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Evaluation of Some Predatory Mites effect Against *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae) Infesting Tomato Crop

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ABSTRACT

In order to maximize the sustainable development and minimize using of chemical insecticide and its hazards to the environment, the current study was designed to elucidate the possible predacious effect of some predatory mites namely; *Neoseiulus californicus, Typhlodrompis swirskii, Neoseiulus cucumeris, Typhlodromus nigavi, Phytoseiulius persimilis* and Vertemic/Egyxide oil combination against *Bemisia tabaci,* in two summer seasons of tomato cultivars, either as a single treatment or in combination in a 2-yr field study; August 2018 and August 2019 in complete randomized block design. The results indicated that the single treatment of *T. swirskii* and *T. nigavi* as well as Vertemic/Egyxide oil (1ml + 2.5 ml/ liter combination) recoded 95.83, 81.16, and 77.39 reduction percentages in *B. tabaci* population in the first season respectively, the general mean of *B. tabaci* in the two seasons was 0.598, 3.307 and 3.379 individual/leaflet respectively after treatment by *T. swirskii* and *T. nigavi* and Vertemic/Egyxide oil. Moreover, a single treatment of *N. californicus* and *N. cucumeris* had a weak reduction effect against *B. tabaci*. Meanwhile, *P. persimilis* reduction effect was non significantly different from the control. Whereas, in the case of combination treatment the results indicated that all combination treatment had a significant reduction effect against *B. tabaci* in the two seasons compared with the control in the two seasons. Our results indicated a considerable role of different predatory mites including; *T. swirskii* and *T. nigavi* as effective biological control agents or Vertemic/Egyxide oil combination against *B. tabaci* and can be useful in integrated management programs of *B. tabaci* pest.

INTRODUCTION

Whitefly; *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae) is one of the dangerous insect pests infested tomato plants *Lycopriscum esclentum* L. (Family: Solanaceae) either in an open field or in the greenhouse due to its high reproductive rate, the short life cycle, and numerous hosts (Oliveira *et al*., 2001). *B. tabaci* still a severe threat to UK horticulture (Cuthbertson 2013).

The whitefly, *Bemisia tabaci* (Hemiptera: Aleyrodidae) is a primary pest of the important economic crops worldwide (Cuthbertson& Vänninen, 2015). Whiteflies have six life stages: the egg, four nymphal instars, and the adult stage (Walker *et al*., 2010). Meanwhile, *B. tabaci* has a major impact on crop production as a global pest, that causing significant loss to a wide variety of agricultural crops due to carrying and transmit viral diseases (perring *et al*., 2018). Tomato leaf curl virus (ToLCV) is transmitted by *B. tabaci*. Moreover, the damage they do in tomato plants is due to the many viruses (>300 species) they can transport, which allow number many genera; Ipomovirus (Potyviridae), Crinivirus (Closteroviridae), Carlavirus (Betaflexiviridae), Begomovirus (Geminiviridae), and Torradovirus (Secoviridae) (Polston *et al*., 2014). *B. tabaci* considered as a virus vector which induce problems in tomato fields, (perring *et al*., 2018). *B. tabaci* usually prefer the middle leaflets (Tsueda *et al*., 2014). On the other hand, as a result of using conventional chemical control is the main prevalent control strategy in *B. tabaci* management case; it developed their resistance to a wide range of chemical pesticides, regardless their environmental risks (Janssen *et al*., 2017**;** Guirao *et al*., 1997).

Thus, biological control is very useful to control *B. tabaci* as an environmentally safe tool as well as no resistance development. Some studies recorded that the phytoseiid predatory mite *Amblyseius swirskii* recorded a high reduction in *B. tabaci* population and can be used as a beneficial biological control tool against it (Bolckmans *et al*., 2005; Hoogerbrugge *et al*., 2005). Fortunately, *A. swirskii* is the most useful tool as a biological control agent for whitefly in both sweet pepper and cucumber plants (Nomikou *et al*., 2001). Also, *B. tabaci* is notorious for its resistance to chemical pesticides, that’s why the biological control tool up an environmentally consistent and potentially fixed management tactic to control this unwanted insect (Jazzar and Hammad, 2004). Moreover, biological control of pests that attack tomato a feasible or suitable alternative to using synthetic pesticides (Lahiri and Orr, 2018).

However, change in chemical control of phytophagous insects in agro-ecosystems is urgently needed to maximize efficiency and to minimize negative effects (Opit *et al*. 2001; Naher *et al*.2006). This work aimed to investigate and elucidate the possible predacious effect of some predatory mites *Neoseiulus californicus, Typhlodrompis swirskii, Neoseiulus cucumeris, Typhlodromus nigavi, Phytoseiulius persimilis*, and Vertemic/Egyxide oil combination against *B. tabaci* as environmentally safe biological control agents against *B. tabaci* in tomato crop either as a single treatment or combination treatment

MATERIALS AND METHODS

This study was conducted in two summer seasons; August 2018 and August 2019 in Agriculture Research Station, Qaliube, Giza.

Tested Predators:

Predatory mites; *Neoseiulus californicus, Typhlodrompis swirskii, Neoseiulus cucumeris, Typhlodromus nigavi, Phytoseiulius persimilis* (predatory-prey ratio of release was 1:5). Vertemic/Egyxide oil combination (1ml + 2.5 ml/ liter) in against B. tabaci infesting Rogina tomato cultivar. Mass rearing of predatory mites was performed according to Afifi *et al.* (2013).

Tested Products:

Vertimec 1.8% (Abamectin) is an Acaricide/Insecticide which used as the biocontrol product against mites and insects on several crops including vegetables, pome fruit, citrus and cotton. Molecular formula: $C_{48} H_{72} O_{14}$ combined with Egyxide oil (1ml + 2.5 ml/ liter).

Experimental Design:

This experiment was performed as a complete randomized block design, divided into 7 plots (three replicates), each plot (3×30×1.75m) was planted with 525 tomato seedlings, as well as a safe area between plots was left.

Experimental Procedure:

The experiment was carried out at Qaleob, village, Qaleobia Governorate Egypt. During two successive early summer seasons 2018 and 2019 in an open field. Rogina tomato seeds were sown in the 3rd week of June in the nursery, then the seedlings were planted in the field in the second week of July. The cultivated area was divided into 12 treatments (6 singles + 5 combined + check) each treatment had three replicates. Application of release and spry started the 1st week of august in both seasons, a check was sprayed with water only. A sample of 10 leaves of tomato was taken randomly from each replicate, before releasing predators or spraying, and then weekly afterward, the sample was carefully examined and the number of *B. tabaci* was recorded.

Data Analysis:

Reduction percentages were calculated according to Henderson & Tilton (1955). The obtained results in this study were statistically analyzed using the IBM SPSS software (Version 20). (One way and two-way) analysis of variance (ANOVA) and Least significant difference (LSD) was performed at α=0.05.

RESULTS

Single Treatment:

Data in table (1) shows the mean of *Bemisia tabaci* population (season 2018) influenced by the single treatment of *T. swirskii*, *P. persimilis*, *N. cucumeris, T. nigavi, N. Californicus,* and Vertemic + Egyxide (1ml + 2.5 ml/ liter) combination compared with the check control. The data proved that the single treatment with predatory mite namely; *T. swirskii, P. persimilis, N. cucumeris, T. nigavi, N. Californicus,* and Vertemic + Egyxide (1ml + 2.5 ml/ liter) against *B. tabaci* recorded 0.83, 19.61, 5.13, 3.79, 11.50 and 4.51individual/leaflet respectively, compared with control which recorded 19.81 individual/leaflet. Moreover, the reduction percentages ranged between 94.91-0.373932%, 94.56414-1.477669%, 92.34771-1.432726%, and 98.7023-0.654% after 4th week, 8th week, 12th week, and 16th week respectively. Meanwhile, the general reduction of *B. tabaci* treated with *T. swirskii, P. persimilis, N. cucumeris, T. nigavi, N. Californicus,* and Vertemic + Egyxide (1ml + 2.5 ml/ liter) after 16 weeks was 95.83, 1.021, 74.27, 81.16, 42.41 and 77.39 respectively. The analysis of variance of the data provided in table (2) proved that F. value was 16.995 which was highly significant compared with F. tabulated value (2.99) $_{(6,\ 105\ \text{at}\ \alpha=0.01)}$. These results indicated that there is a significant difference at least between the two treatments. Thus, the Least significant difference (LSD) value was 2.67, when comparing the different means according to LSD it was found that, the single treatment with *T. swirskii* was the most efficient in the reduction of *B. tabaci* population, followed by *T. nigavi*. Moderate results can be obtained by Vertemic + Egyxide (1ml + 2.5 ml/ liter) followed by *N. cucumeris* then *N. Californicus.* Whereas, *P. persimilis* has no effect on *B. tabaci* population compared with untreated control.

Table 1. Effect of single treatment on all stages of *Bemisia tabaci* infesting tomato plants during summer season 2018

No. of weeks	*T. swirskii*	*P. persimilis*	*N. cucumeris*	*T. nigavi*	*N. californicus*	Vertemic+ Egyxide	control
pre-treatment	1.27	1.26	1.27	1.28	1.27	1.27	1.26
1st week	0.17	3.11	0.94	0.25	1.1	0	1.1
2nd week	0.28	3.28	0.87	0.5	2.25	0.04	3.31
3rd week	0.2	5.16	1.11	0.9	3.1	0.09	5.17
4th week	0.31	7.1	1.2	0.94	6.14	5.17	9.14
Mean	0.24	4.6625	1.03	0.6475	3.1475	1.325	4.68
Reduction%	94.91217	0.373932	78.16475	86.38071	33.27529	71.9109	
5th week	0.45	13.11	1.34	1.06	7	0.66	11.9
6th week	0.9	15.32	1.6	1.14	9.01	2.15	14.8
7th week	0.91	14.01	2.14	1.95	10.04	5.9	15.81
8th week	1.04	16.9	3.26	2.14	11.45	7.5	17.72
Mean	0.825	14.835	2.085	1.5725	9.375	4.0525	15.057
Reduction%	94.56414	1.477669	86.26211	89.71988	38.22892	73.2984	
9th week	0.98	21.34	4.11	2.68	14.25	11.4	19.75
10th week	1.11	25.2	4.6	3.7	13.11	14.06	21.74
11th week	2.13	22.8	5.8	3.88	15.6	0.01	23.68
12th week	2.94	22.16	7.14	5.9	15.1	0.4	27.66
Mean	1.79	22.875	5.4125	4.04	14.515	6.4675	23.207
Reduction%	92.34771	1.432726	76.86144	82.86384	37.94804	72.3512	
13th week	0.98	28.19	9.11	6.81	17.8	0.94	31.63
14th week	0.77	36.11	11.15	8.89	18.15	3.9	35.54
15th week	0.14	40.5	13.7	10.32	19.9	7.4	37.48
16th week	0.01	39.51	14.15	9.6	23.01	13.61	40.61
Mean	0.475	36.0775	12.0275	8.905	19.715	6.4625	36.315
Reduction%	98.7023	0.654	67.14086	75.8616	46.13861	82.3444	
General mean	0.8325^a	19.6125^ns	5.13875^bc	3.79125^b	11.50063^e	4.51437^b	19.815^ns
General Reduction%	95.83	1.021	74.27	81.16	42.41	77.39	
LSD	2.67						
P. value	0.000						
F. value (0.01)	16.995**						

Note: Means with the same litter is not significantly different, **= highly significant at (α=0.01)

Table 2. Analysis of variance of single treatment of *B. tabaci* in season 2018

Source of variance	Sum of Squares	Df	Mean Square	F. value	P. value
Between Groups	5824.274	6	970.712	16.995**	.000
Within Groups	5997.395	105	57.118		
Total	11821.669	111			

Note: **= highly significant at (α=0.01)

Data illustrated in table (3) showed that *B. tabaci* population (season 2019) was influenced by a single treatment of different predacious mites and Vertemic + Egyxide oil combinations compared with untreated control. The mean of *B. tabaci* population was 0.36, 10.09, 5.41, 2.82, 6.34 and 2.241individual/leaflet after treatment with *T. swirskii, P. persimilis, N. cucumeris, T. nigavi, N. Californicus* and Vertemic + Egyxide combination respectively, compared with control which recorded 10.19 individual/leaflet. Moreover, the reduction percentages ranged between 88.14219-1.232394%, 91.46905-1.789709%, 94.00739-0.780061% and 99.51-0.782329% after 4th week, 8th week, 12th week and 16th week respectively. Meanwhile, the general reduction of *B. tabaci* was 96.45825, 0.907753, 47.35361, 73.08384, 38.93199and 75.9618 after treatment with different predacious mites, *T. swirskii*, *P. persimilis*, *N. cucumeris*, *T. nigavi*, *N. Californicus,* and Vertemic + Egyxide combination rrespectively. The analysis of variance of the data provided in table (4) proved that, F. value was 7.990 which was highly significant compared with F. tabulated value (2.99) (6, 105 at α=0.01). These results indicated that there is significant difference between treatments. When compared according to the Least significant difference (LSD) value which was1.91, the single treatment of *T. swirskii* was the most efficient one in the reduction of *B. tabaci* population, followed by Vertemic + Egyxide combination and *T. nigavi*. Moderate results can be obtained by *N. Californicus* then *N. cucumeris.* Whereas, *P. persimilis* has no significant effect on *B. tabaci* population compared with untreated control.

Table 3. Biocontrol agents of *Bemisia tabaci* on tomato plants during summer season 2019 in tomatoes

No. of weeks	*T. Swirskii*	*P. persimilis*	*N. cucumeris*	*T. nigavi*	*N. californicus*	Vertemic+ Egyxide	Control
pre-treatment	1.05	1.04	1.05	1.07	1.06	1.05	1.04
1st week	0.1	1.17	0.17	0.14	0.8	0	1.18
2nd week	0.14	1.27	0.2	0.18	0.25	0.01	1.29
3rd week	0.1	1.28	0.24	0.25	0.26	0.04	1.31
4th week	0.34	1.89	0.6	0.78	0.78	0.68	1.9
Mean	0.17	1.4025	0.3025	0.3375	0.5225	0.1825	1.42
Reduction%	88.14219	1.232394	78.90007	76.89878	63.89849	87.27029	
5th week	0.31	1.54	0.75	0.77	1.12	0.16	1.6
6th week	0.32	3.7	1.4	1.16	1.35	0.98	3.89
7th week	0.4	5.31	3.1	1.77	3.6	3.45	5.41
8th week	0.51	7.01	4.5	2.14	4.8	4.66	6.98
Mean	0.385	4.39	2.4375	1.46	2.7175	2.3125	4.47
Reduction%	91.46905	1.789709	45.98913	68.25357	40.35288	48.75892	
9th week	0.61	9.9	7.35	3.15	8.4	7.78	10.14
10th week	0.81	12.4	8.5	3.21	8.9	9.34	12.51
11th week	0.92	14.87	9.14	3.11	8.75	0.04	14.5
12th week	0.84	14.98	9.32	4.34	9.14	0.89	15.41
Mean	0.795	13.0375	8.5775	3.4525	8.7975	4.5125	13.14
Reduction%	94.00739	0.780061	35.34392	74.46194	34.31119	65.98536	
13th week	0.19	17.91	10.71	4.81	10.1	0.9	17.23
14th week	0.11	20.19	9.7	5.32	13.4	0.94	21.21
15th week	0.09	22.01	8.65	6.18	14.93	1.32	23.18
16th week	0.04	26.13	12.33	7.84	14.9	4.7	25.3
Mean	0.1075	21.56	10.3475	6.0375	13.3325	1.965	21.73
Reduction%	99.51	0.782329	52.83501	72.99483	39.80238	91.04332	
General Average	0.364375[a]	10.09[ns]	5.41625[b]	2.821875[a]	6.3425[b]	2.243125[a]	10.19[ns]
General Reduction%	96.45825	0.907753	47.35361	73.08384	38.93199	75.9618	
LSD	1.91						
P. value	0.001						
F. value (0.01)	7.990**						

Note: Means with the same litter is not significantly different, **= highly significant at (α=0.01)

Table (4). Analysis of variance of single treatment of *B. tabaci* in season 2019

Source of variance	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	1405.668	6	234.278	7.990**	.000
Within Groups	3078.732	105	29.321		
Total	4484.400	111			

Note: **= highly significant at (α=0.01)

Data illustrated in table (5) and Fig. (1) shows the mean of means and Confidence Interval of the effect of different single predacious mites on *B. tabaci*, descriptive analysis between the two seasons indicated that the mean of the population of *B. tabaci* after treatment with *T. swirskii* (0.598) obtained high significant effect in the two seasons against *B. tabaci* followed by *T. nigavi* (3.307) and Vertemic + Egyxide combination (3.37). Also, *N. cucumeris* (5.278) and *N. Californicus* (8.922) obtained moderate effect against such pest in the two seasons. Whereas, *P. persimilis* (14.855) has no significant effect against *B. tabaci* in the two seasons compared with the control.

On the other hand, according to the data in table (5) we could conclude that we have confidence up to 95% that the mean of *B. tabaci* after treatment with *T. swirskii* is included between (-1.693: 2.88/ leaflet) compared with the control which reached (12.712: 17.293/ leaflet).

Table 5. General mean effect of predacious mites in the two seasons 2018-2019

Species	Mean	LSD	95% Confidence Interval	
			Lower Bound	Upper Bound
Typhlodrompis swirskii	0.598^{a}	1.162	-1.693	2.889
Phytoseiulius persimilis	14.855^{ns}		12.564	17.146
Neoseiulus cucumeris	5.278^{bc}		2.987	7.568
Typhlodromus nigavi	3.307^{b}		1.016	5.598
Neoseiulus californicus	8.922^{d}		6.631	11.213
Vertemic+ Egyxide	3.379^{a}		1.088	5.670
Control	15.003^{ns}		12.712	17.293

LSD: least significant difference, means with the same litter is not significantly different, ns: no significantly different

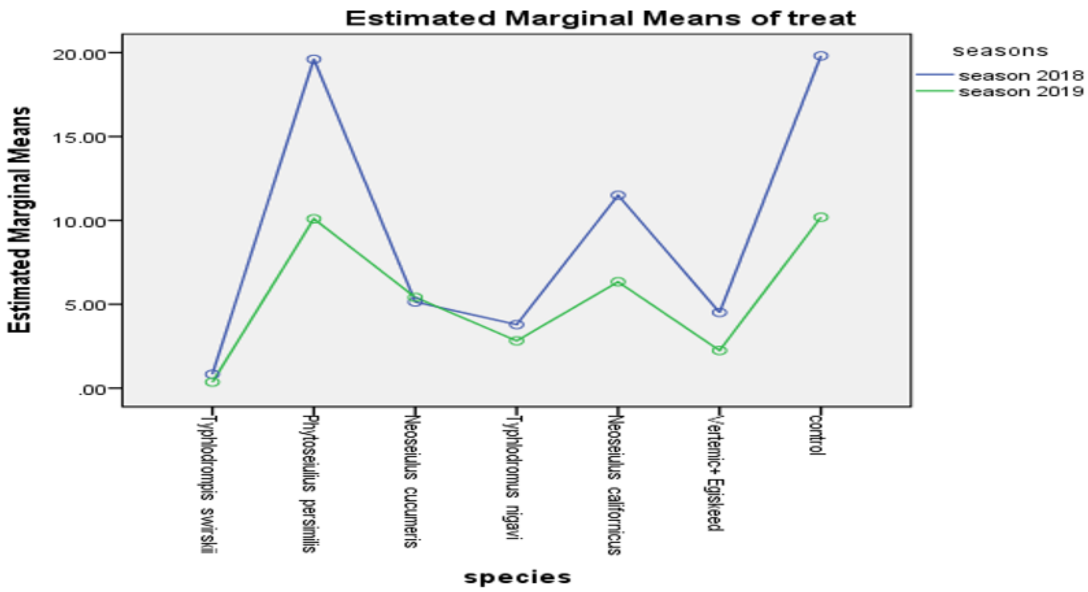

Fig. 1. Means of *B. tabaci* after treatment with different single treatment in two seasons (2018-2109).

Data in table (6) illustrated the comparison of different single predacious mites against *B. tabaci* in two different seasons 2018 and 2019 and the interaction between seasons and species, analysis of variance indicated that there was a significant difference among different species against *B. tabaci* according to F. value (24.60) and P. value (0.00) in two seasons. Also, analysis of variance between seasons and species indicated that there was a significant difference between different species in different seasons according to F. value (3.28) and P. value (0.004), this difference may due to temperature variations, humidity, or different climatic changes. Also, when comparing between the two seasons, the variance between the reduction effect of different treatment in the two seasons was statistically different F value (20.33) and P. value (0.00), this may due to an increase in B. tabaci number or to climatic changes, but generally, the results indicated the efficient effect of *T. swirskii* followed by *T. nigavi* and Vertemic + Egyxide oil combination.

Table (6) analysis of variance between two seasons 2018-2019 in single treatment

Source	Sum of Squares	df	Mean Square	F. value	P. value
Corrected Model	8108.706[a]	13	623.747	14.432	.000
Intercept	12049.498	1	12049.498	278.797	.000
Species	6379.294	6	1063.216	24.600	.000
Seasons	878.764	1	878.764	20.333	.000
species * seasons	850.648	6	141.775	3.280	.004
Error	9076.127	210	43.220		
Total	29234.331	224			
Corrected Total	17184.833	223			
a. R Squared = .472 (Adjusted R Squared = .439)					

Combined Treatment:

Data in table (7) shows the mean of *Bemisia tabaci* population (season 2018) influenced by combined treatment of *T. swirskii &P. persimilis, T. swirskii &N. Californicus, T. swirskii &N. cucumeris, T. swirskii &T. nigavi,* and *T. swirskii* &Vertemic + Egyxide (1ml + 2.5 ml/ liter) combination were 0.82, 0.42, 0.06, 0.45, 0.02 compared with the check control which recorded 19.8 individual/leaflet. Whereas the reduction percentages ranged between 94.91217-98.78104%, 94.7124-99.73644%, 92.40115-99.96794% and 98.70913-100% after 4th week, 8th week, 12th week and 16th week respectively. Analysis of variance between the different combinations indicated that there are significant differences (F. value = 39.863 > F. Tabulated (5 and 90, α=1%) between one of them at least and control. The least significant difference (LSD) between all treatments in summer season 2018 was 1.78.

On the other hand, the mean of *Bemisia tabaci* population (season 2019) influenced by combined treatment of *T. swirskii &P. persimilis, T. swirskii &N. Californicus, T. swirskii &N. cucumeris, T. swirskii &T. nigavi,* and *T. swirskii* &Vertemic + Egyxide (1ml + 2.5 ml/ liter) combination were 0.37, 0.2825, 0.005, 0.2925, 0.009375 compared with the check control which recorded 10.19 individual/leaflet respectively. Whereas the reduction percentages ranged between 86.79-98.53%, 92.17-100%, 95.20-100% and 99.17-100% after 4th week, 8th week, 12th week and 16th week respectively. Analysis of variance between the different combinations indicated that there are significant differences (F. value = 22.32> F. Tabulated (5 and 90, α=1%) between one of them at least and control. The least significant difference (LSD) between all treatments in summer season 2019 was 1.22.

Data in table (8) illustrated the comparison of different combined predacious mites against *B. tabaci* in two different seasons 2018 and 2019 and the interaction between seasons and species, analysis of variance indicated that there was a significant difference among different species against *B. tabaci* according to F. value (62.086) and P. value (0.00) in two seasons. Also, analysis of variance between seasons and species indicated that there was a significant difference between different species and season according to F. value (6.404) and P. value (0.00), this difference may due to another factor as climatic changes. Also, when comparing between the two seasons, the variance between the reduction effect of different treatment in the two seasons was statistically different F value (7.809) and P. value (0.006), but generally, the results indicated the efficient effect of a combination of *T.*

swirskii + vertemic followed *by T. swirskii + N. cucumeris* then *T. swirskii + N. californicus* then *T. swirskii + T. nigavi* and *T. swirskii + P. persimilis,* Table (9) and Figure (2).

Table 7: Combination Biocontrol agents of *Bemisia tabaci* on tomato cultivars during summer season 2018 and 2019

No. of weeks	Treatments					
	T. swirskii + P. persimilis	*T. swirskii + N. californicus*	*T. swirskii + N. cucumeris*	*T. swirskii + T. nigavi*	*T. swirskii + vertemic*	untreated control
Summer season 2018						
pre-treatment	1.27	1.28	1.27	1.28	1.27	1.26
Mean (4th week)	0.24	0.2175	0.1225	0.2	0.0575	4.68
Reduction%	94.91217	95.42518	97.40309	95.79327	98.78104	
Mean (8th week)	0.8025	0.5575	0.135	0.58	0.04	15.0575
Reduction%	94.7124	96.35538	99.1105	96.20828	99.73644	
Mean (12th week)	1.7775	0.6475	0.0025	0.735	0.0075	23.2075
Reduction%	92.40115	97.25355	99.98931	96.88241	99.96794	
Mean (16th week)	0.4725	0.26	0.0	0.2975	0	36.315
Reduction%	98.70913	99.29523	100	99.19358	100	
General Average	0.823125	0.420625	0.065	0.453125	0.02625	19.815
General Reduction%	95.87866	97.91041	99.67455	97.74895	99.86857	
LSD	1.78					
P. value	0.000					
F. value	39.863					
Summer season 2019						
Pre-treatment	1.04	1.05	1.06	1.07	1.06	1.04
Mean (4th week)	0.1775	0.1375	0.02	0.1325	0.03	1.344
Reduction%	86.79315	89.86678	98.53998	90.41778	97.80997	
Mean (8th week)	0.35	0.295	0.0	0.27	0.0025	4.47
Reduction%	92.17002	93.4633	100	94.12908	99.94513	
Mean (12th week)	0.63	0.5175	0.0	0.5025	0.005	13.14
Reduction%	95.20548	96.09915	100	96.28302	99.96267	
Mean (16th week)	0.3225	0.18	0.0	0.265	0	21.73
Reduction%	98.51588	99.17954	100	98.81468	100	
General Average	0.37	0.2825	0.005	0.2925	0.009375	10.19
General Reduction%	96.36899	97.25408	99.95186	97.21002	99.90973	
LSD	1.22					
P. value	0.00					
F. value	22.32**					

Table (8) analysis of variance between two seasons 2018 and 2019 in combined treatments

Source	Sum of Squares	df	Mean Square	F.	P. value
Corrected Model	6535.097[a]	11	594.100	31.842	0.000
Intercept	1430.302	1	1430.302	76.660**	0.000
Species	5791.939	5	1158.388	62.086**	0.000
Seasons	145.708	1	145.708	7.809**	0.006
species * seasons	597.450	5	119.490	6.404**	0.000
Error	3358.407	180	18.658		
Total	11323.806	192			
Corrected Total	9893.504	191			
a. R Squared = .661 (Adjusted R Squared = .640)					

Table 9: mean of two seasons 2018 and 2019 in combined treatments

Treatments	Mean	LSD	95% Confidence Interval	
			Lower Bound	Upper Bound
T. swirskii + P. persimilis	0.597[a]	0.764	-.910	2.10
T. swirskii + N. californicus	0.352[a]		-1.155	1.85
T. swirskii + N. cucumeris	0.035[a]		-1.472	1.54
T. swirskii + T. nigavi	0.373[a]		-1.134	1.88
T. swirskii + vertemic	0.018[a]		-1.489	1.52
untreated control	15.002[b]		13.496	16.50

LSD: least significant difference, means with the same litter is not significantly different

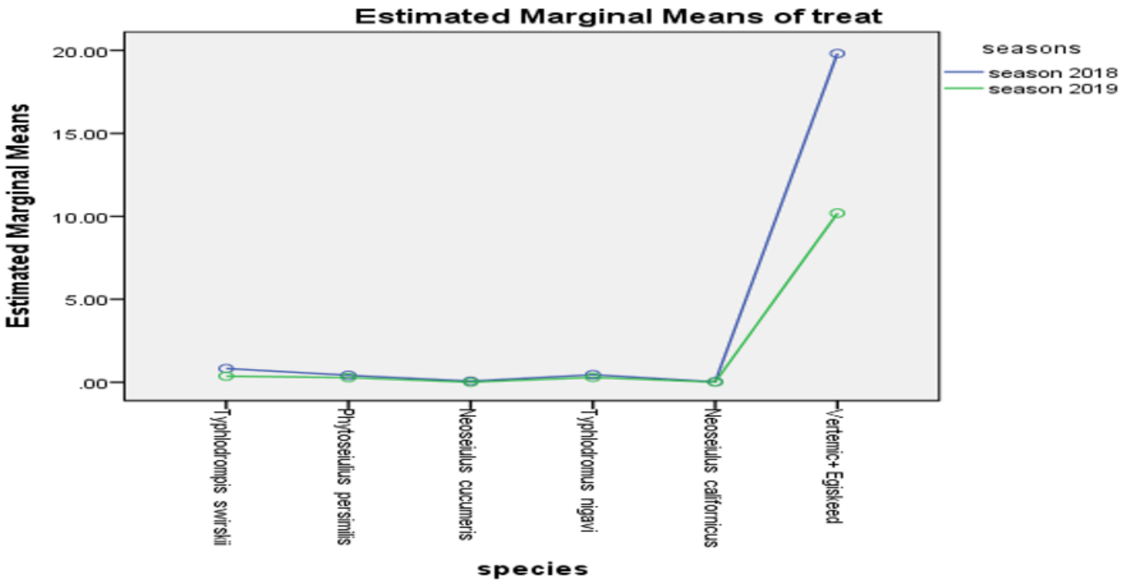

Fig. 2. Means of *B. tabaci* after treatment with different combination treatments in two seasons (2018-2109).

DISCUSSION

As before, *Bemisia tabaci* population (season 2018) was highly reduced by a single treatment of *T. swirskii* followed by *T. nigavi*, Vertemic + Egyxide combination, and *N. cucumeris, then Neoseiulus californicus.* Whereas, *P. persimilis* have no reduction effect against *B. tabaci* in tomato plants.

Also, in season 2019 the *B. tabaci* population can be reduced significantly by *T. swirskii* followed by Vertemic + Egyxide combination, *T. nigavi, N. cucumeris, then Neoseiulus Californicus, while P. persimilis* have no reduction effect against *B. tabaci* in tomato plants. The accumulated reduction effect of the different treatments against *B. tabaci* in the two seasons, according to the data revealed, the highest reduction percentage was recorded by *T. swirskii* followed by *T. nigavi* and Vertemic + Egyxide combination. Whereas, *N. cucumeris* and *Neoseiulus Californicus* have moderate reduction effect on *B. tabaci*. Meanwhile, *P. persimilis* not different from the control.

On the other hand, in the case of using combination treatments against *B. tabaci* in the open field, the combination in two different seasons 2018 and 2019 of (*T. swirskii* + vertemic combination) recorded highly effect for *B. tabaci* management, followed by (*T. swirskii* + *T. nigavi*), (*T. swirskii* + *N. cucumeris*) and (*T. swirskii* + *N. californicus*). While the combination of two predators (*T. swirskii* + *P. persimilis*) had less effect than the single treatment. But generally, all combinations had a significant reduction effect against *B. tabaci* compared with the untreated control.

The obtained results agree with those recorded by Nomikou *et al*. (2002) how recorded that, Phytoseiid mites are known to be suppressed or attack whitefly populations in cucumber plants greenhouse. Predatory mites including; *Typhlodromalus limonicus, Amblyseius swirskii*, and *Transeius montdorensis* were screened for their reduction effect against different *B. tabaci* stages, *A. swirskii* increased mortality percentages of *B. tabaci* (Cuthbertson, 2014). *Amblyseius tamatavensis* is one of the promising phytosiid predatory mites for the control of the whitefly, a polyphagous pest (Marina *et al*., 2019). *Amblyseius tamatavensis* has been reported as potentially useful for Bemisia tabaci control of in over 20 countries around the world (Marcela *et al*., 2019). *Amblyseius swirskii* predatory mite has been used to control thrips, whiteflies pest in the greenhouse (Fathipour *et al*., 2020). *Amblyse*ius *swirskii* recoded high efficacy against both of silver leaf whitefly and two-spotted spider mite (Asadi *et al*., 2019). However, our knowledge about the possible effects of mixed predators in the biological performance of this predatory mite is so restricted.

A similar observation was recorded by Arthurs *et al*., (2009) who reported that *N. cucumeris*, is known as a generalist predator for a spectrum of pests such as whiteflies and thrips as a biocontrol agent. Also, Kakkar *et al*., (2016) found that the *N. cucumeris* suppressed melon thrips on cucumber leave significantly. Pehlivan *et al*., (2020) determined under laboratory conditions many predators that feed on numerous pest insects including whitefly. Al-Zyoud (2014) reported that *Amblyseius swirskii and Euseius ovalis* were the most common predatory mites for *B. tabaci.*

Predatory mites namely; Amblyseius swirskii was recorded as the most promising bi-control agent against *B. tabaci* (Nomikou *et al.*, 2001a; Hagler *et al*., 2004). Nomikou *et al.*, (2001b) recorded that *A. swirskii* reduced *B. tabaci* populations up to 16- to 21-fold on cucumber plants compared to the control.

CONCLUSION

Bemisia tabaci still a severe threat infesting tomato plant. The continuous insecticide resistance of *B. tabaci* is a true challenge regarding maintaining development in agriculture. The predatory mites which investigated are compatible with numerous insecticides. Thus, predatory mites can be incorporated into existing eradication strategies of *B. tabaci*. Our results indicated a considerable role of different predatory mites including; *T. swirskii* and *T. nigavi* as effective biological control agents or Vertemic/Egyxide oil combination against *B. tabaci* and can be useful integrated management programs of *B. tabaci* pest.

List of abbreviations:

ANOVA: Analysis of variance

LSD: Least significant difference

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