوده به گیاهان بامیه (رقم بلدی) انجام شد. با همان ویم، تأثیر شرایط آب و هوایی و سن گیاه بر تغییرات فصلی آفت حشره آزمایش شده تعیین شد. نتایج نشان داد که P. solenopsis بوته های بامیه را از هفته اول اسفند تا پایان تیرماه در هر فصل آلوده کرده و دارای سه پیک فعالیت در هر فصل بوده است که در هفته اول فروردین، هفته سوم اردیبهشت و هفته سوم اردیبهشت ماه ثبت شد. هفته چهارم ژوئن میانگین تراکم کل جمعیت P. solenopsis در هر ۱۰ برگ در کل فصل اول ۱۶/۰۵ ± ۲۳۵/۹۶ نفر و برای فصل دوم ۱۷/۰۱ ± ۲۴۲/۱۳ نفر بود. ژوئن مساعدترین ماه برای افزایش جمعیت P. solenopsis بود (همانطور که در طول بازرسی های هفتگی اندازه گیری شد)، در حالی که مارس در هر دو فصل رشد کمترین مطلوبیت را داشت. اثرات ترکیبی شرایط محیطی و سن گیاه با تراکم جمعیت P. solenopsis، با واریانس توضیح داده شده 93.26 (EV) ٪ در فصل اول و ۹۵.۰۹٪ در فصل دوم، در طول دو فصل، رابطه قوی دارد. میانگین رطوبت نسبی روزانه موثرترین متغیر در توضیح تغییرات در تراکم جمعیت P. solenopsis برای فصل اول (۲۰۲۱) بود، در حالی که میانگین حداقل دمای روزانه مهمترین عنصر تأثیرگذار

بر تغییرات جمعیت در فصل دوم (۲۰۲۲) بود. . از سوی دیگر، دمای حداکثر روزانه به وضوح کمترین عامل موثر در تغییرات جمعیت در هر دو فصل بود. داده های ارائه شده در اینجا می تواند به نظارت بر نوسانات در تراکم جمعیت این آفت کمک کند.

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