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Ecological and control studies of the cotton aphids, *Aphis gossypii* (Glover.) on eggplant, *Solanum melongena* L.

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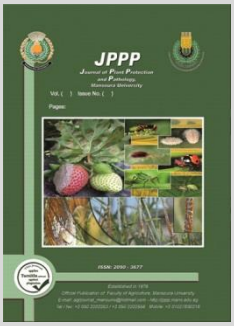

ABSTRACT

The present study was conducted to estimate the distribution of apterous and alates cotton aphids within and between plants. Also, population dynamic of cotton aphid and its predators, and the effects of foliar spray with elicitors viz, salicylic acids (SA), jasmonic acids (JA) and β-aminobutyric acid (BABA) on the population density of *A. gossypii* were estimated. The experiments were carried out in an eggplant field at Nobaria district, El-Beheira Governorate, Egypt. The results of spatial distribution of apterous *A. gossypii* by using the diffusion coefficient (S^2/ m) was >1, by using David-Moore index (I_{DM}) was positive value for negative binomial, by using patch index (m*/m) was >1 and with using Cassie index (C_a)was>0 and positive values. All these indices are indicative of aggregation (the individuals tend to occur in clumps) distribution model for the apterous *A. gossypii* in all the sampling dates throughout the two successive seasons 2019 and 2020. On contrary, all of these indices refer to a uniform spatial distribution for the alates *A. gossypii*., there were proportionally greater numbers of the alates individuals on the middle part of eggplants. The results also showed that the seasonal mean population of cotton aphids was higher during 1st season than during the 2nd season The apterous aphid populations were significantly higher within the upper level than other levels of the plant. The foliar spray of JA, SA and BABA resulted in decreasing the cotton aphid population density in eggplant crop. SA proved to be less efficacious than JA and BABA.

***Keywords*:** Aphis gossypii, Eggplant, Spatial distribution, Aphidophagous predators, Salicylic, Jasmonic, β-aminobutyric

INTRODUCTION

From sowing until harvest, eggplants, *Solanum melongena* L. (family: Solanaceae) are suffering from severe infestation with different insect pests (Abou-Taleb and Barrania, 2014; Amin, *et al.*, 2018). Cotton aphid, *Aphis gossypii* (Glover.) (Hemipetra: Aphididae) is considered one of the most destructive insect pests of crops including eggplant (Rahman, *et al* 2011; Azouz, *et al*., 2014; Abdul Alim, *et al.*, 2015; Rashwan and Gado, 2017). Agriculturally and economically, cotton aphid, *A. gossypii* is one of the most important sucking mouthparts insect pests. It attacks a broad spectrum of hosts (over 320 plant species belong to about 46 families) (Blackman and Eastop, 2000). The cotton aphid, *A. gossypii* punctures the leaf tissue and feed on the phloem of its host plants using its sucking mouth parts, hence excretion of honeydew led to development of black sooty mold fungi. Consequently, the sever infestation with *A. gossypii* reduces the plant vitality and productivity and finally causing great losses in the yield. In addition to direct damage, the cotton aphid transmits several plant viruses reach to more than fifty plant viruses (indirect damage) (Blackman and Eastop, 2000). Both of the seasonal dynamics and population spatial distribution patterns of the insect pests are two of the major topics in the study of insect ecology and pest control systems (Fernandes, *et al*., 2012 and Ni Li, *et al*., 2017). The field monitoring and/or scouting is one of the essential components of the integrated pest management (IPM). Scientists and growers use information gathered from monitoring to select the appropriate control tactics. The dispersion (or population distribution) of an insect is a term that describes the arrangement of members of an insect population within a habitat (Sevacherian and Stern, 1972). The knowledge of the spatial distribution patterns of arthropod pests is very useful for more efficient sampling schemes (which consider one of the most important factor determines the decision making in the programs of integrated pest management) and analysis procedures. Consequently, this is lead to insight into the basic ecology of these insect pests (Khaing, 2002). The chemical elicitor compounds such as salicylic acid (SA), jasmonic acid (JA) β-aminobutyric acid (BABA) activate chemical defenses in plants and have been widely used in controlling insect pests in IPM programs (Boughton, *et al.*, 2006; Cao *et al*., 2014; Zhong *et al*., 2014**;** Duan, *et al*., 2015; Moreno-Delafuente, *et al.*, 2020). Thus, keeping in view the above mentioned information, the present work was planned to study the insect distribution (spatial distribution) within and between plants, population dynamic of alates and apterous cotton aphid, *A. gossypii*, and its associated predators and the effect of foliar spray of elicitors JA, SA and BABA on population density of *A. gossypii* in an attempt to develop the IPM programs of *A. gossypii*.

MATERIALS AND METHODS

The present study was carried out in a private farm of two feddan (0.84 ha) cultivated with eggplant (*Solanum melongena* L.) cv of Black Beauty at Nobaria district, Beheira Governorate, Egypt. The eggplant seedlings were

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transplanted at March 8, 2019 and March 13, 2020 (as a summer plantation), with spacing between rows of 1 m and 0.5 m between plants. During the whole cultivation period, all of the recommended agricultural practices were followed except application of insecticides. The experiment area was divided into a grid with 16 equal plots. Population of *A. gossypii* was recorded after two weeks of transplanting at weekly intervals until the end of harvest. Five plants representing the four corners and the center of each plot were randomly selected. The boarder rows of each plot were avoided. Three leaves represented the three levels of each plant (lower, middle and upper) were chosen from each plant. Collected leaves were kept in paper bags and transferred to the laboratory for examination. The population density of the cotton aphid population (apterous and alates) was then determined.

Spatial distribution (Between-plant Distribution)

Throughout the growing season, spatial distribution (between-plant distribution) of the cotton aphid, *A. gossypii* was determined for each sampling date using the following distribution indices:

1-The diffusion coefficient (C), **$C = S^2/m$** (Southwood and Henderson, 2000).

(C=1 Random, C>1Aggregated, <1 Regular spatial distribution)

2- David-Moore index (the index of clumping or aggregation) **(I_{DM}), $I_{DM} = (S^2/m) - 1$**

(David and Moore, 1954).

($I_{DM} < 0$ uniform, $I_{DM} = 0$ random, $I_{DM} > 0$ aggregative)

3- Cassie index (C_a), **$C_a = (S^2-m)/m^2$**

(C_a=0 random, $C_a < 0$ uniform, $C_a > 0$ aggregative)

4- Mean crowding (m*), **$m^* = m + I_{DM} = m + ((S^2/m) - 1)$** (Lloyd,1967)

(m* = m random, m* < m uniform, m* > m aggregative)

5- The K value of negative binomial distribution (K), $K = m^2/(s^2-m)$ (waters, 1959; Southwood and Henderson, 2000 and Costa *et al*., 2010)

(k = 0-2 highly aggregated, k = 2 - 8 moderate aggregation, k > 8 = random population).

6- The Patch index (m*/m), (Lloyd, 1967)

(m*/m =1 random, m*/m <1 uniform, m*/m >1 aggregative

7- Taylor's power law, **$S^2 = am^b$ or Log S^2 = log a +b log m** (Taylor, 1961)

8- The Iwao's patchiness regression **$m^* = \alpha + \beta m$, (Iwao, 1972)**

Where

S^2: the variance,

m: the mean density

Within-plant Distribution

Mean number of the alates and apterous aphids of *A. gossypii* settling at two different plant growth stages were recorded. In the second plant growth stage (reproductive stage), aphid density on each plant was recorded in three levels, upper (leaves were taken from the upper part of the stem, 10-15 cm), middle and lower parts (leaves from the rest of the stem). The data of aphid preference for each level was recorded and statistically analyzed by using one-way ANOVA and means were compared by using least significance difference test at 5% level of probability. The CoStat (Ver. 6.400) program was used to analyze the data according to Steel *et al*. (1997).

Survey and population dynamics of *Aphis gossypii* predators:

To determine the population density of the most abundant predators of cotton aphids, data of larvae, pupae and adults of coccinellid predators, larvae of *C. carnea*, *Orius* sp and *Syrphus* larvae were assessed visually and recorded on one randomly chosen plant from each blot (16 plants) at weekly intervals. The correlation coefficients between cotton aphid populations and each of their predators were also determined.

Effect of foliar spray with chemical elicitor compounds on population density of *A. gossypii*:

The effect of foliar spray with exogenous chemical elicitors, salicylic acid (SA), jasmonic acid (JA) and β-aminobutyric (BABA) on the population density of *A. gossypii* on eggplants was evaluated. The treatments included salicylic acid at 100 ppm and 200 ppm, jasmonic acid at 100 ppm and 200 ppm (100 mg/l and 200 mg/l) β-aminobutyric (BABA) at 50 and 100 ppm and control. Salicylic acid was dissolved in a few drops of ethanol and then dispersed. Control was sprayed only by water. Treatments were arranged in a randomized complete block design (RCBD) in a separate farm in Nobaria. Each treatment was replicated four times (100 m^2 per each treatment). The plants were sprayed after 6 weeks of transplanting (April 12, 2019 and April 17, 2020) for three times at one week intervals. The elicitors were sprayed by knapsack sprayer equipment (CP^3) at the rate of 200 liter per feddan. The population density of *A. gossypii* was determined pre-spray and also one week, two weeks and three weeks after the spray. The data of population density of cotton aphid in each treatment was recorded and statistically analyzed by using one-way ANOVA and means were compared by using least significance difference test at 5% level of probability. The CoStat (Ver. 6.400) program was used to analyze the data according to Steel *et al*. (1997).

Results

Spatial distribution of the apterous cotton aphids, *A. gossypii*:

The different aggregation indices of the apterous cotton aphids, *A. gosypii* in the eggplant field throughout two consecutive seasons 2019 and 2020 are presented in Tables 1 and 2. The spatial distribution pattern of the cotton aphid, *A. gosypii* was found to be highly aggregated in accordance with various indices of dispersion. In all investigation dates, the diffusion coefficient (ratio of variance-to-mean) (S^2/ m) was of significant departure from 1.00 (ranging from 1.126 in the 14th week to 3.331 in the 8th week). In all the sampling dates, the Cassie index (*Ca*) of the apterous cotton aphids was greater than zero, which indicated that apterous *A. gossypii* on eggplant has an aggregation distribution. Patch index (m*/m) of *A. gossypii* during all investigation dates were greater than 1.00 (ranging from 1.206 in the 1st week to 1.01 in the 14th week). The values of aggregation index (I_{DM}) were greater than 0.00, indicating that the population of *A. gosypii* in the eggplant field followed aggregative distribution (negative binomial distribution). In the 2nd season, 2020, the ratio of variance-to-mean was greater than unity for all the sampling dates (the mean was less than the variance) and this indicating an aggregated distribution for the cotton aphids, *A. gossypii* throughout the eggplant growing period. To analyze the relationship between the level of aggregation from one hand and the mean density from the other hand, the Taylor power

law was used. The equations of variance (S^2) and mean density (m) at the alates and apterous cotton aphids, *A. gossypii* were log S^2 = log 0.193+ 1.067 log m and log S^2 = log 0.055+ 1.226 log m during the 1st and 2nd seasons, respectively. The Iwao's patchiness regression fitted to the negative binomial **was m* = 0.852+1.006 m (R^2=0.995)** and **m*=0.910+1.017 m (R^2=0.989)** for apterous aphids during the consecutive seasons, 2019 and 2020, respectively.

Table 1. Spatial distribution indices for apterous *Aphis gossypii* in eggplant field during 2019.

Date	m	S^2	C	I_{DM}	C_a	m*	m*/m	K
05-Apr	5.604	12.073	2.154	1.154	0.206	6.758	1.206	4.855
12-Apr	10.938	21.445	1.961	0.961	0.088	11.898	1.088	11.385
19-Apr	18.258	26.942	1.476	0.476	0.026	18.734	1.026	38.392
26-Apr	18.958	52.845	2.787	1.787	0.094	20.746	1.094	10.606
03-May	21.496	37.941	1.765	0.765	0.036	22.261	1.0356	28.097
10-May	36.763	83.359	2.268	1.268	0.034	38.03	1.0345	29.004
17-May	26.288	53.497	2.035	1.035	0.039	27.323	1.039	25.396
24-May	17.6	58.617	3.331	2.331	0.132	19.931	1.132	7.552
31-May	13.796	29.008	2.103	1.103	0.08	14.898	1.08	12.512
07-Jun	18.154	29.239	1.611	0.611	0.033	18.765	1.034	29.732
14-Jun	20.65	37.002	1.792	0.792	0.038	21.442	1.038	26.077
21-Jun	30.483	44.62	1.464	0.464	0.015	30.947	1.015	65.734
28-Jun	16.975	40.832	2.405	1.405	0.083	18.38	1.083	12.078
05-Jul	12.729	14.328	1.126	0.126	0.01	12.855	1.01	101.345
12-Jul	10.68	12.965	1.214	0.214	0.02	10.893	1.02	49.882

Table 2. Spatial distribution indices for apterous *Aphis gossypii* in eggplant field during 2020.

Date	m	S^2	C	I_{DM}	C_a	m*	m*/m	K
10-Apr	2.0125	2.132	1.06	0.06	0.03	2.072	1.03	33.814
17-Apr	7.6	20.306	2.672	1.672	0.22	9.272	1.22	4.546
24-Apr	8.738	26.683	3.054	2.054	0.235	10.791	1.235	4.254
01-May	13.588	40.018	2.945	1.945	0.143	15.533	1.143	6.985
08-May	18.117	36.793	2.031	1.031	0.057	19.148	1.057	17.574
15-May	30.433	56.574	1.859	0.859	0.028	31.292	1.028	35.431
22-May	20.9	53.509	2.56	1.56	0.075	22.46	1.075	13.4
29-May	18.379	58.567	3.187	2.187	0.119	20.566	1.119	8.405
05-Jun	14.579	28.582	1.96	0.96	0.066	15.54	1.066	15.179
12-Jun	14.792	27.851	1.883	0.883	0.06	15.675	1.0597	16.754
19-Jun	22.513	45.9	2.039	1.039	0.046	23.551	1.046	21.671
26-Jun	17.258	35.44	2.053	1.053	0.061	18.312	1.061	16.382
03-Jul	17.054	52.176	3.059	2.059	0.121	19.114	1.121	8.281
10-Jul	13.513	13.918	1.036	0.03	0.002	13.543	1.002	450.22
17-Jul	11.446	12.95	1.131	0.131	0.011	11.577	1.011	87.076

Spatial distribution of the alates cotton aphids, *A. gossypii*:

The aggregation indices of the alates *A. gossypii* in the eggplant field throughout two consecutive seasons 2019 and 2020 (as shown in Tables 3 and 4) refer to a uniform spatial distribution for alates *A. gossypii*. Both of patch index (m*/m) and diffusion coefficient are less than unity. On contrary, the Cassie index (*Ca*) of the alates cotton aphids was lower than zero (uniform distribution). Also, the results revealed that the mean density (m) is greater than the mean crowding (m*). I_{DM} (the index of clumping or aggregation) and the K value of the negative binomial distribution are less than 0.000. The equations of variance (S^2) and mean density (m) at the alates cotton aphids, *A. gossypii* were log S^2 = log -0.296+ 1.447 log m and log S^2 = log -0.165+ 1.132 log m during 2019 and 2020 seasons, respectively. The Iwao's patchiness regression fitted to the negative binomial for the alates aphids were m* = -0.743+1.240m (R^2=0.961), m*= -0.992 +1.324m (R^2=0.984) during the consecutive seasons, 2019 and 2020, respectively

Population dynamics of *Aphis gossypii* during eggplant growing seasons 2019/20:

The cotton aphids, *A. gossypii* remained a regular pest on eggplant during the growing season. The population buildup of apterous *A. gossypii* started from the 1st week of April and remained active up to the second week of July and from the second week of April to third week of July in 2019 and 2020 seasons, respectively. *A. gossypii* was first observed on 5th April 2019 (5.598 aphids leaf^{-1}) and (2.009 aphids leaf^{-1}) on 10th April 2020 (Fig. 1 and 2). The population of *A. gossypii* was increased gradually to achieved two peaks in May 10th (with an average of 38.0005 aphids/leaf) and in June 21st (30.489 aphids/leaf) in the first season, 2019. While in the second season, 2020 these peaks were recorded 30.437 aphids leaf^{-1} and 22.926 aphids leaf^{-1} in May 15th and June 19th, respectively. Later, the population decreased to 10.677 aphids leaf^{-1} in the year 2019 and 11.447 aphids leaf^{-1} in 2020 towards the mid of July as the crop near the end of the harvest. Population density of alates individuals of *A. gossypii* was always lower than apterous individuals (in all the sampling dates) and accounted for only 5.75 and 5.872 % of the total population throughout the plant growth period of the 1st and 2nd seasons, respectively.

Within-plant distribution of *A. gossypii* on eggplant:

Data illustrated in Figs. 3 and 4 refer to the distribution of *A. gossypii* within eggplants. As a general mean of the reproductive stage of the eggplant, the results clearly revealed that apterous cotton aphid population was significantly highest on the upper part of the plants. The means of population density in the upper level were 6.8115 and 7.4375 individuals/ leaf during 2019 and 2020 seasons, respectively.

Table 3. Spatial distribution indices for alates *Aphis gossypii* in eggplant field during 2019.

Date	m	S^2	C	I_{DM}	C_a	m*	m*/m	K
19-Apr	0.1875	0.052	0.279	-0.721	-3.85	-0.534	-2.846	-0.26
26-Apr	0.363	0.134	0.369	-0.631	-1.74	-0.268	-0.74	-0.575
03-May	0.579	0.163	0.281	-0.719	-1.24	-0.14	-0.241	-0.806
10-May	1.092	0.648	0.593	-0.407	-0.37	0.685	0.627	-2.684
17-May	0.788	0.199	0.252	-0.748	-0.95	0.04	0.05	-1.053
24-May	1.042	0.645	0.619	-0.381	-0.366	0.661	0.634	-2.733
31-May	1.342	1.2663	0.944	-0.056	-0.042	1.286	0.958	-23.883
07-Jun	2.075	1.427	0.688	-0.312	-0.15	1.763	0.85	-6.649
14-Jun	2.288	1.212	0.53	-0.47	-0.205	1.817	0.795	-4.867
21-Jun	1.817	0.823	0.453	-0.547	-0.301	1.27	0.699	-3.321
28-Jun	1.836	1.732	0.943	-0.057	-0.027	1.779	0.969	-32.448
05-Jul	2.587	2.597	1.004	0.0037	0.001	2.591	1.001	701.24
12-Jul	1.246	0.652	0.523	-0.477	-0.386	0.77	0.617	-2.614

Table 4. Spatial distribution indices for alates *Aphis gossypii* in eggplant field during 2020.

Date	m	S^2	C	I_{DM}	C_a	m*	m*/m	K
17-Apr	0.004	0.0003	0.067	-0.933	-224	-0.929	-223	-0.004
24-Apr	0.096	0.01	0.105	-0.896	-9.34	-0.799	-8.34	-0.107
01-May	0.2625	0.038	0.143	-0.857	-3.264	-0.594	-2.264	-0.306
08-May	0.521	0.069	0.133	-0.867	-1.664	-0.346	-0.664	-0.601
15-May	0.988	0.271	0.274	-0.726	-0.735	0.262	0.265	-1.361
22-May	1.517	0.609	0.402	-0.598	-0.39	0.919	0.606	-2.536
29-May	0.775	0.22	0.284	-0.716	-0.923	0.059	0.077	-1.083
05-Jun	0.838	0.287	0.343	-0.657	-0.784	0.181	0.216	-1.275
12-Jun	1.425	0.488	0.342	-0.658	-0.462	0.767	0.538	-2.166
19-Jun	1.588	0.84	0.529	-0.471	-0.297	1.117	0.703	-3.371
26-Jun	2.092	1.178	0.563	-0.437	-0.21	1.655	0.791	-4.788
03-Jul	1.775	1.336	0.753	-0.247	-0.139	1.5278	0.861	-7.18
10-Jul	2.396	2.463	1.028	0.028	0.012	2.424	1.012	86.1
17-Jul	1.83	0.776	0.423	-0.577	-0.314	1.257	0.69	-3.18

Fig. 1. The population density of cotton aphids, *A. gossypii* (apterous and alates) on eggplant during the 1st season, 2019

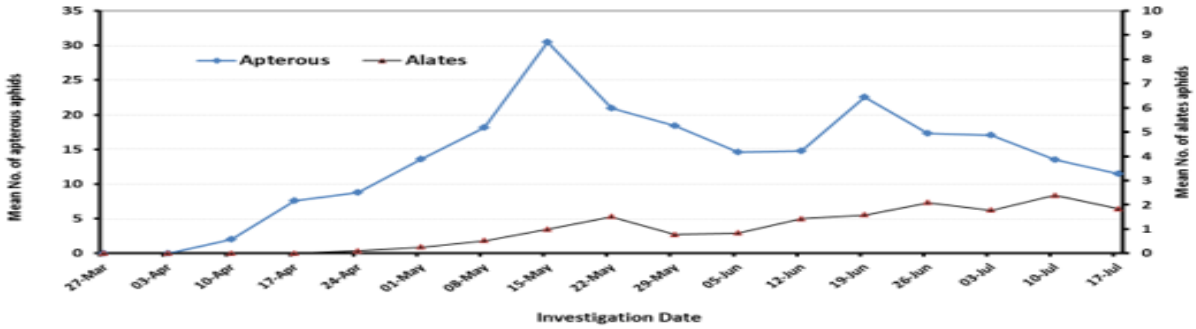

Fig. 2. The population density of cotton aphids, *A. gossypii* (apterous and alates) on eggplant during the second season, 2020

The middle leaves of eggplant harbored the intermediate population of *A. gossypii* with means of 5.1375 and 5.3661 individuals/ leaf, respectivelly. Finally, the lower portion had the lowest means of population density of *A. gossypii* with a general means of 4.2427 and 4.821 individuals/ leaf. Concerning the vertical distribution of the alate cotton aphids, there were significantly differences between the three vertical heights of the plant with higher numbers of aphids were recorded on the middle parts during both seasons. In regard, the vertical distribution of the apterous cotton aphids, there were significantly differences between the three vertical heights of the plant with higher numbers of aphids were recorded on the upper parts during both seasons.

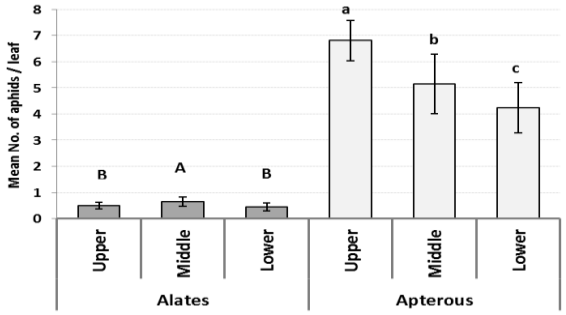

Fig. 3. Within plant distribution of the alates and apterous individuals of cotton aphids, *Aphis gossypii* during the reproductive stage of eggplant throughout the 1st season, 2019. (F= 7.369, L.S.D.= 0.1122 for alates aphids; F= 28.93, L.S.D.= 0.6908 for apterous aphids)
Bars with the same letter(s) are not significantly different at P > 0.05, upper cases for alates aphids and lower cases for apterous aphids)

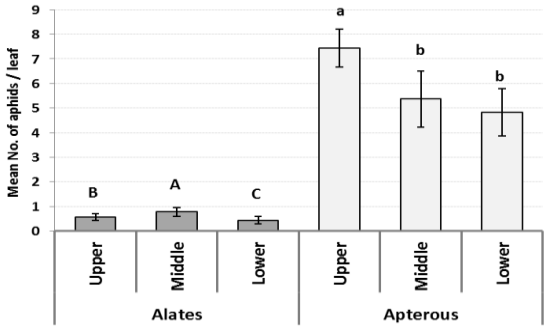

Fig 4. Within plant distribution of the alates and apterous individuals of cotton aphids, *Aphis gossypii* during the reproductive stage of eggplant throughout the 2nd season, 2020. (F= 17.576, L.S.D.= 0.1146 for alates aphids; F= 21.933, L.S.D.= 0.83965 for apterous aphids)Bars with the same letter(s) are not significantly different at P > 0.05, upper cases for alates aphids and lower cases for apterous aphids)

Population density of the aphidophagous predators of *A. gossypii* in eggplant field:

The associated natural enemies of cotton aphids on eggplants included coccinellids [*Coccinella septempunctata* Linneaus, *Coccinella undecimpunctata* Linneaus, *Cheilomenes vicina isis* (Crotch,) and *Cheilomenes vicina nilotica* (Mulsant), Coccinellidae: Coleoptera]; the aphid lion [*Chrysoperla carnea Steph.,* Chrysopidae: Neuroptera]; the pirate bugs, [*Orius* sp, Anthocoridae: Hemiptera]; and syrphid flies [*Syrphus* sp., Syrphidae: Diptera]. In accordance to the cotton aphid numerical abundance and being density-dependent, the associated aphidophagous predators were relatively a little more during the 1st season, 2019 as compared to that during the 2nd season, 2020. The mean larvae coccinellid population (which inclusive of 4 species) ranged from 0 to 18.125 larvae per plant (in June 21st) with the seasonal mean of 6.8125 grub and pupa per plant on the 1st season, 2019; while the corresponding values for 2nd season, 2020 were 0 to 14.625 per plant (in June 19th) with the seasonal mean of 5.746 grub and pupa per plant. The adults of coccinellid had a seasonal mean population of 0.97 and 0.68 per plant during 1st and 2nd seasons, respectively. The larvae of aphid lion, *c. carnea* was in significant numbers with the seasonal mean of 2.68 and 2.099 larvae per plant during 1st and 2nd seasons, respectively. The pirate bugs had a seasonal mean population of 0.55 and 0.496 per plant, while the syrphids were 0.165 and 0.096 per plant during the 1st, 2019 and 2nd, 2020 seasons, respectively.

The results obtained in Table (5)and fig (5) cleared that the correlation coefficient between the population dynamic of apterous and alates of the cotton aphids and the population dynamic of its associated different predators in 2019 and 2020 season. All of these correlation coefficient was positive and the most of them are statistically high significant.

Effect of foliar spray of chemical elicitors on the population density of *A. gossypii*:

The results presented in Tables 6 and 7 show the population density (mean numbers/leaf) of cotton aphids on the eggplant leaves which treated with salicylic acid (at rates of 100 and 200 ppm), jasmonic acid (at rates of 100 and 200 ppm) and β-aminobutyric (BABA) (at rates of 50 and 100 ppm) as compared with the control plots. Plants in control plots had a significant higher numbers of cotton aphids than in the treated plots. After one week the results show that there were higher numbers of *A. gossypii* on eggplants treated with SA than in the plants treated with JA and BABA. After two weeks the lowest number of *A. gossypii* was noticed in the plants treated with BABA. The general means of *A. gossypii* per eggplant leaf recorded 28.72, 21.59, 17.65, 16.48, 13.71, 14.32 and 12.76 individual /leaf in untreated plants, plant treated with SA (100 ppm), SA (200 ppm), JA (100 ppm), JA (200 ppm) BABA (50 ppm) and BABA (100 ppm) during the 1st season, 2019; while the corresponding values for 2nd season, 2020 were 23.95, 19.06, 15.65, 12.88, 11.11, 15.39 and 12.98 individual/ leaf. Therefore, this experiment also indicated that the jasmonic and β-aminobutyric acid enhances the resistant of eggplants for the cotton aphids as compared with control plots.

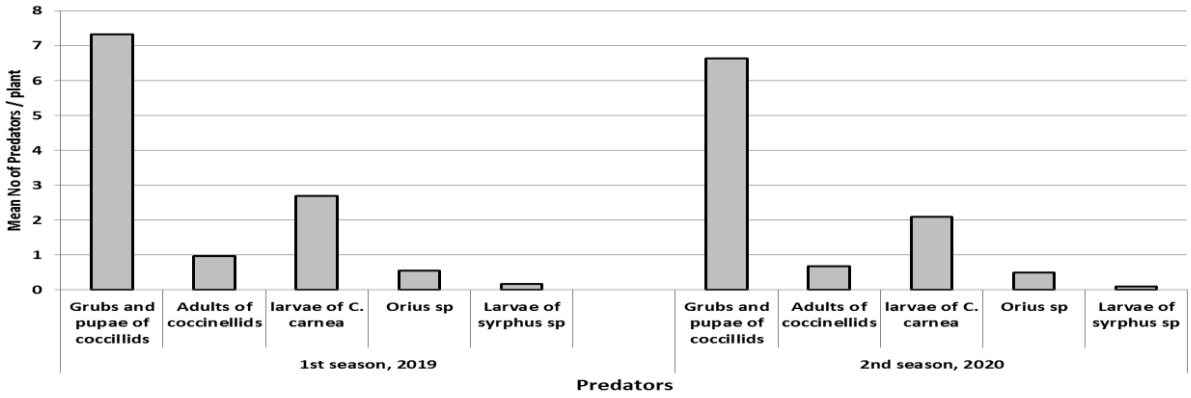

Fig 5. Seasonal mean number of cotton aphid predators in eggplant field throughout two successive seasons 2019 and 2020

Table 5. The correlation coefficient between the population fluctuation of the alates and apterous cotton aphids and its associated different predators:

Different predators	1st season, 2019		2nd season, 2020	
	Apterous *A. gossypii*	Alates *A. gossypii*	Apterous *A. gossypii*	Alates *A. gossypii*
Larvae and pupae of coccinellids	0.49*	0.88**	0.71**	0.74**
Adults of coccinellids	0.46	0.88**	0.39	0.82**
Larvae of *C. carnea*	0.63**	0.79**	0.58*	0.77**
Larvae of *Orius* sp.	0.53*	0.67**	0.49*	0.92**
Larvae *Syrphus* sp. (larvae)	0.53*	0.64**	0.39	0.47

*** Significant correlation coefficient ** highly significant correlation coefficient**

Table 6. Mean number of cotton aphid *A. gossypii* (±SD), by direct count on eggplants in untreated and treated plots with three chemical elicitors during the 1st season, 2019

Weeks post spray	1 week	2 weeks	3 weeks	General mean
Control	22.53±1.81^{a}	35.88±3.35^{a}	27.75±2.34^{a}	28.72±6.19^{a}
SA (100 ppm)	17.18±2.55^{b}	27.63±3.39^{b}	19.975±1.8^{b}	21.59±5.2^{b}
SA (200 ppm)	13.2±2.38^{cd}	21.15±2.49^{c}	18.6±2.01^{bc}	17.65±4.04^{c}
JA (100 ppm)	12.03±1.51^{de}	20.05±1.74^{c}	17.35±1.43^{bcd}	16.48±3.76^{cd}
JA (100 ppm)	10.13±1.27^{e}	16.25±1.98^{d}	14.75±1.52^{de}	13.71±3.09^{de}
BABA(50 ppm)	15.43±1.15^{bc}	10.94±2.31^{e}	16.6±2.09^{cde}	14.32±3.09^{cde}
BABA(100ppm)	14.33±2.59^{cd}	10.18±1.32^{e}	13.775±2.98^{e}	12.76±2.78^{e}

Means bearing the same letter(s) in the same column are not significantly different at P > 0.05

Table 7. Mean number of cotton aphid, *A. gossypii* (±SD) by direct count on eggplants in untreated and treated plots with three chemical elicitors during the 2nd season, 2020

Weeks post spray	1 week	2 weeks	3 weeks	General mean
Control	18.7±2.37^{a}	31.28±3.65^{a}	21.88±2.26^{a}	23.95±6.14^{a}
SA (100 ppm)	15.7±2.27^{ab}	24.18±2.6^{b}	17.3±2.55^{b}	19.06±4.45^{b}
SA (200 ppm)	12.45±1.68^{cd}	18.88±2.32^{c}	15.63±2^{bcd}	15.65±3.29^{c}
JA (100 ppm)	9.5±2.14b^{de}	16.1±2.69^{cd}	13.05±2.44^{cde}	12.88±3.57^{cd}
JA (100 ppm)	7.75±1.92^{e}	14.55±2.32^{d}	11.03±2.08^{e}	11.11±3.47^{d}
BABA(50 ppm)	14.53±1.68^{bc}	15.23±2.57^{cd}	16.43±2.79^{bc}	15.39±2.32^{c}
BABA(100ppm)	11.88±2.13^{cd}	14.23±2.01^{d}	12.53±1.98^{de}	12.98±2.19^{cd}

Means bearing the same letter(s) in the same column are not significantly different at P > 0.05

DISCUSSION

Knowledge of the distribution within and between plants of an insect pest on any plant species could help optimize decision making in IPM programs. In this study, the indices of spatial distribution model indicate the aggregative distribution of the apterous cotton aphids (the individuals tends to occur in clumps). The present results corroborate the results of Rai and Singh (1993), who studied the spatial distribution of the aphids infesting cabbage and cauliflower; Singh *et al*. (2016) who studied the spatial distribution and interaction of *Eriosoma lanigerum* and its parasitoid wasp, *Aphelinus mali* on apple; and Verma *et al.* (2018) who studied the spatial distribution of green peach aphid, *Myzus persicae* in bell pepper plants. In case of the alates (winged) cotton aphids, the variance was less than the mean (uniform or regular spatial model). The current results clearly show that a higher proportion of apterous cotton aphid is distributed in the top part of eggplant than in the middle and bottom parts. These results are in agreement with those of Gonzaga *et al*. (1991) who studied the vertical distribution of *A. gossypii* on non-transgenic cotton plants. Nematollahi *et al.* (2014) studied the vertical distribution of cabbage aphid, *Brevicoryne brassicae* (L.), on canola plants and reported significantly higher populations preferred upper parts of the plants. In disagreement with our results, Idris and Mohamad Roff (2002) studied the vertical distribution of *A. gossypii* on different chilli (*Capsicum annuum*) varieties and they found that the total number of *A. gossypii* is significantly lower in the upper and middle strata than the lower ones. In this study,

the results of occurrence periods of *A. gossypii* on eggplant are in harmony with those of Ibrahim and Megahed (2017) and Rahman *et al*. (2009) who studied the population dynamic of *A. gossypii* on different crops including eggplants. The most abundant predators of the cotton aphid were the coccinellid predators as the same findings of Lu *et al.* (2015). Based in the present results, the foliar spray of JA, BABA and SA resulted in declining the cotton aphid populations in eggplant crop. These results are in the same line with those of many authors such as Moreno-Delafuente *et al.* (2020) and Elhamahmy *et al*. (2016) who stated that the chemical elicitors such as salicylic acid induce systemic acquired resistance by promoting plant resistance against some insect pests such as *A. gossypii*. and *Brevicoryne brassicae*. The findings presented here support the results of Omer *et al.* (2001) in cotton plants, they found that the application of methyl ester of JA significantly decreased the preference of *A. gossypii*, *Tetranychus urticae* and *Frankliniella occidentalis* on treated plants compared with non-treated plants. Similarly, the population density of cotton aphid, *A. gossypii* was reduced by application of BABA compared to control and these findings agree with the results of who stated that the use of BABA by drench application significantly reduced the number of eggs of *Diaphorina citri* while the foliar application of BABA significantly reduced the number of adults of the insect when compared with a water control treatment.

CONCLUSION

In the present study, based on the spatial distribution indices, the spatial distribution of the apterous and alates cotton aphids in eggplant field was determined as an aggregated and uniform distribution, respectively. In both years, the apterous aphid populations were significantly higher within the upper level than with other levels. The foliar spray of JA, SA and BABA resulted in decreasing the cotton aphid populations in eggplant crop. The SA proved to be less effective than JA.

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دراسات بيئية ومكافحة لحشرة من القطن *Aphis gossypii* (Glover.) علي نبات الباذنجان *Solanum melongena*

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تعتبر حشرة من القطن *Aphis gossypii* (Glover.) واحدة من أخطر الحشرات الناقية الماصة علي مستوي العالم. في هذا البحث تم دراسة التوزيع بين وداخل النباتات للافراد المجنحة وغير المجنحة لحشرة من القطن، التقلبات العددية للحشرة وأعدائها الطبيعية بالاضافة الي تأثير الرش الورقي بحمض الساليسالليك وحمض الجاسمونيك وحمض البيتاامينوبيوتريك علي الكثافة العددية للحشرة علي نباتات الباذنجان في منطقة النوبارية، محافظة البحيرة، جمهورية مصر العربية. بينت النتائج أن التوزيع بين النباتات (التوزيع المكاني) للافراد المجنحة spatial distribution باستخدام دلائل التوزيع (معدل التباين إلى المتوسط، مؤشر ديفد وموريس للتشتت، التوزيع الثنائي السالب، مؤشر لولدز للتزاحم، قانون تايلور) كان ذو طبيعه تجمعية aggregation distribution وبالنسبة للافراد الغير مجنحة كان ذو طبيعة انفرادية uniform spatial distribution. بالنسبة للتوزيع داخل النبات فإن الكثافة العددية للافراد غير المجنحة علي الأوراق في الجزء العلوي من النبات أعلي بالمقارنة بالجزء الاوسط والسفلي. أما الكثافة العددية للافراد المجنحة علي الاوراق في الجزء الاوسط كانت أعلي من الاجزاء الاخري لنباتات الباذنجان. كما بينت النتائج ان متوسط التعداد الموسمي للحشرة أعلي في الموسم الاول عن متوسط التعداد الموسمي في الموسم الثاني. وبالمثل فان متوسط التعداد للمفترسات الحشرية لحشرة من القطن اعلي قليلا في الموسم الاول عن الموسم الثاني. وفيما يتعلق بتأثير الرش الورقي بكلا من JA و SA و BABA فإن استعمال هذه المركبات يؤدي الي انخفاض معنوي في الكثافة العددية لحشرة المن بالمقارنة بالكثافة العددية علي النباتات غير المعاملة.