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Population Density and Spatial Distribution Patterns of *Aphis gossypii* (Glov.) (Hemiptera: Aphididae) on Certain Tomato Cultivars

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Abstract

The present study was carried out throughout two successive growing seasons (2018/2019 and 2019/2020) at Mansoura district, Dakhlia Governorate, Egypt, to study the performance of some tomato cultivars to infestation by the cotton aphid, *Aphis gossypii* (Glov.) (Hemiptera: Aphididae) and their spatial distribution patterns. The obtained results showed that insect population of *A. gossypii* occurred on all different tomato cultivars all the season round. These varieties varied significantly in their susceptibility to population density of *A. gossypii*. Hybrid T4 84 tomato cultivar was the highest population density and was rated as highly susceptible (H.S.) to infestation by the total population density of *A. gossypii*, followed by Hybrid T4 70 and Fiona cultivars were appeared as susceptible (S), while, Maram and Rawan cultivars were observed to be relatively resistant (RR). But, Beto 86 cultivar had the lowest population density and was rated as relative resistant (MR) of pest over the entire season. These pieces of information can be useful for establishing IPM strategies against this pest. Data were analysed using twenty two distribution indices. All distribution indices indicated significant aggregation behaviour during each growing season in all the tested tomato cultivars. This study may be add some information to be used in integrated pest management programs for controlling the aphid on tomato plants.

Keywords: Aphis gossypii; Population Abundance; Tomato Cultivars; Spatial Distribution

Abbreviations: HS: Highly Susceptible; SE: Standard Error; MR: Moderate Resistant; RR: Relative Resistant; CV: Coefficient of Variance.

Introduction

Tomato (Lycopersicon spp.) is economically one of the most important vegetables [1]. Tomato plants are attacked by many insect pests in the field. The cotton aphid, *Aphis gossypii* (Glov.) is one of the most important insect pests of tomato all over the world. This pest is a phytophage cosmopolitan and polyphagous species [2]. It is a direct plant sucking pest and it can cause serious problems on leaves, stems and fruits and it rapidly increase in numbers [3]. It also causes direct damage by secreting honeydew that causes development of sooty-mould, which prevents photosynthesis resulting in wilt and death of the plants. These factors cause economic losses in yield and quality of crops [4]. This pest effects very nearly all the area parts of the tomato plant from the early development stages till to the fruit maturation stage

[5,6]. Feeding frequently brings about stunting, twisting or yellowing of plant green foliage [7]. Extreme infestations may eliminate the plant absolutely [8].

Loss acquired because of sucking to the growing tomato crop is difficult [8]. Spatial distribution is one of the most characteristic properties of insect populations; in most cases, it allows us to define them and is an important characteristic of ecological communities [9]. Knowledge of spatial distribution of aphids at the field scale can be used to create or improve pest monitoring procedures and adjust pesticide application programs, as well as to effectively plan augmentative releases of biological control agents [10]. No field sampling can be efficient without understanding the underlying spatial distribution of the population [11]. An understanding of the spatial distribution (i.e. regular, random, or aggregated) of populations provides useful information, not only for theoretical population biology but also for field monitoring programmes, especially sequential sampling [12,13].

A reliable sampling programmer for estimating the population density should include a proper sampling time (date of sampling), sampling unit, and number of samplings in which the determination of spatial distribution is crucial [14,15]. No information is available in the literature regarding the spatial distribution of *A. gossypii*. Therefore, the present study was undertaken to determining the suitable tomato cultivar to manage aphids infesting tomato as well as the estimated the spatial distribution pattern for monitoring of this pest on some tomato cultivars. The results of this research can be used to draft monitoring methods for this pest and ultimately to establish pest management programmer strategies for *A. gossypii*.

Materials and Methods

Population Densities of *A. gossypii* on Some Tomato Cultivars

Field trials on tomato cultivars were carried out at Mansoura district, Dakhlia Governorate, Egypt, during two successive growing seasons (2018/2019 and 2019/2020). Six commercial cultivars of tomato viz. (Hybrid T_4 84, Hybrid T_4 70, Fiona, Rawan, Maram and Beto 86). Four replicates for each cultivar of tomato (replicate dimensions: 5 m × 5 m log = 25 m2) were distributed in completely randomized block design, were sown in autumn (beginning of September every season). All agricultural practices were applied except for pest control throughout the whole period of the study. For estimating the population densities of *A. gossypii* on different cultivars of tomato plants, random samples of five plants per replicate i.e. (20 plants per each cultivar); at early morning, were picked up half-monthly, using 10x lenses in the field. Began as soon as the plants appeared above ground and continued until the crop harvesting in each season. Direct count of aphid samples was conducted at the same day according to Dewar, et al. [16]. Numbers of alive insects (nymphs and apteral individuals) on tomato plants were counted and recorded, linked to the inspection date, and presented as mean number of individuals per five plants ± standard error (SE), to express the population size of pest, using 10x lenses in the field. Identification of aphid was carried out by taxonomy specialists at the Department of Piercing-Sucking insects, Plant Protection Research Institute, Agriculture Research Center, Giza, Egypt.

General Sampling Method

All sampling was conducted from 1920 plants on 16 dates over a two-season period, i.e. 4 replicate × 5 plants × 6 cultivars × 16 dates.

- **Susceptibility degrees:** Classification of the tested tomato cultivars to their susceptibility degrees was adopted as described by Semeada [17,18] based on a quantitative approach found to the following assumptions:
- **Varieties were grouped into five categories**; i.e. resistant (R), moderate resistant (MR), relative resistant (RR), susceptible (S), and highly susceptible (HS).
- **General mean number of individuals** = (MN)
- **Range of change** (RC) between the maximum mean number values and minimum for the cultivars of tomato plants was calculated by applying the following equation:
  RC = MN max – MN min
  Where,
  MN max = maximum number of individuals/ cultivars.
  MN min= minimum number of individuals/ cultivars.
- **Unit change in tomato cultivars (UC)** was the amount of change in cultivars from one degree of resistance or susceptibility to the preceding degree (from MR to R or from MR to RR …etc).

According to the above mentioned equation, the tested tomato cultivars could be classified as the follows:

- The highly susceptible group (HS): cultivars of tomato with infestation more than (MN + UC).
- The susceptible group (S): cultivars of tomato with infestation ranging from MN to (MN+UC).
- The relative resistant group (RR): cultivars of tomato with infestation less than MN to (MN-UC).
- The moderate resistant group (MR): cultivars of tomato with infestation ranging from < (MN-UC) to (MN-2UC).
- The resistant group (R): cultivars of tomato with infestation less than (MN- 2UC).

However, it is an important to point out herein that the pest mean numbers must refer to and / or agree with the resistance degree of cultivars of tomato. The data obtained were statistically analyzed according to the complete randomized block design. The means were compared according to Duncan's Multiple Range Test [19] and Least Significant Difference test (LSD) at the 5% level were used to determine the significance among means of varieties of tomato was carried out by computer [20] and were depicted graphically by Microsoft Excel 2010.

Spatial distribution of *A. gossypii*:

To study the spatial distribution of *A. gossypii* among the sample units was determined using twenty two indices of distribution.

- **Distribution indices:** Several estimates are based on sample means and variances, such as index of dispersion, clumping, crowding and Green's index [21].
- **Mean ($\bar{X}$):** the mean number of individuals as a general average per sample (5 plants) during the whole season.
- **Range of means of a population:** The difference between the maximum mean number of a population and the minimum for the whole season was calculated by applying the following equation:
- **Range of Density (R)** = Population density maximum – population density minimum during the whole season.
- Variance (S^2), standard deviation (S), standard error (SE) and median (Me) for samples were determined.
- **Coefficient of variance (C.V.):** To assess the fidelity of sampling, the coefficients of variation values for the studied seasons were compared.

$$\text{C.V.} = \frac{S}{X} \times 100$$

Where, S is the standard deviation of the mean and is the mean of population.

- Relative Variation (R.V.) is employed to compare the efficiency of various sampling methods [22]. The relative variation for the studied seasons was calculated as follows:

$$\text{R.V.} = \left(\text{SE}/\bar{X}\right) \times 100$$

Where, SE is the standard error of the mean and is the mean of population.

- **Variance to mean ratio** $\left(S^2/\bar{X}\right)$ **:** The simplest approach used for determining the insect distribution was variance to mean ratio suggested by Patil and Stiteler [23]. The value of variance-to-mean is one for 'Poisson' distribution, less than one for positive binomial and more than one for negative binomial distribution. Dispersion of a population can be classified through a calculation of the variance-to-mean ratio; namely: $\left(S^2/\bar{X}\right) = 1$ random distribution, < 1 regular distribution and > 1 aggregated distribution (where, S^2 = sample variance; $\bar{X}$ = mean of population).

- **Index of Lewis (I_L):** Lewis index was also calculated as per the formula given hereunder to determine the dispersion of *A. gossypii*.

$$I_L = \sqrt{S^2/\bar{X}}$$

The value of this index revealed >1 contagious; <1: regular and =1 random distribution.

- **Cassie index (Ca):**

$$\text{Ca} = \left(S^2 - \bar{X}\right)/\bar{X}^2$$

The spatial distribution pattern is aggregative, random and uniform when Ca>0, Ca = 0 and Ca<0, respectively [24].

- **The K value of negative binomial distribution:** The parameter k of the negative binomial distribution is one measure of aggregation that can be used for insect species having clumped or aggregated spatial pattern. When k values are low and positive (k < 2), they indicate a highly aggregated population; k values ranging from 2 to 8 indicate moderate aggregation; and values higher than 8 (k > 8) indicate a random population [25]. The k values were calculated by the moment's method [26], and given by:

$$K = \bar{X}^2 / (S^2 - \bar{X})$$

- Departure from a random distribution can be tested by calculating the index of dispersion (I_D), where, n: denotes the number of samples:

$$I_D = (n-1)S^2 / \bar{X}$$

I_D is approximately distributed as x^2 with n-1 degrees of freedom. Values of I_D which fall outside a confidence interval bounded with n-1 degrees of freedom and selected probability levels of 0.95 and 0.05, for instance, would indicate a significant departure from a random distribution. This index can be tested by Z value as follows:

$$Z = \sqrt{2I_D} - \sqrt{(2\nu - 1)}$$

v = n - 1

If 1.96 ≥ Z ≥ -1.96, the spatial distribution would be random, but if Z < -1.96 or Z > 1.96, it would be uniform and aggregated, respectively [23].

- **Index of mean clumping (I_{DM})** [27]:

$$(I_{DM}) = (S^2/\overline{X}) - 1$$

The David and Moore index of clumping values increase with increasing aggregation. If the index value = 0, the distribution is random, positive value for negative binomial (aggregated) and negative value for positive binomial (regular).

- **Lloyd's mean crowding ($\overset{*}{X}$):** Mean crowding ($\overset{*}{X}$) was proposed by Lloyd to indicate the possible effect of mutual interference or competition among individuals. Theoretically mean crowding is the mean number of other individuals per individual in the same quadrate:

$$\overset{*}{X} = \overline{X} + [(S^2 / \overline{X}) - 1]$$

As an index, mean crowding is highly dependent upon both the degree of clumping and population density. To remove the effect of changes in density, Lloyd introduced the index of patchiness, expressed as the ratio of mean crowding to the mean. As with the variance-to-mean ratio, the index of patchiness is dependent upon quadrate size [28].

- **Index of patchiness (I_p):** is dependent upon quadrate size.

$$I_P = (\overset{*}{X} / \overline{X})$$

If IP = 1, then is random; if < 1 then is regular; and if > 1 is aggregated

- **Green's index (GI):**

$$GI = [(S^2 / \overline{X}) - 1] / (n - 1)$$

This index is a modification of the index of cluster size that is independent of n [21]. If GI > 0 or positive values are indicative of aggregation dispersion, GI < 0 or negative values indicative of uniformity or regular dispersion, and GI = 0 or negative values closer to 0 indicate randomness.

To evaluate temporal changes in spatial pattern of *A. gossypii* population during the studied seasons, an aggregation index (1/k) [15] was used.

It was calculated by the formula of

$$1/k = (\overset{*}{X} / \overline{X}) - 1$$

Where: 1/k is aggregation index or Cassie's index C and ($\overset{*}{X} / \overline{X}$) is Lloyd's patchiness index. The values of 1/k < 0, = 0, and > 0 represent regularity, randomness, and aggregation of the population in spatial pattern, respectively [29].

The population aggregations mean (λ) [30] was used to analysis the causes for the insect population being in an aggregated state, and was calculated as follows:

$$\lambda = m / 2k \times \gamma$$

Where, y equals to $X^2 0.5$ when the value of the degree of freedom is 2K. The aggregation of insect individuals is caused by environmental factors when λ < 2; on the other hand, if λ > 2, the phenomenon is caused by aggregation behavior or the aggregation behavior works in combination with the environment.

Result and Discussion

Population Densities of *A. gossypii* on Certain Tomato Cultivars

Data presented in Table 1 and illustrated in Figure 1, showed that insect population of *A. gossypii* occurred on all different tomato cultivars all the season round. The obtained results cleared that the mean total population density of *A. gossypii* through the whole season was 49.44 ± 1.73 and 48.03 ± 1.50 individuals per five plants over the first and second growing seasons, respectively. The statistical analysis of data indicated that, there was a highly significant differences among the tomato cultivars regarding the level of infestation by *A. gossypii* were obtained (L.S.D were 3.77 and 3.31) throughout the two successive growing seasons, respectively. It is clear from the results that the highest number of *A. gossypii* individuals was observed on Hybrid T4 84, with an a general average of (65.47 ± 4.61 and 66.63 ± 3.86 individuals per five plants) during the first and second growing season, respectively, as compared with the other tested cultivars of tomato, and this cultivar was rated as highly susceptible (HS). On the other hand, Beto 86 cultivar demonstrated the lowest number of *A. gossypii* individuals on the basis of a general average of (28.34 ± 1.90 and 26.60 ± 1.86) during the first and second growing season, respectively, and the cultivar was rated as moderately resistance to infestation (MR), this cultivar of tomato plants should be promoted in the areas of high aphid infestation. While, Hybrid T_4 70 and Fiona cultivars of tomato, exhibited sensitivity degree as susceptible to infestation (S), with a general average of (56.40 ± 4.17 and 54.91 ± 4.10) during the first season and it was (54.55 ± 3.37 and 51.77 ± 3.25) through the second growing season, respectively, Table 1.

Tomato cultivars	Average no. of individuals of insect per 5 plants ± S.E			
	First season(2018/2019)		Second season (2019/2020)	
	Mean ± SE	Sensitivity degree	Mean ± SE	Sensitivity degree
Hybrid T_4 84	65.47 ± 4.61 A	HS	66.63 ± 3.86 A	HS
Beto 86	28.34 ± 1.90 D	MR	26.60 ± 1.86 E	MR
Hybrid T_4 70	56.40 ± 4.17 B	S	54.55 ± 3.37 B	S
Fiona	54.91 ± 4.10 B	S	51.77 ± 3.25 B	S
Maram	44.98 ± 3.57 C	RR	41.97 ± 2.80 D	RR
Rawan	46.53 ± 3.55 C	RR	46.65 ± 2.47 C	RR
Mean	49.44 ± 1.73		48.03 ± 1.50	
L.S.D. at 0.05 between cultivars	3.77 **		3.31 **	

Table 1: Average numbers of *A. gossypii* per five plants and sensitivity degrees of certain tomato cultivars during the two successive growing seasons (2018/2019 and 2019/2020).
Means followed by the same letter (s), in each column, are not significantly different at 0.05 level probability, by Duncan's multiple range test (DRMT).

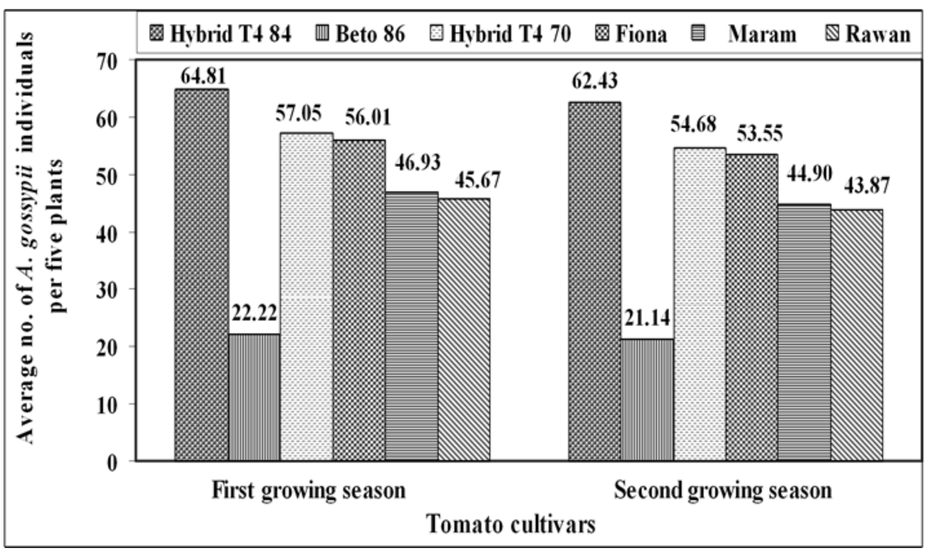

Figure 1: Average numbers of *A. gossypii* per five plants on certain tomato cultivars during two successive growing seasons (2018/2019 and 2019/2020).

But, the Maram and Rawan cultivars showed some sort of resistance and appeared as relatively resistant (RR), with and a general average of (44.98 ± 3.57 and 46.53 ± 3.55) during the first season and it was (41.97 ± 2.80 and 46.65 ± 2.47) through the second growing season, respectively. Homopterous sap sucking species were the most dominant insect pests infesting potato where they formed 86.4 - 94.2% of insects occurred on tomato plants in the field [31]. Clarified that the rate of insect's population abundance at any location is influenced by the environmental factors at that location [32]. In general, it could be concluded that Hybrid T_4 84 tomato cultivar was the most preference to the cotton aphid, *Aphis gossypii* (Glov.) the cotton aphid, *A. gossypii*, while the Beto 86 cultivar was less preferable cultivar for this insect. The tested varieties could be arranged according to their susceptibility in a descending order as follows:

Hybrid T_4 84 > Hybrid T_4 70 > Fiona > Rawan > Maram > Beto 86

It is clear that the differences in the population densities of *A. gossypii* on different tomato cultivars which may be due to the differences not only in the environmental conditions (such as temperature, relative humidity) but also there are numerous other factors such as the leaf structure (density of stomata, softness of tissues and size of leaves) for the tested tomato cultivars. We concluded that the host plant affects the development of pest and that the choice of the most resistance cultivar can help to reduce pest infestation, and are therefore an additional component to be included in the integrated pest management of tomato plants. Variations in the aphid populations among the different tomato cultivars has been reported by Abdallah and Faraj [33] who recorded that Hybrid Super tomato cultivar harbored a relatively lower population by *A. gossypii* than Crystal HYB during 2012 summer season (t = 0.61).

Sampling Program

The obtained values in Tables 2 & 3 showed that the relative variation (R.V.%) for the primary sampling data of *A. gossypii* indicated that the population densities of pest ranging from (6.69 to 7.95 %) and (5.29 to 6.98%) in the all different cultivars of tomato through the two growing seasons, respectively. As well, the R.V. (%) for the primary sampling data of *A. gossypii* indicated that the mean population densities was 3.50 and 3.12% during the first and second growing seasons, respectively Tables 2 & 3.

Parameters	Hybrid T_4, 84	Beto 86	Hybrid T_4, 70	Fiona	Maram	Rawan	Average of cultivars
Max	124.35	49.22	116.31	117.61	97.74	90.63	124.35
Min	28.90	14.86	24.94	25.70	19.42	22.26	14.86
Mean	65.47	28.34	56.40	54.91	44.98	46.53	49.44
Range of mean	95.44	34.36	91.37	91.92	78.32	68.37	109.48
Median	63.04	25.08	51.46	50.05	40.59	39.55	42.87
S^2	681.04	115.08	556.81	537.39	408.91	402.59	574.02
S	26.10	10.73	23.60	23.18	20.22	20.06	23.96
SE	4.61	1.90	4.17	4.10	3.57	3.55	1.73
CV	39.86	37.85	41.84	42.22	44.96	43.12	48.46
RV	7.05	6.69	7.40	7.46	7.95	7.62	3.50
S^2/m	10.40	4.06	9.87	9.79	9.09	8.65	11.61
Lewis Index	3.23	2.01	3.14	3.13	3.02	2.94	3.41
Cassie index	0.14	0.11	0.16	0.16	0.18	0.16	0.21
K	6.96	9.26	6.36	6.25	5.56	6.08	4.66
I_D	322.45	125.87	306.06	303.40	281.81	268.22	2217.64
Z value	17.58	8.06	16.93	16.82	15.93	15.35	47.08
I_{dm}	9.40	3.06	8.87	8.79	8.09	7.65	10.61
x*	74.88	31.40	65.27	63.69	53.07	54.18	60.05
x*tm	1.14	1.11	1.16	1.16	1.18	1.16	1.21
GI	0.30	0.10	0.29	0.28	0.26	0.25	0.06
1/k	0.14	0.11	0.16	0.16	0.18	0.16	0.21
λ	0.35	0.08	0.36	0.39	0.39	0.34	0.64

Table 2: Estimated parameters for spatial distribution of *A. gossypii* individuals on certain tomato cultivars during the first growing season (2018/2019).

Parameters	Hybrid T4, 84	Beto 86	Hybrid T4, 70	Fiona	Maram	Rawan	Average of cultivars
Max	118.15	52.49	104.99	103.51	85.44	73.91	118.15
Min	31.51	8.34	25.83	25.94	21.06	24.58	8.34
Mean	66.63	26.60	54.55	51.77	41.97	46.65	48.03
Range of mean	86.64	44.15	79.16	77.56	64.38	49.33	109.81
Median	64.81	25.79	51.59	49.80	41.17	45.35	43.76
S^2	476.07	110.48	363.03	338.60	251.51	194.52	432.33
S	21.82	10.51	19.05	18.40	15.86	13.95	20.79
SE	3.86	1.86	3.37	3.25	2.80	2.47	1.50
CV	32.75	39.51	34.93	35.54	37.79	29.90	43.29
RV	5.79	6.98	6.17	6.28	6.68	5.29	3.12
s^2/m	7.14	4.15	6.65	6.54	5.99	4.17	9.00
Lewis Index	2.67	2.04	2.58	2.56	2.45	2.04	3.00
Cassie index	0.09	0.12	0.10	0.11	0.12	0.07	0.17
K	10.84	8.44	9.65	9.35	8.41	14.71	6.00
I_D	221.48	128.74	206.29	202.74	185.77	129.27	1719.24
Z value	13.24	8.24	12.50	12.33	11.46	8.27	39.12
I_{DM}	6.14	3.15	5.65	5.54	4.99	3.17	8.00
X*	72.78	29.75	60.21	57.31	46.96	49.82	56.03
X*/m	1.09	1.12	1.10	1.11	1.12	1.07	1.17
GI	0.20	0.10	0.18	0.18	0.16	0.10	0.04
1/k	0.09	0.12	0.10	0.11	0.12	0.07	0.17
Λ	0.14	0.10	0.15	0.15	0.15	0.06	0:35

Table 3: Estimated parameters for spatial distribution of *A. gossypii* individuals on certain tomato cultivars during the second growing season (2019/2020).

The values of R.V.% were very appropriate for a sampling program. However, with different insect species and different host, Bakry [34] recorded that the R.V. (%) for the primary sampling data of Parlatoria oleae on mango trees indicated that the total population density was 2.41, 2.35 and 1.73% during the first and second years, and for the two years combined, respectively. Bakry and Arbab [35] reported that the relative variation for the primary sampling data of Icerya seychellarum ((Hemiptera: Monophlebidae) on guava trees indicated that total population density was 4.07 (2017-2018), 5.62 (2018-2019) and 3.55% (pooled). Bakry and Abdel-Baky [36] recorded that the relative variation for the primary sampling data of Aulacaspis tubercularis (Newstead) (Hemiptera: Diaspididae) indicated that the mean population densities were 5.49, 4.69, and 4.78% during the first and second years, and for the two years combined, respectively. Bakry and Shakal [37] mentioned that the relative variation for the primary sampling data of Schizaphis graminum (Hemiptera: Aphididae) on wheat plants indicated that the mean population densities was 9.78 and 8.04% during the first and second growing seasons, respectively.

Spatial Distribution

The results in Tables 2 & 3 showed that the spatial distribution among the sample units was determined by twenty two indices of distribution. The results of distribution using the variance of *A. gossypii* population on different tomato cultivars was greater than the general average of the population densities by *A. gossypii*, and thus the variance-to-mean ratio (S^2/m) was greater than one were recorded in the all tested tomato cultivars. Therefore, the spatial distribution of *A. gossypii* individuals was an aggregated distribution for all tomato cultivars and over the entire growing season. When the population means (number of aphids, *A. gossypii* per cotton leaf) increases, the variance also increases which means that the fluctuation of the number of aphids per leaf increases [2]. The Lewis index of the pest was significantly greater than the index of contagious dispersion. Similar conclusions were made from the results of the Cassie index. The mean population of *A. gossypii* distribution was greater than zero; therefore, *A. gossypii* on the all tested cultivars of tomato had an aggregated distribution.

The K values of the negative binomial distribution of *A. gossypii* population ranged from 2 to 8 in the all tomato cultivars during first season, thus indicating moderate aggregation. Except, Beto 86 cultivar, the value K was higher than 8 i.e., it being 9.26 indicate a random distribution (Tables 2). On the other hand, during the second growing season, the K values for the mean population densities was higher than 8, thus indicating moderate aggregation in the all the different tomato cultivars (Table 3). Elliott and Kieckhefer [38] stated that the multiple factors affect spatial distribution of aphids including climatic conditions and some biotic factors such as quality of host plants, dispersal efficacy of aphids and natural enemies. The Index values of mean clumping (I_{DM}) of the pest in the all cultivars of tomato were positive for the negative binomial. The Z-test values were greater than 1.96. The index of patchiness was greater than one and Green's index was greater than zero (Tables 2 & 3). All these indices showed an aggregated distribution for the population of *A. gossypii* in the all the different tomato cultivars during the two growing seasons (Tables 2 & 3). The temporal changes in the spatial distribution pattern of *A. gossypii* population during each growing season were evaluated using 1/k (the aggregation index). The value was greater than zero, thus indicating an aggregated pattern that became more dispersed with time in all tested tomato cultivars and over the entire growing season (Tables 2 & 3). As well, the values of population aggregations (λ) of *A. gossypii* population were all less than 2 in all tested tomato cultivars over the entire season, however, indicating that the aggregation phenomenon may be caused by environment variations (Tables 2 & 3). A similar conclusion was found to occur in distribution of Parapoynx crisonalis (Lepidoptera: Crambidae) on water chestnuts plant [39] and Bakry and Abdel-Baky [36] who observed in population densities of A. tubercularis (Hemiptera: Diaspididae) on certain mango cultivars and recoded that the aggregation phenomenon may be caused by environment variations.

It is clear that the tomato cultivars affect the population density and spatial distribution of *A. gossypii*. Therefore, the spatial distribution for the population of *A. gossypii* using twenty two distribution indices indicated an aggregated distribution in the all tomato cultivars during the two successive seasons (Tables 2 & 3). Most authors in the literature had results that in full harmony with our results. Celini and Vaillant [2] mentioned that the aphid's aggregation increases with population density of *A. gossypii* on cotton plants. Rodrigues, et al. [40] recorded that the spatial distribution analysis for *A. gossypii*, the aggregation indexes, showed aggregated distribution in both cultivars (Bt and non-Bt cotton crop). However, there is no study in the literature regarding the distribution patterns of *A. gossypii*. Studying different insect species and different hosts, Chellappan, et al. [41] reported that the value of mean crowding increased with an increase in the mean population density of Paracoccus marginatus (Hemiptera: Pseudococcidae). Li, et al. [42] recorded that the K value of the negative binomial distribution, aggregation index, and Cassie index were all higher than zero during May.

This would indicate that Parapoynx crisonalis (Lepidoptera: Crambidae) larvae were in an aggregated distribution. Bala and Kumar [43] recorded that the values of the Lewis index for all sampling dates of the bug, Chauliops fallax (Hemiptera: Malcidae) population on soybean were also found to be more than one, thus indicating that the distribution of the bug population was aggregated. Bakry [43] studied the spatial distribution of Parlatoria oleae (Hemiptera: Diaspididae) on mango trees using twenty one distribution indices. All indices of distribution indicated significant aggregation behaviour in each year, except, the K values of the negative binomial distribution of the total P. oleae (Hemiptera: Diaspididae) population ranged about 15-17 for each year during the two successive years, indicating random behavior. Bakry and Abdel-Baky [36] mentioned that the spatial distribution for the population of Aulacaspis tubercularis (Newstead) (Hemiptera: Diaspididae) using twenty two distribution indices, indicated an aggregated distribution in all different mango cultivars in the two successive years and on the two cumulative years (2017-2019). Bakry and Shakal [37] studied the spatial distribution of Schizaphis graminum (Hemiptera: Aphididae) on some wheat cultivars and lines using twenty one distribution indices. Who recorded that the all distribution indices indicated significant aggregation behavior during each growing season in all the tested wheat cultivars and lines.

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