

Effect of Some Integrated Pest Management Elements on the Population Density of *Bemisia Tabaci* (Gennadius) (Hemiptera: Aleyrodidae) on Tomato Plants (*Solanum Lycopersicum* L.)

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ABSTRACT

Management of the whitefly, *Bemisia tabaci* (Gennadius) is considered one of the challenges to worldwide scientists and farmers for achieving agricultural and environmental sustainability. In this work, we studied the effect of plant spacing, different combination of chemical fertilizers, treatment with potassium silicate, diurnal activity and some of chemical insecticides on the population density of *B. tabaci* on tomato plants under field conditions. The results showed that minimum population of whitefly nymphs were recorded to be per tomato leaves from those plots where maximum plant spacing (50 cm) was maintained. The results of effect of different rates of chemical fertilizers revealed that the treatment with nitrogen fertilizer was the most important factor affecting the population density of *B. tabaci* followed by potassium fertilizers and finally phosphorus fertilizers. The results also confirm that there are positive correlations between population densities of *B. tabaci* and levels of nitrogen fertilizer on tomato plants. The results concerning the diurnal activity of adults of *B. tabaci* clearly shown that there are significantly greater numbers of adults of *B. tabaci* were collected at 10:00 am and 11:00 am in summer and nili plantations, respectively compared with the other different times of the day. The tested insecticides against *B. tabaci* nymphs can be arranged as follows sulfoxaflor, thiamethoxam, acetamiprid, pyriproxphene, buprofezin and finally dinotefuran.

Key words: *Bemisia tabaci*, plant spacing, potassium silicate, chemical fertilization, circadian rhythm, insecticides.

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important vegetables crop in the world, including Egypt. The cultivated area in Egypt (in 2015) estimated by about 469,000 fed (197 thousand ha) with an average yield of 16.28 tons per fed., and about 7.7 million tons as a total production (Siam and Abdelhakim, 2018). From sowing until harvest, tomato plants are subject to attack by several insect pests. Whitefly *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) is one of the most destructive insect pests which attack the tomato plants (Firdaus, *et al.*, 2012; Mahmoud, 2017; Jahel, *et al.*, 2017; Prado Maluta, *et al.* 2020). Agriculturally and economically, the whitefly, *B. tabaci* is one of the most important insect pests worldwide, it attacks a broad

spectrum of hosts (extremely polyphagous insect pest) (Perring, 2001; Stansly and Naranjo, 2010; Shao-Jian, *et al.* 2011). By using its piercing sucking mouth parts, the whitefly punctures the leaf tissue and feed on the phloem; excretion of honeydew which followed by development of black sooty mold fungi, reduces plant vitality and consequently productivity causing great losses in the yield of its plant hosts (Palumbo *et al.*, 2000). In addition to direct damage, the whitefly transmits several plant viruses to tomato plants (indirect damage) (Polston, *et al.* 2014; Rojas, *et al.* 2018; Prado Maluta, *et al.* 2020). Many factors can affect the population density of whitefly in its plant hosts such as the weather factors (Jha and Kumar, 2017; Aregbesola, *et al.*, 2019), different fertilization rates (Idriss, *et al.*, 2015), planting spaces, dates and varieties (Mohamed, 2012). Any comprehensive integrated pest management (IPM) program requires an understanding of the pest's ecological information and the ecological relationships between crops, pests, and the environment. Thus, keeping in view the above information, in the present study, an effort was made to study the effect of some integrated pest management elements on the population density of *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) on tomato plants (*Solanum lycopersicum* L.). These elements included effect of plant spacing, different combination of chemical fertilizers, foliar spray with potassium silicate, diurnal activity and some insecticides in an attempt to develop the integrated pest management programs of this insect pest.

MATERIALS AND METHODS

Field experiments were carried out throughout two successive seasons (2019 and 2020) on tomato plants variety "Super strain B" at Nobaria district, Beheira Governorate, Egypt. Five separated experiments were conducted as follows:

Effect of plant spacing (plant density) of tomato plants on the population density of *B. tabaci* nymphs:

The 1st experiment was set up to study the effect of plant spacing (plant density) of tomato plants on the population density of *B. tabaci*. The experiment was laid out in a randomized complete block design (RCBD) with four replications (a single factor trial). Four treatments of

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different plant spacing namely 20 cm (about 50000 plants ha⁻¹), 30 cm (about 30000 plants ha⁻¹), 40cm (about 25000 plants ha⁻¹) and 50cm (about 20000 plants ha⁻¹) on the one side of beds, 100 cm width (1 m between rows). The experiment comprised of 16 plots, each measuring 6m × 5m, and 1 m between replications. At weekly interval, samples of 10 leaflets were picked from each replicate. The samples collected, placed in paper bags and transferred to the laboratory for examination under a stereomicroscope to determine number of nymphs /leaflets. The seedlings were planted at the experimental site on mid-February in the summer plantation and in mid-July in the nili plantation. The sampling was started 15 days post seedlings planting and continues up to the end of the season. During the growing seasons, all the recommended agriculture practices were performed as usual. No pesticides were used throughout the experiment.

Effect of different combination of chemical fertilizers on the population density of *B. tabaci*:

The present experiment aimed to study the effect of different rates of chemical fertilizers on the population density of *B. tabaci*. The experiment was laid out in a randomized complete block design (RCBD) with four replications. Seven treatments of different chemical fertilizers rates were tested as follow:

- 1- 120 N: 50 P: 100 K (control)
- 2- 180N: 50 P: 100 K (150 % of recommended nitrogen rate)
- 3- 60 N: 50 P: 100 K (50 % of recommended nitrogen rate)
- 4- 120 N: 75 P: 100 K (150 % of recommended phosphorus rate)
- 5- 120 N: 25 P: 100 K (50 % of recommended phosphorus rate)
- 6- 120 N: 50 P: 50 K (50 % of recommended potassium rate)
- 7- 120 N: 50 P: 150 K (150 % of recommended potassium rate)

Each treatment of N:P:K ratio was applied to the soil in four amounts in 15, 45, 65 and 85 days after transplanting. All the remaining agricultural practices were adopted as usual. The chemical fertilizers which used in this experiment were ammonium sulfate (20.6 % N) and/or ammonium nitrate (33.5% N) as a source of nitrogen (N), potassium sulphate (24% K₂SO₄) and super phosphate (15% P₂O₅) as sources of potassium and phosphorus, respectively. Population density of whitefly nymphs was monitored weekly during a growing season (as mentioned above). Weekly 10 leaflets were picked from each replicate, placed in paper bags and transferred to the laboratory for examination under a

stereomicroscope to determine number of nymphs /leaflets.

The samples were taken as mentioned above. Weekly 10 leaflets were picked from each replicate, placed in paper bags and transferred to the laboratory for examination under a stereomicroscope to determine number of nymphs /leaflets.

Effect of the foliar application with potassium silicate K₂SiO₃:

The 3rd experiment was planned to study the effect of the foliar application with potassium silicate K₂SiO₃ as a chemical inducers on tomato plants against the whitefly, *B. tabaci*. Three treatments were arranged in randomized complete block design with four replicates (50 m² per each) as follow:

- 1- 0 ppm potassium silicate (tap water spray) (control)
- 2- 200 ppm potassium silicate
- 3- 400 ppm potassium silicate

The treatments were applied (sprayed) by knapsack sprayer equipment (CP3) at the rate of 200 liter per feddan. Treatment of tomato plants repeatedly at by-weekly intervals, the spraying and sampling were started 15 days post-planting and continue up to the end of the season (weekly 10 leaflets were picked from each replicate). During the growing seasons, all the recommended agriculture practices were performed as usual. No pesticides were used throughout the experiment.

The diurnal activity or circadian rhythm of the whitefly, *B. tabaci*:

The objective of this experiment was to study the diurnal activity or circadian rhythm of the whitefly adults in tomato plants. The yellow sticky traps (20 x 15 cm) were used in this experiment. Ten traps were placed at 5m distances and hung at 50 cm above the ground levels. The traps were inspected at 2 hours intervals from 8 am to 8 pm in the summer plantation and from 7 am to 5 pm in the nili plantation (the traps were hung 2 hours before the 1st inspection). The captured adults of *B. tabaci* were counted and recorded. The experiment was performed in the Friday from each week for 6 weeks in summer and nili plantations of the two consecutive seasons 2019 and 2020.

Field performance of insecticides treatments against nymph stage of whitefly:

This experiment was carried out in the summer plantation of tomato plants during the two successive seasons 2019 and 2020. The experiment was laid out in a randomized complete block design (RCBD) with four replications for each treatment (50 m² each). The tested insecticides (Table 1) were applied by a manual knapsack sprayer (CP3) at the recommended field rate (200 liters

Table 1. The active ingredient, trade name, formulations and recommended rate of the tested insecticide

| Active ingredient | Trade name | % and formulation | Manufacturer | Recommended rates |
|-------------------|------------|-------------------|--|--------------------------|
| Acetamiprid | Mospilan® | 20% SP | Nippon Soda Chemical Industry Co. Ltd. | 25 mg L ⁻¹ |
| Thiamethoxam | Actara® | 25% WDG | Syngenta Agro | 50 mg L ⁻¹ |
| Pyriproxyfen | Admiral® | 10% EC | Sumitomo Chemical Co. Ltd | 75 ml/100 liter |
| Buprofezin | Applaud® | 25% SC | Shaanxi Dideu Medichem Co. Ltd | 50 mL/100L ⁻¹ |
| Sulfoxaflor | Closer® | 24% SC | DowAgro Sciences Co., Ltd | 100cm/Fadden |
| Dinotefuran | Ochin® | 20% SG | Mitsui Chemicals | 50 mg L ⁻¹ |

*The used recommended rates were determined based on the recommendations of Egyptian Ministry of Agriculture

per feddan), while control plots were sprayed by water only. All the agricultural practices were applied as usual. The blocks were separated from each other the by untreated two rows. The samples taken before treatment, 1, 4, 7 and 14 days post treatment (randomly ten leaflet of each plot). The reduction percentages of numbers of *B. tabaci* nymphs were calculated according to the equation of Henderson and Tilton's (1955):

$$\text{Reduction (\%)} = (1 - (Ma * Mc / Mb * Md)) * 100$$

Where:

Ma = mean numbers of *B. tabaci* nymphs in treatment after application

Mc = mean number of *B. tabaci* nymphs in control before application

Mb = mean number of *B. tabaci* nymphs in treatment before application

Md = mean number of *B. tabaci* nymphs in control after application

Statistical Analysis

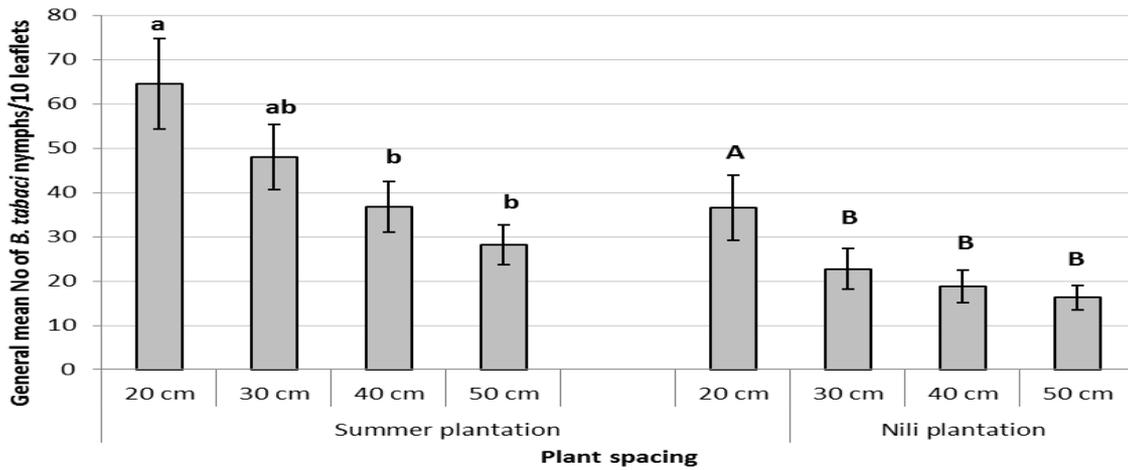
All the data were statistically analyzed and expressed as mean values \pm standard error of the mean (SEM). The least significant differences (LSD) were calculated using the Student-Newman-Keuls (SNK) method at probability level of 0.05 SAS (2016).

RESULTS AND DISCUSSION

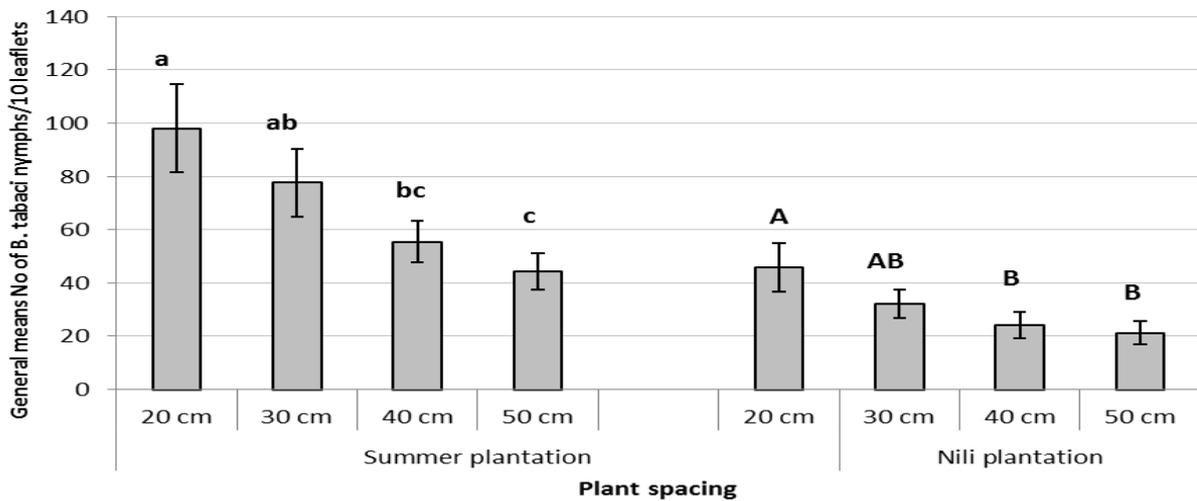
Results

Effect of plant spacing of tomato plants on the population density of *B. tabaci*:

Data presented in Figs. 1 and 2 show the effect of plant spacing on the density of *B. Tabaci* on tomato plants under open field conditions. The mean numbers of *B. tabaci* nymphs increased by decreasing planting space in both of the plantation dates throughout the two investigated seasons. As a mean of the whole season, the highest level of infestation with *B. tabaci* nymphs was occurred on tomato which plants sown at the shortest space (20 cm between plants) with mean numbers of 64.55 and 36.51 nymphs/10 leaflets in summer and nili plantation, respectively during the 1st season, 2019. In the 2nd season, 2020 these means recorded 98.052 and 45.92 nymphs/10 leaflets in summer and nili plantation, respectively. The tomato plants which sown at 30 cm and 40 cm plant spacing were recorded intermediate infestation rates. At 30 cm spacing, (as a whole seasonal mean) general means of 47.91 and 77.7 nymphs/10 leaflets were recorded in the summer plantation and 22.71 and 32.16 nymphs/10 leaflets in the nili plantation during the two successive seasons 2019 and 2020, respectively. Concerning the plants sown at 40 cm, these means decreased to 36.76 and 18.86 in the 1st season, and 55.48 and 24.14 in the 2nd season in summer and nili plantation, respectively. The lowest population densities of *B. tabaci* nymphs were recorded on tomato plants planted at the longest space (50 cm between plants) with mean numbers of (28.13 and 16.25 nymphs/10 leaflets and 44.28 and 21.18 nymphs/10 leaflets) in the two plantation dates throughout the two successive seasons, respectively.



**Fig. 1. The whole seasonal means of population density (\pm SE) of *Bemisia tabaci* on tomato plants sown at different plant spacing in the 1st season, 2019. (F= 4.706, L.S.D.= 20.43065 for summer plantation; F= 3.413, L.S.D.= 13.76085 for nili plantation)
 Bars with the same letter(s) are not significantly different at P > 0.05, lower cases for summer and upper cases for nili plantation)**



**Fig. 2. The whole seasonal means of population density (means \pm SE) of *Bemisia tabaci* on tomato plants sown at different plant spacing in the 2nd season 2020. (F= 4.203, L.S.D.= 32.97975 for summer plantation; F= 3.185, L.S.D.= 17.47785 for summer plantation)
 Bars with the same letter(s) are not significantly different at P > 0.05, lower cases for summer and upper cases for nili plantation)**

Effect of different combination of chemical fertilizers:

Data shown in Fig. 3 and 4 clearly demonstrated that nitrogen fertilizer was the most important factor affecting the population density of *B. tabaci*. The results also confirm that there is a positive correlation between population densities of *B. tabaci* and levels of nitrogen fertilizer on tomato plants. In summer plantation the general means of population density of *B. tabaci* nymphs increased from 47.49/ 10 leaflet to 78.67 /10 leaflet and from 69.99 /10 leaflet to 91.5/10 leaflet when the nitrogen fertilizers increase from 120 N: P: K to 180N: P: K (150 % of recommended nitrogen rate) in 2019 and 2020 respectively. Similar results were obtained in the nili plantation whereas the population density of *B. tabaci* significantly increased from 23.45/10 leaflet to 35.88 / 10 leaflet and from 31.42/10 leaflet to 46.62 / 10 leaflet in 2019 and 2020, respectively. On the other hand, tomato plants which fertilized with 60 N: 50 P: 100 K ratio (50 % of recommended nitrogen rate) had a lower

density of *B. tabaci* nymphs (30.47 and 55.74 nymphs /10 leaflets in summer plantation and 15.83 and 25.5/ 10 leaflets in nili plantation during the two seasons, respectively) compared with the tomato plant treated with the recommended rates.

The effect of different rates of potassium fertilizers on *B. tabaci* was the second noticed important effect. The tomato plants which fertilized with N: P: 1.5 K ratios (150 % of recommended potassium rate) infested with low densities of *B. tabaci* nymphs, whereas the general means of population density of *B. tabaci* nymphs recorded 29.29 and 13.34 nymphs /10 leaflets in the summer and nili plantations during the 1st season. The statistical analysis of the obtained results revealed that the different rates of phosphorus fertilizers on tomato plant had the least effect on the population density of *B. tabaci* compared with nitrogen and/or potassium fertilizers.

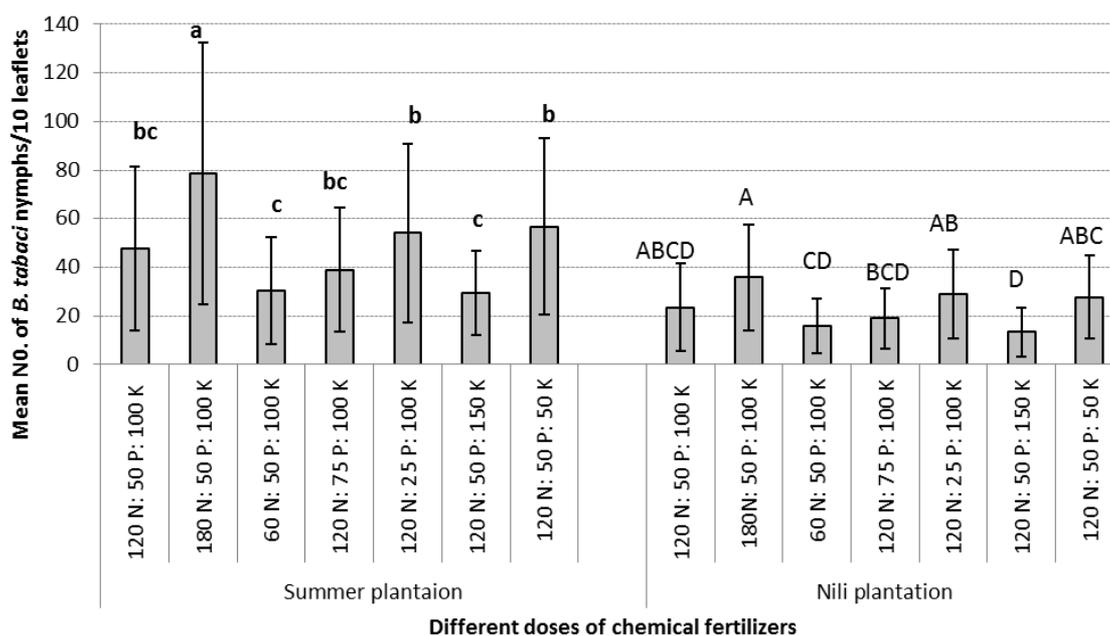


Fig. 3. The whole seasonal means of population density (means \pm SD) of Bemisia tabaci on tomato fertilized with different combinations of chemical fertilizers in the 1st season 2019. (F= 4.892, L.S.D.= 21.8832 for summer plantation; F= 5.272, L.S.D.= 12.75765 for nili plantation)

Bars with the same letter(s) are not significantly different at $P > 0.05$, lower cases for summer and upper cases for nili plantation)

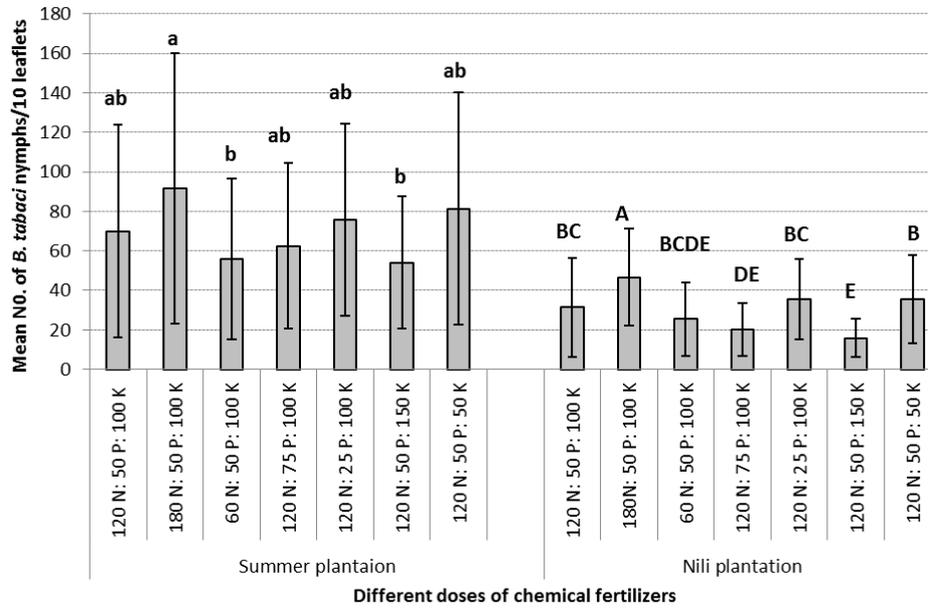


Fig. 4. The whole seasonal means of population density (means \pm SD) of *Bemisia tabaci* on tomato fertilized with different combinations of chemical fertilizers in the 2nd season 2020. (F = 1.409, L.S.D.= 32.50065 for summer plantation; F = 4.724, L.S.D.= 10.3209 for nili plantation)

Bars with the same letter(s) are not significantly different at $P > 0.05$, lower cases for summer and upper cases for nili plantation)

As shown in Figs. 5 and 6, throughout growing season of tomato plants, the treatment with potassium silicate as a foliar spray (400 ppm) lead to significantly decreasing in the density of *B. tabaci* in the nili plantation and insignificantly decreasing in summer plantation. These

results were repeated in both seasons of study, 2019 and 2020. The high density of *B. tabaci* in summer plantation than nili plantation might be the reason of the insignificantly in the decreasing of *B. tabaci* in the summer plantation.

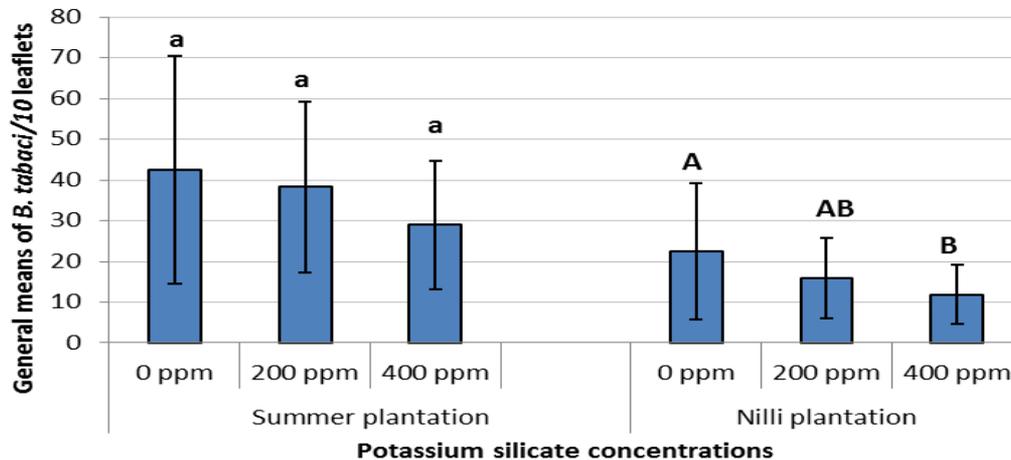


Fig. 5. The whole seasonal means of population density (\pm SD) of *Bemisia tabaci* on tomato treated with potassium silicate in the 1st season 2019. (F = 1.846, L.S.D.= 14.3732 for summer plantation; F = 3.744, L.S.D.= 8.03325 for nili plantation)

Bars with the same letter(s) are not significantly different at $P > 0.05$, lower cases for summer and upper cases for nili plantation)

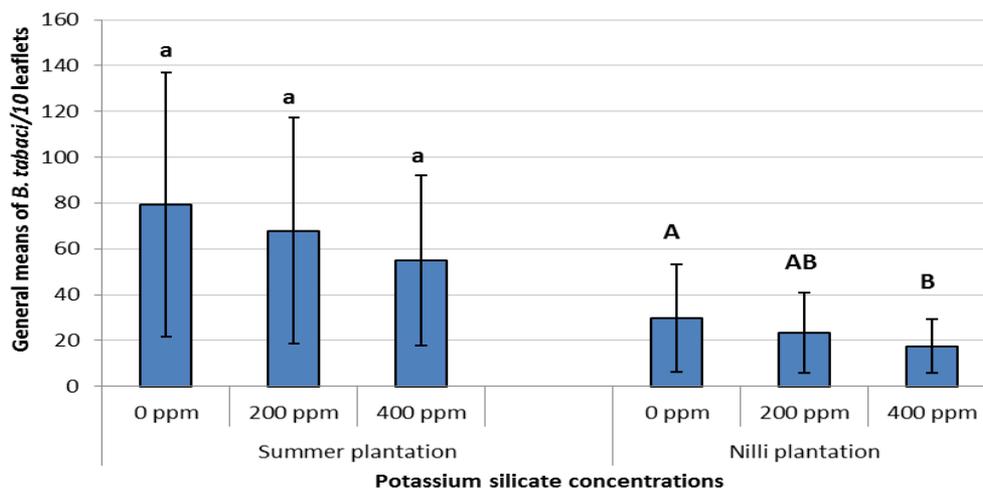


Fig. 6. The whole seasonal means of population density (\pm SD) of *Bemisia tabaci* on tomato treated with potassium silicate in the 2nd season 2020. (F= 1.179, L.S.D.= 31.782 for summer plantation; F= 2.164, L.S.D.= 11.8658 for nili plantation)

Bars with the same letter(s) are not significantly different at $P > 0.05$, lower cases for summer and upper cases for nili plantation)

The diurnal activity or circadian rhythm of the whitefly, *Bemisia tabaci*:

The mean numbers of *B. tabaci* collected at different seven times of the day (in summer plantation) and/or five times (nili plantation) during the day are shown in Figs 7 and 8. Significantly greater numbers of adults of *B. tabaci* were collected at 10:00 am and 11:00 am in summer and nili plantations, respectively compared with

the other different time of the day. In summer plantation, the number of adults decreased gradually up to the next peak which recorded at 4:00 pm, while in nili plantation the number of adults decreased gradually up to completely disappeared in the yellow trap. These results are repeated in the two successive seasons 2019 and 2020. The results also revealed that the circadian rhythms of whiteflies were different in the different planting dates.

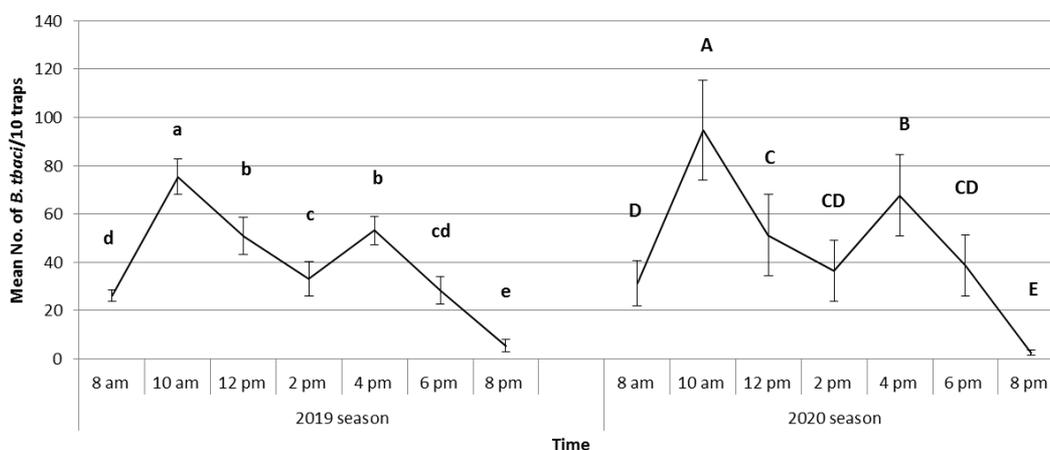


Fig. 7. The means of population density (means \pm SD) of *Bemisia tabaci* on tomato plants at different day hours in the summer plantation of 2019 and 2020 seasons. (F= 90.627, L.S.D.= 6.85015 for 2019 season; F= 25.708, L.S.D.= 16.53445 for 2020 season)

Bars with the same letter(s) are not significantly different at $P > 0.05$, lower cases for summer and upper cases for nili plantation)

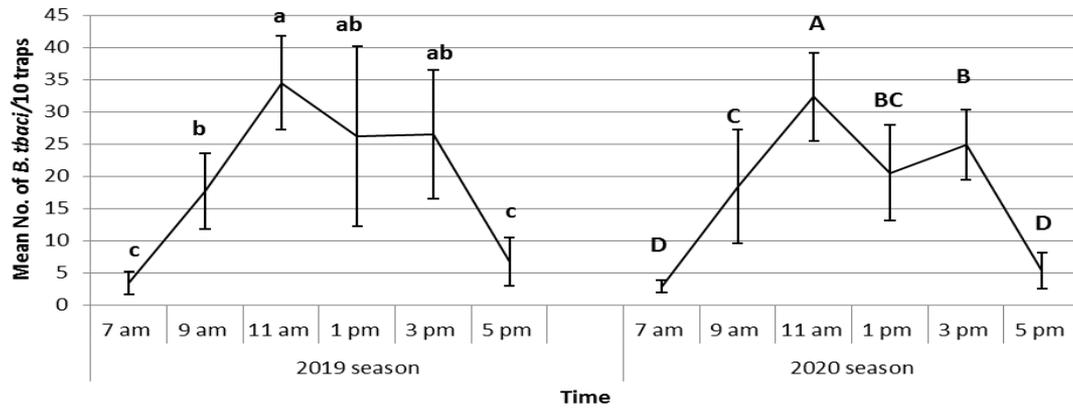


Fig. 8. The means of population density (means \pm SD) of *Bemisia tabaci* on tomato plants at different day hours in the nili plantation of 2019 and 2020 seasons. ($F= 13.435$, $L.S.D.= 9.63175$ for 2019 season; $F= 21.252$, $L.S.D.= 7.1241$ for 2020 season)

Bars with the same letter(s) are not significantly different at $P > 0.05$, lower cases for summer and upper cases for nili plantation)

Field evaluation of different selected insecticides against nymphs of *B. tabaci*

Results shown in Tables (2-5) revealed that, all the tested insecticide achieved considerable reduction percentages in *B. tabaci* nymphs during the two seasons, 2019 and 2020. During 2019 season, sulfoxaflor achieved the highest efficiency, gave the following reduction percentages (93.7, 94.75, 88.85 and 83.62 % after 1, 4, 7 and 14 days, respectively) with general mean 90.23 % and (95.97, 97.51, 92.99 and 86.88 % after 1, 4, 7 and 14 days, respectively) with general mean 93.34 after 1st and 2nd spray, respectively. The insecticide thiamethoxam came in the 2nd rank giving (80.55, 87.65, 91.1 and 81.94 % after 1, 4, 7 and 14 days, respectively) with a general mean of 85.31 % and (80.92, 84.14, 80.38 and 77.58 % after 1, 4, 7 and 14 days, respectively) with a general mean of 80.75 % after 1st and 2nd spray, respectively. In the 3rd place comes the insecticides acetamiprid which achieved (83.93, 89.31, 83.72 and 77.18 % after 1, 4, 7 and 14 days, respectively) with a general mean of 83.54% and (74.66, 83.2, 83.01 and 67.25 % after 1, 4, 7 and 14 days, respectively) with a general mean of 77.03 % after 1st and 2nd spray, respectively. The insecticides pyriproxyfen gave

reduction percentages of (64.24, 71.73, 81.57 and 76.93% after 1, 4, 7 and 14 days, respectively) with general mean 73.62% and (63.67, 73.46, 74.83 and 66.76 % after 1, 4, 7 and 14 days, respectively) with a general mean of 69.98 % after 1st and 2nd spray, respectively. The reduction percentages of buprofezin insecticide recorded (65.77, 75.52, 72.36 and 64.78 % after 1, 4, 7 and 14 days, respectively) with general mean 69.61% and (66.81, 71.19, 62.42 and 63.15) with general mean 65.89% after 1st and 2nd spray, respectively. Dinotefuran insecticide achieved the least efficacy, giving the following reduction percentages (64.02, 60.84, 57.11 and 54.14 % after 1, 4, 7 and 14 days, respectively) with a general mean of 59.03 % and (68.85, 64.99, 58.41 and 51.22 % after 1, 4, 7 and 14 days, respectively) with a general mean of 60.87 % after 1st and 2nd spray, respectively. In 2020 season, similar results were obtained whereas the reduction percentages of the tested insecticides according to its efficiency against nymphs of *B. tabaci* can be arranged discerningly as follows: sulfoxaflor, thiamethoxam, acetamiprid, pyriproxyfen, buprofezin and dinotefuran with general means of 94.17, 83.52, 83.06, 76.57, 66.24 and 56.97% after the 1st spray and 89.19, 83.08, 80.78, 70.84, 67.91, 62.07% after the 2nd spray, respectively.

Table 2. Effect of six insecticides on nymphs of *Bemisia tabaci* on tomato plants under field conditions during 2019 season (after 1st spray)

| Insecticides | Days post treatment | | | | General means±SD |
|---------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| | 1 | 4 | 7 | 14 | |
| Acetamiprid | 83.93±5.29 ^{bc} | 89.31±3.43 ^{ab} | 83.72±4.19 ^{bc} | 77.18±4.45 ^b | 83.54±5.93 ^b |
| Sulfoxaflor | 93.7±2.32 ^a | 94.75±1.14 ^a | 88.85±2.78 ^{ab} | 83.62±4.07 ^a | 90.23±5.2 ^a |
| Dinotefuran | 64.02±6.99 ^d | 60.84±6.16 ^d | 57.11±5.52 ^e | 54.14±5.85 ^d | 59.03±6.72 ^e |
| Pyriproxphene | 64.24±6.75 ^d | 71.73±6.26 ^c | 81.57±3.67 ^c | 76.93±3.19 ^b | 73.62±8.12 ^{cd} |
| Thiamethoxam | 80.55±7.14 ^c | 87.65±3.81 ^b | 91.1±2.73 ^a | 81.95±3.93 ^{ab} | 85.31±6.9 ^b |
| Buprofezin | 65.77±5.23 ^d | 75.52±4.99 ^c | 72.36±1.59 ^d | 64.78±1.38 ^c | 69.61±5.73 ^d |
| F value | 18.198 | 30.323 | 48.263 | 31.756 | 53.384 |
| L. S. D. | 8.70565 | 6.9029 | 5.39535 | 6.0077 | 4.47115 |

The means superscripted with the same alphabets in the same columns do not significantly differ from each other as per least significant difference test ($p \geq 0.05$)

Table 3. Effect of six insecticides on nymphs of *Bemisia tabaci* on tomato plants under field conditions during 2019 season (after 2nd spray)

| Insecticides | Days post treatment | | | | General means ±SD |
|---------------|--------------------------|--------------------------|--------------------------|-------------------------|-------------------------|
| | 1 | 4 | 7 | 14 | |
| Acetamiprid | 74.66±5.76 ^{bc} | 83.2±7.63 ^b | 83.01±3.47 ^b | 67.25±2.39 ^c | 77.03±8.28 ^b |
| Sulfoxaflor | 95.97±1.55 ^a | 97.51±3.85 ^a | 92.99±2.57 ^a | 86.88±5.63 ^a | 93.34±5.36 ^a |
| Dinotefuran | 68.85±8.03 ^{cd} | 64.99±5.15 ^d | 58.41±5.92 ^d | 51.22±3.99 ^d | 60.87±8.74 ^d |
| Pyriproxphene | 63.67±7.85 ^d | 73.46±6.43 ^c | 74.83±6.33 ^c | 66.76±8.18 ^c | 69.68±8.05 ^c |
| Thiamethoxam | 80.92±3.01 ^b | 84.14±6.27 ^b | 80.38±4.79 ^{bc} | 77.58±7.37 ^b | 80.75±5.56 ^b |
| Buprofezin | 66.81±7.5 ^{cd} | 71.19±6.59 ^{cd} | 62.42±7.02 ^d | 63.15±6.75 ^c | 65.89±7.2 ^{cd} |
| F value | 14.987 | 14.482 | 24.544 | 16.373 | 40.864 |
| L. S. D. | 9.1346 | 9.0686 | 7.8174 | 9.00055 | 5.1387 |

The means superscripted with the same alphabets in the same columns do not significantly differ from each other as per least significant difference test ($p \geq 0.05$)

Table 4. Effect of six insecticides on nymphs of *Bemisia tabaci* on tomato plants under field conditions during 2020 season (after 1st spray)

| Insecticides | Days post treatment | | | | General means ±SD |
|---------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| | 1 | 4 | 7 | 14 | |
| Acetamiprid | 81.08±3.37 ^b | 88.43±2.33 ^b | 85.2±3 ^b | 77.51±2.45 ^b | 83.06±4.95 ^b |
| Sulfoxaflor | 95.41±1.44 ^a | 97.15±1.86 ^a | 93.41±1.91 ^a | 90.72±2.71 ^a | 94.17±3.07 ^a |
| Dinotefuran | 59.89±6.08 ^c | 57.02±2.67 ^e | 59.13±5.75 ^e | 51.85±4 ^d | 56.97±5.4 ^e |
| Pyriproxphene | 76.82±3 ^b | 78.3±3.68 ^c | 80.24±2.68 ^c | 70.94±4.3 ^c | 76.57±4.71 ^c |
| Thiamethoxam | 79.07±3.1 ^b | 84.04±2.89 ^b | 90.11±1.09 ^a | 80.84±2.36 ^b | 83.52±4.88 ^b |
| Buprofezin | 61.66±6.63 ^c | 66.46±4.45 ^d | 69.92±1.23 ^d | 66.92±5.16 ^c | 66.24±5.26 ^d |
| F value | 37.278 | 90.152 | 73.028 | 54.041 | 125.063 |
| L. S. D. | 6.4446 | 4.60535 | 4.5213 | 5.3748 | 3.3529 |

The means superscripted with the same alphabets in the same columns do not significantly differ from each other as per least significant difference test ($p \geq 0.05$)

Table 5. Effect of six insecticides on nymphs of Bemisia tabaci on tomato plants under field conditions during 2020 season (after 2nd spray)

| Insecticides | Days post treatment | | | | General means ±SD |
|---------------|--------------------------|--------------------------|--------------------------|-------------------------|--------------------------|
| | 1 | 4 | 7 | 14 | |
| Acetamiprid | 78.93±4.38 ^{bc} | 81.26±3.74 ^b | 81.64±4.52 ^b | 81.28±4.13 ^b | 80.78±3.92 ^b |
| Sulfoxaflor | 87.57±5.98 ^a | 89.19±5.31 ^a | 90.54±2.13 ^a | 89.48±3.33 ^a | 89.19±4.14 ^a |
| Dinotefuran | 74.79±2.29 ^c | 63.47±2.84 ^d | 57.4±3.62 ^d | 52.6±3.03 ^d | 62.07±8.97 ^d |
| Pyriproxphene | 67.06±5.9 ^{cd} | 75.01±4.92 ^c | 71.98±3.7 ^c | 69.32±8.84 ^c | 70.84±6.29 ^c |
| Thiamethoxam | 83.46±3.41 ^{ab} | 85.91±1.71 ^{ab} | 85.23±2.12 ^{ab} | 77.73±3.58 ^b | 83.08±4.17 ^b |
| Buprofezin | 61.54±10.57 ^d | 83.31±3.4 ^{ab} | 69.12±7.66 ^c | 57.68±4.11 ^d | 67.91±11.92 ^c |
| F value | 10.714 | 23.176 | 30.792 | 33.420 | 32.760 |
| L. S. D. | 8.64325 | 5.7194 | 6.5033 | 7.30585 | 5.06565 |

The means superscripted with the same alphabets in the same columns do not significantly differ from each other as per least significant difference test ($p \geq 0.05$)

Discussion

In an attempt to help in developing an integrated pest management program of the whitefly, *B. tabaci*, the present effort was made to study the effect of some factors on its density on tomato plants under the open field conditions. The results clearly show that the population density of whitefly, *B. tabaci* was significantly more abundant in the narrow spacing (20 cm) than the other spaces (30, 40 and 50 cm). These results are in synchronized with those stated by Abd El-Malak and Salem (2002) who studied the effect of plant spacing of sweetpotato plants (20, 25 and 30 cm) on the population density of six arthropods include *B. tabaci* and found that the highest population densities were recorded in the shortest spacing. The present results also are in agreement with both of Emam *et al.* (2006) on their studies on sweetpea plants, Mohamed (2012) on his studies on cucumber plants and Momtaz, *et al.*, (2018) on cotton plants who reported highest mean numbers of *B. tabaci* in the narrow plant spacing. The present results indicated that there are significantly increasing of population density of *B. tabaci* nymphs by increasing nitrogen fertilizer (from 120N to 180 N). These results are in harmony with the experiments of Bi, *et al.*, (2001) on cotton plants and Draz, *et al.*, (2013) who found that increasing in nitrogen fertilizer affect the biological aspects of *Bemisia argentifolii* (lead to longer of adult longevity, higher survival rates and also increased of longest of reproductive periods). Also, Minkenberg and Ottenheim (1990) reported that the increasing of nitrogen in tomato leaves lead to greater rate of eggs laid per day and fecundity of *B. tabaci*. LU Zhong-xian, *et al.*, (2007) attributed the positive effects on population density of the insect pests which feeding on plants treated with high rates of nitrogen fertilizer to the increasing of the soluble protein content. our results suggest that the increases of potassium fertilizer rates lead to reduction in the density of *B. tabaci* in agreement with the results of Perrenoud (1977) and AL-Khazraji, *et al.* (2018). Concerning the

treatment with potassium silicate, our results in line with the results of Abbasi *et al.*, (2020) who suggested that the foliar application with silicon sources for controlling *B. tabaci* is effective and an eco-friendly approach.

The study of diurnal activity clearly shows that there are significant differences in the collected number of *B. tabaci* at different times of the day. Our results confirmed the results of Pan, *et al.* (2015) who found that the flight activity of whitefly, *B. tabaci* was low in near of both sunrise and sunset and increased in the other day hours. The current study revealed that during the day hours the whitefly, *B. tabaci* has two active peaks. In disagreement with this results, Bellows *et al.* (1988) found that the whitefly, *B. tabaci* showed a unimodal activity. In this study, the insecticide sulfoxaflor (Closer®) was the most effective insecticide among the six tested insecticides followed by thiamethoxam, acetamiprid, pyriproxphene, buprofezin and finally dinotefuran. Thus, our results are synchronized with that of Jahel, *et al.* (2017) who found that the insecticide sulfoxaflor was the most effective insecticide among Sulfoxaflor, Azadirachtin, *Beauveria bassiana* insecticides. Also, the present results are in agreement with Barrania and Abou-Taleb (2014) who tested five insecticides viz., pyriproxifen, novaluron, thiamethoxam, imidacloprid, acetamiprid and chlorantraniliprole against immature stages of *B. tabaci*. They found that all tested insecticides were comparable against *B. tabaci* nymphs, and both of thiamethoxam and acetamiprid achieved the highest reduction percentage in two consecutive seasons. The present results show that the chitin synthesis inhibitors (pyriproxifen and Buprofezin) were effective against *B. tabaci* nymphs in agreement with both of Lee *et al.*, (2002) and Cutler *et al.*, (2005) who found that the insect growth regulator, pyriproxifen and novaluron were effective against immature stages of *B. tabaci* and relatively low effective against the adult stage. In general, the current results recommended to use sulfoxaflor or thiamethoxam insecticides or in a sequential treatment with chitin

inhibitors, at the proper diurnal activity of *B. tabaci* to control the pest, beside the use appropriate plant spacing and the better rates of chemical fertilizers (NPK) in the IPM programs.

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الملخص العربي

تأثير بعض عناصر مكافحة المتكاملة علي الكثافة العددية لحشرة الذبابة البيضاء *Bemisia tabaci* علي نباتات الطماطم (*Solanum lycopersicum* L. (Gennadius)

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بالسماد البوتاسي والفوسفاتي، وأشارت النتائج الي وجود علاقة ارتباط موجبة بين السماد النيتروجيني وتعداد الذبابة وعلاقة ارتباط سالبة بين تعداد الذبابة والتسميد البوتاسي. وفيما يتعلق بالنشاط النهاري للحشرة الكاملة للذبابة البيضاء فإن النتائج بينت أن أعداد الذبابة البيضاء تكون أعلى معنويًا في كلا من الساعة العاشرة والحادية عشر صباحًا مقارنة ببقية ساعات النهار الأخرى وتكررت هذه النتائج في كلا من العروة النيلية والعروة الصيفية. هذا ويمكن ترتيب المبيدات التي تم اختبارها علي تعداد الذبابة البيضاء كالآتي السلفوكسافلور sulfoxafloor، الثياميسوكسام thiamethoxam، الاسيتامبريد acetamiprid، البيريبروكسفين pyriproxphene، البروفيزين buprofezin، واخيرًا مبيد الداينيتروفوران dinotefuran.

الإدارة المتكاملة للذبابة البيضاء *Bemisia tabaci* تعتبر واحدة من أهم التحديات التي تواجه العلماء والمزارعين وذلك لتحقيق تنمية زراعية مستدامة. في هذا البحث تم دراسة تأثير كلا من مسافات الزراعة، نسب أو تراكيب مختلفة من الأسمدة الكيماوية، المعاملة بسليكات البوتاسيوم، النشاط النهاري للحشرة البالغة وكذلك تأثير المعاملة ببعض المبيدات الحشرية علي الكثافة العددية للحشرة علي نباتات الطماطم تحت ظروف الحقل المفتوح. أوضحت النتائج أن أقل كثافة عددية للحشرة تم تسجيلها علي أوراق نباتات الطماطم التي تم زراعتها علي مسافات ٥٠ سم. أوضحت النتائج أيضًا أن السماد النيتروجيني كان العامل الرئيسي الذي يؤثر في تعداد الذبابة البيضاء مقارنة