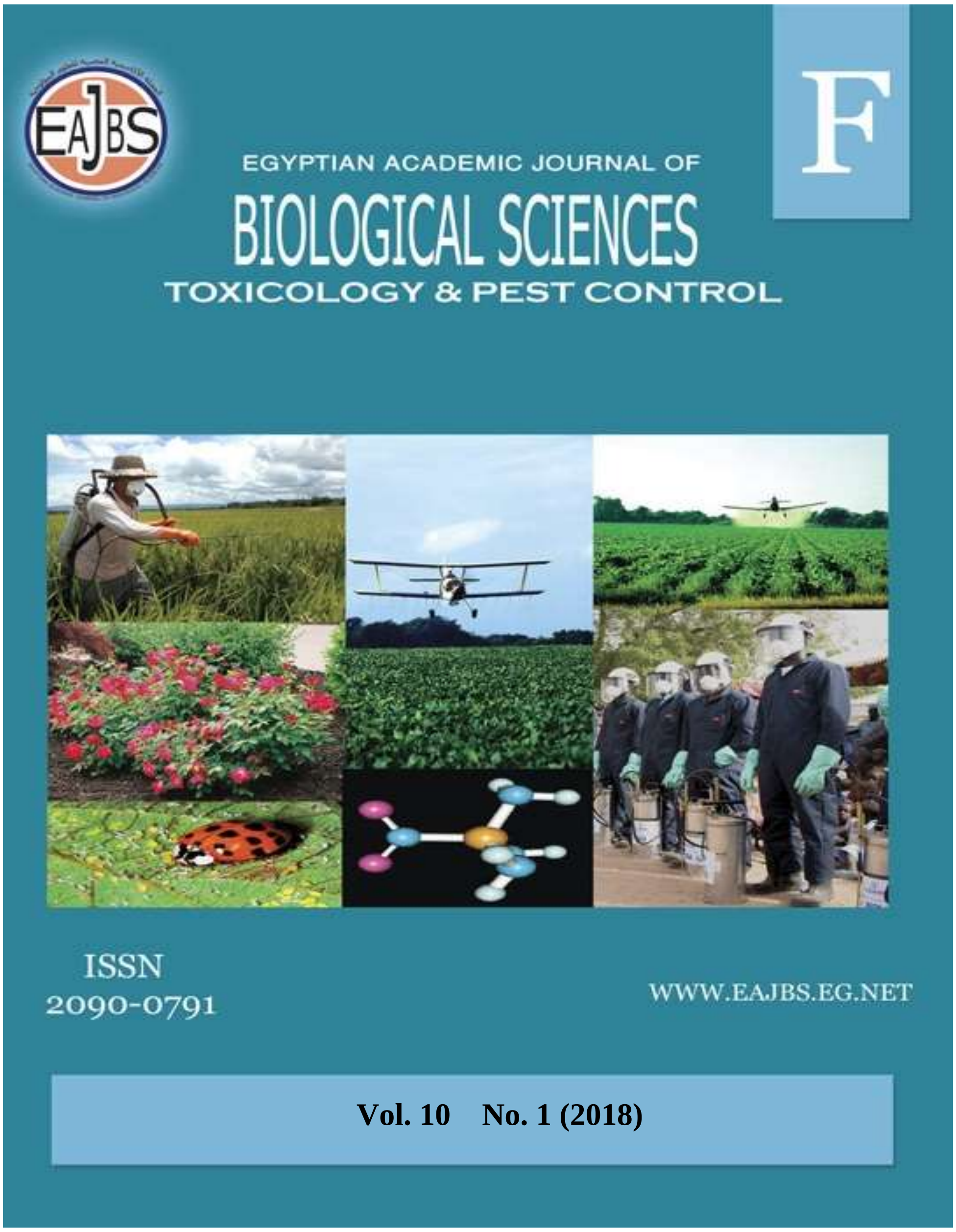

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Residuals Efficacy of Thiamethoxam and Thiaclopride Soil Applications against Whitefly, *Bemisia tabaci* (Homoptera; Aleyrodidae) and Their Impact on Soil Microarthropods

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ABSTRACT

Field studies were carried out to investigate the efficacy of thiamethoxam (TMX) and thiaclopride (THI) via three different types of soil against whitefly, *Bemisia tabaci*, on tomato seedlings during two successive seasons. Physical and chemical criteria were determined in each of soil type. Results revealed that, the soil types were loamy sand (Al-Maamoura), silt loam (Bangar Al-Sokkar) and clay (Abou-Homous). During 2016 and 2017, clay soil had the highest contents in organic matter (3.43 and 3.48% respectively) and organic carbon (1.99 and 2.03% respectively). The highest mean reduction percentages of whitefly treated with the TMX in loamy sand soil were 79.35 and 80.12% and in silt loam were 78.39 and 81.60% during 2016 and 2017comparing to clay soil. Likewise, THI had the highest mean reduction percentages during 2016 and 2017 in loamy sand soil (78.06 and 79.88% respectively) and silt loam (77.12 and 78.56% respectively) compared to clay soil. Residuals efficacy of TMX and THI extended to 15 days in loamy sand and silt loam soils compared to 9 days in clay soil during the two seasons and the season of 2016 respectively. During the season of 2017, THI had more extension for a week in the three tested soils. Initial effects against whitefly had a rapid onset on the 3rd day post-treatments of TMX in loamy sand and THI in silt loam and clay soils during the two seasons. Initial effects delayed on the 9th day post treatment of TMX in silt loam soil during season of 2017and in clay soil during the two seasons. Retardations, extended to the 9th day of THI treatment in loamy sand soil during the season of 2017. The efficiencies of TMX and THI via soils of loamy sand and silt loam against whitefly were significantly more than clay soil. Full recovery levels of micro-arthropods revealed at the end of the 7th week in all soil's depths of loamy sand and silt loam treated with TMX and in loamy sand soil treated with THI during the two seasons. Treated areas of high OM -clay soil failed to reach the recovery levels.

INTRODUCTION

Whitefly (*Bemisia tabaci*) is one of the major tomato pests, potentially could cause a privation in yield up to 100% (Mutisya *et al*., 2016). *B. tabaci* was associated with many viral diseases transmission that leads to negative impact on yield (Mansoor *et al*., 2003). Over the last twenty years, neonics have become the most widely used in the global market more than the chemical classes of organophosphates, carbamates, phenyl-pyrazoles, and pyrethroids. Neonicotinoids (neonics) are active against wide major sap-sucking insects, including aphids, whitefly, leafhoppers, western corn rootworm, wireworms, planthoppers, mealybugs, and phytophagous mites (Elbert *et al*., 2008; Jeschke *et al*., 2011; Simon-Delso *et al*., 2014). Some of these pests considered being vectors that contribute in transmitting viruses, thus neonics could be entitled to control insect vectors of crop viral diseases (Castle *et al*., 2009; Maini *et al*., 2010; Megchún-García *et al*., 2016).

Neonics have an agonist action on nAChRs that induce depolarizing currents in insects. Regarding to thiacloprid (THI) and its derivatives, as one of the first neonic generation, they stress a nerve-blocking activity, (Kagabu *et al*., 2008; Toshima *et al*., 2008; Simon-Delso *et al*. 2014). On the other hand, TMX represents the second neonic generation, acts differently to THI as it acts as a poor agonist on nAChRs (Nauen *et al*., 2003; Tan *et al*., 2007; Benzidane *et al*., 2010). Nevertheless, TMX also has a full agonist at afferent/giant interneuron synapses (Thany, 2011) and able to bind to mixed nicotinic/muscarinic receptors (Lapied *et al*., 1990). Due to the high systemic action of neonics on treated plants, more safe alternative uses as seed dressing and/or root application of neonics in soil were entitled instead of foliar spray (Nault *et al.*, 2004; Elbert *et al*., 2008). Their systemic activities were varied according to applied dosage, the age of treated plant and soil's physical and chemical criteria. The most advantages of using systemic insecticides versus to contact insecticides are due to the continuous and extending protection for treated plants in order to eliminate numbers and repeatability of applications all over the growing season (Herbert *et al*., 2008).

Well known fact, that insecticides applications in field contaminate the soil and cause a disturbance in both quantitative and qualitative properties of non-target soil fauna. The soil fauna are involved in organic matter (OM) bio-degradation processes, regulations of microbial activities, nutrient cycles, and crumbly structure (Cortet *et al*., 1999). The degradation of neonics occurred mainly via nitrate reduction and so influenced the soil nitrifying process (Zhang *et al.,* 2017). The total degradation or biodegradation of neonics was the fastest in the soil with the highest organic carbon (OC) content. Neonics bio-availability was not the primary influencing factor due to their weak sorption. Thus, the addition of OM for improving soil quality could decrease the degradation of neonics due to the sorption-desorption characteristics of the chemicals (Zhang *et al.,* 2018; Cox *et al*., 1997). Soil micro-arthropods are often used as bio-indicators of agricultural soil quality (Paoletti and Bressan, 1996). Therefore, the present work was carried out to study the efficacy of soil drainage application of THI and TMX in tomato field to control whitefly in different soil types during seasons of 2016 and 2017. The side effects of these neonics on the populations of non-target soil fauna as bio-indicators were also investigated.

MATERIALS AND METHODS

Tested Insecticides:

Thiacloprid (Blanch 48%SC**)**, agency of Starchem Co., Giangsuio industry limited and Thiamethoxam (Actra 25% WG**)**, agency of Syngenta Agrow Egypt, Sweden.

Field Trials:

The field application experiments were achieved as soil drainage adjacent to the root system of tomato seedling. Tomato seedlings (variety 186) of age about two weeks (more than 10 true leaves) were selected to undergo the field experiments in two successive growing seasons of 2016 and 2017. The field experiment was carried out in three different locations of Al-Maamoura, Bangar Al-Sokkar and Abou-Homous. The field applications undergo the complete block design. The area of each micro-plot was about 80 m^3. Four replicates were submitted for each treatment. The recommended doses of diluted THI and TMX in 10 Liters as total volumes of water per each micro-plot were 2 ml and 2 gm respectively. Soil drainage treatments were added at the time of irrigation in dripper system or after few days in fold irrigation in clay soil. Pre-treatment counts were done just before application while post-treatment counts were made at 5 hrs and 1, 3, 9, 15, 21, and 28 days after treatment. The reduction percentage of the population was estimated according to the formula of Henderson and Tilton, (1955) to determine the initial effect and the residual effect of the tested insecticides. Twenty tomato plants from each replicate were randomly chosen for the Whitefly counts. Counts were done in the early morning when flight activity is minimal according to Butler *et al*., (1988).

Soil Analysis:

Physical and chemical analyses of treated soil samples were achieved to study the correlations between the efficacies of soil application of TMX and THI against adult stage of whitefly (*B.tabaci*). Field experiments were carried out in three different classes of soil represented in Al-Maamoura, Bangar Al-Sokkar and Abou-Homous locations during two growing seasons of 2016 and 2017. Soil physical tests were assigned to estimate mainly soil texture classification as well as chemical tests were subjected to determine total OM and OC.

Extraction of Soil Micro-Arthropods:

Sample Collection:

Soil samples of treated areas with TMX and THI and untreated areas were collected every week till the 7th week post treatment. Samples were drawn from two depths, 0-10 and 10-20 cm adjacent to root regions and collected in labeled polyethylene bags. The samples were transferred to “Plant Protection Research Laboratory” to be submitted for extraction process of soil micro-arthropods.

Berlese-Tullgren Funnels Extractor:

According to Berlese-Tullgren funnel extractor designed by (Bano and Roy, 2016), the performance of this extractor was designed to suit micro-arthropod’s mobility and dimension sizes (Wallwork, 1970). The efficiency of these extractors proved to be about 90% (Hopkin, 1997). Simulator sets to Berlese-Tullgren Funnel extractor were assigned for the extraction processes of soil micro-arthropods in the laboratory. The required time for good extraction was 48 hrs. Finally, the extracted soil micro-arthropods were trapped into 70% alcohol solution in small containers. Each treatment was replicated with three independent sets.

Sorting, Preservation and Identification:

The extracted organisms were immediately separated as individual species by using a sucking pipette in separate vials containing 70% alcohol solution. These individual species were preserved until further time to mountain on slides for screening under a binocular dissecting microscope. Then extracted micro-arthropods from each treatment could be identified, counted.

Statistical Analysis:

The reduction percentages of the adult stage of whitefly population and mean percentages of survival soil micro-arthropods population in treated and untreated areas were estimated by using the equation of (Henderson and Tilton, 1955) and subjected to analysis of variance (ANOVA). Means were determined for significance at 0.05 using LSD test (SAS Statistical software, 2002).

RESULTS

Physical and Chemical Analysis of Soil Types:

Physical analyses were carried out in different regions of Al-Maamoura, Bangar Al-Sokkar and Abou-Homous. The obtained soil samples were classified according to their portions of the main contents of sand, silt, and clay. These contents of sand, silt and clay, which had portions of 71.2, 16 and 11.6% respectively in Al-Maamoura soil samples were classified as loamy sand soil. On the other hand, soil samples of Bangar Al-Sokkar location were featured by high content of silt (69.6%) comparing to contents of sand (24.3%) and clay (5.1%) had been classified as silt loam soil. Whereas, Abou-Homous soil samples were characterized by the major portion of clay (77.6%) among low portions of sand and silt contents. In addition, gravel residues of 1.2 and 1.09% were found in Al-Maamoura and Bangar Al-Sokkar locations respectively. The chemical analysis of these locations included OM and OC contents in two successive growing seasons of 2016 and 2017. Abou-Homous soil samples had the highest contents of OM and OC compared to the other locations (Table 1).

Table 1: Physical and chemical analysis of soil types in different locations:

Tests type	Criteria	Al-Maamoura	Bangar Al-Sokkar	Abou-Homous	Sampling time
Physical	Sand%	71.2	24.3	12.3	Season 2016
	Silt%	16	69.6	10.1	
	Clay%	11.6	5.1	77.6	
	Gravel%	1.2	1.0	-	
	Soil texture type	Loamy sand	Silt loam	Clay	
Chemical	Organic matter%	1.715	1.37	3.43	Season 2016
		1.510	1.252	3.480	Season 2017
	Organic carbon%	0.995	0.798	1.995	Season 2016
		0.878	0.728	2.023	Season 2017
	pH	8.20	8.49	8.50	Season 2016
		8.10	8.52	8.48	Season 2017

Reduction Evaluation and Residuals Efficacy of the Tested Neonics:

The time of mean of residual efficacy (days) was expressed by the mean of whitefly reductions percentages synchronized with gradual depression of mean numbers of whitefly population and ended by an upturn in mean number exceeds the estimated threshold limit. The threshold limit of whitefly was calculated to be 5 individuals per 10 leaves of tomato seedling according to (Schuster *et al.,* 2004). In another word, the threshold limit of whitefly calculated as 75 individuals per 15 tomato seedlings for each replicate.

In season of 2016, the data of mean reduction of TMX and THI were monitored within 0.2(5hrs), 1, 3, 9, 15, 21, and 28 days post-treatments (Table 2). Generally, no significant values of overall mean reduction percentages in treated whitefly populations with the tested neonics between Al-Maamoura (78.71%) and Bangar Al-Sokkar (77.75%) but these two locations had a significant reduction values more than Abou-Homous location (66.27%). Particularly, no significant reduction values in whitefly populations between TMX and THI in each of Al-Maamoura (loamy sand soil) and Bangar Al-Sokkar (silt loam soil). Where it is clear that, the mean reduction percentages in Al-Maamoura (loamy sand soil) were 79.35% and 78.06% for treatments of TMX and THI respectively as well as in Bangar Al-Sokkar (silt loam soil) the values were 78.39% and 77.12% for treatments of TMX and THI respectively. On contrary, the mean reduction percentage in Abou-Homous (clay soil) for treatment of TMX (62.78%) was significantly less than THI (69.77%). Obviously, mean of residual efficacies percentages in Al-Maamoura (loamy sand soil) of TMX and THI treatments were 80.63% and 77.19% respectively at withholding periods reached up to 15 days for both treatments. Likewise, TMX and THI treatments in Bangar Al-Sokkar (silt loam soil) were 78.67% and 77.99% respectively at withholding periods of 15 days for both treatments. In contrast, mean of residual efficacies percentages in Abou-Homous (clay soil) for TMX and THI treatments were 63.51% and 66.31% at withholding periods for both of them 9 days. Thus, the efficiency of both TMX and THI were clearly the lowest in Abou-Homous region (clay soil).

In the season of 2017, the data of mean reduction of TMX and THI had been monitored within 0.2 (5 hrs), 1, 3, 9, 15, 21 and 28 days post-treatments (Table 3). In general, no significant values of overall mean reduction percentages in treated whitefly populations with the tested neonics between Al-Maamoura (80.00%) and Bangar Al-Sokkar (80.08%) but these two locations had a significant reduction values more than Abou-Homous location (63.96%). Particularly, no significant reduction values in whitefly populations between TMX and THI in Al-Maamoura (loamy sand soil) where the mean reduction percentages were 80.12% and 79.88% for treatments of TMX and THI respectively. While the mean reduction percentages in Bangar Al-Sokkar (silt loam soil) for treatment of TMX (81.60%) was significantly more than THI (78.56%). On the contrary, data of mean reduction percentages in Abou-Homous (clay soil) for TMX (59.67%) was significantly less than THI (68.24%). The mean residual efficacies values in Al-Maamoura (loamy sand soil) for TMX treatment was 82.25% at withhold periods reached up to 15 days and for THI treatment was 81.23% at withholding periods extended to 21 days. The same results occurred in Bangar Al-Sokkar (silt loam soil) for TMX treatment was 80.61% at withholding periods reached up to 15 days and for THI treatment was 81.17% at withholding periods extended to 21 days. In contrast, mean of residual efficacy percentages in Abou-Homous (clay soil) for TMX treatment was 65.40% at withhold periods of 9 days, while for THI treatment mean of residual efficacy percentages was 67.53% at more withhold periods of 15 days. Thus, efficacy effects of both TMX and THI in the season of 2017, as well as in the season of 2016, were clearly the lowest in Abou-Homous region (clay soil). Observation on the efficacy effects in the season of 2017 for THI treatments in all tested locations had more lasting 7 days than their corresponding values in season of 2016.

Eventually, in both seasons of 2016 and 2017, no significant differences for overall mean of reduction percentages by tested neonics between Al-Maamoura (loamy sand soil) and Bangar Al-Sokkar (silt loam soil) but these two locations were significantly higher than those values occurred in Abou-Homous location (clay soil).

Initial Action of Tested Neonics:

The initial time of tested neonics action (days) were expressed by the first appearance of the high significant value of mean reduction of whitefly adult stage that synchronized with the first depression in the mean number of whitefly below the estimated threshold limit.

Data of Initial effects of TMX in loamy sand soil and THI in silt loam soil against whitefly populations appeared early at the 3rd day post-treatment in the two successive seasons. While initial effects of TMX in clay soil against whitefly populations delayed at the 9th day post-treatment in the two successive seasons. Meantime, data of initial effects of THI in loamy sand, TMX in silt loam soil and THI in clay soil had a variable initial time ranged between the 3rd up to 9th day post treatment during the two successive seasons (Table 2 and 3).

Table 2: Residuals efficacy of thiamethoxam and thiaclopride treatments via three different types of soils against adult stage of whitefly, season of 2016.

Day(s) after treatments	Reduction% of Whitefly (adult stage)					
	Al Maamoura		Bangar Al-Sokkar		Abou-Homous	
	Thiamethoxam	Thiaclopride	Thiamethoxam	Thiaclopride	Thiamethoxam	Thiaclopride
5 hrs	32.54^{n}	32.17^{n}	16.18^{o}	17.35^{o}	7.72^{p}	16.79^{o}
1	80.54^{fgh}	83.89^{efg}	83.73^{efg}	78.81^{hig}	63.32^{l}	62.01^{l}
3	*96.83^{ab}	86.29^{ef}	*96.36^{abc}	*96.88^{ab}	89.30^{de}	89.72^{cde}
9	99.47^{a}	*93.22^{abcd}	99.54^{a}	99.38^{a}	*93.71^{abcd}	*96.71^{ab}
15	93.75^{abcd}	90.36^{bcde}	97.53^{a}	97.53^{a}	72.34^{ij}	83.55^{efg}
21	80.60^{fgh}	87.81^{de}	84.23^{efg}	88.57^{de}	70.34^{jk}	75.59^{hij}
28	71.73^{j}	72.70^{ij}	71.14^{j}	61.33^{l}	42.70^{m}	63.99^{kl}
Mean Reduction%±SD	79.35±22.99^{a}	78.06±21.26^{a}	78.39±29.22^{a}	77.12±29.60^{a}	62.78±29.56^{b}	69.77±26.61^{ab}
Mean Residual efficacies% (days)	80.63(15)	77.19(15)	78.67(15)	77.99(15)	63.51(9)	66.31(9)
Overall mean of reductions% in each location	78.71^{a}		77.75^{a}		66.27^{b}	

- (*): the initial effects of the tested neonics estimated at threshold limit of whitefly (5 per 10 leaves).
- Residual efficacy period (days) of the tested insecticides estimated at threshold limit of whitefly (5 per 10 leaves).
- Means followed by the same letters are not significantly different according to the $LSD_{0.05}$ of insecticides = 1.5025; $LSD_{0.05}$ of Locations = 1.8402; $LSD_{0.05}$ of interaction between insecticides & location =13.504.

Table 3: Residuals efficacy of thiamethoxam and thiaclopride treatments via three different types of soils against adult stage of whitefly, season of 2017.

Day(s) after treatments	Reduction% of Whitefly (adult stage)					
	Al Maamoura		Bangar Al-Sokkar		Abou-Homous	
	Thiamethoxam	Thiaclopride	Thiamethoxam	Thiaclopride	Thiamethoxam	Thiaclopride
5 hrs	42.16^{m}	29.66^{n}	38.00^{m}	29.96^{n}	25.98^{n}	-3.52^{o}
1	81.32^{gh}	79.43^{gh}	82.36^{fg}	75.19^{h}	64.29^{jk}	64.29^{jk}
3	*95.14^{abcd}	*90.82^{bcde}	88.69^{bdef}	*93.67^{abcd}	79.70^{gh}	*91.30^{bcde}
9	98.91^{a}	96.74^{abc}	*99.18^{a}	98.85^{a}	*91.61^{bcd}	94.91^{abcd}
15	93.72^{abcd}	97.23^{ab}	94.80^{abcd}	99.13^{a}	68.70^{ijk}	90.65^{bcde}
21	79.64^{gh}	93.49^{abcd}	83.36^{fg}	90.19^{cde}	43.95^{m}	82.45^{fg}
28	69.94^{ij}	71.79^{i}	84.83^{efg}	62.95^{kl}	43.50^{m}	57.59^{l}
Mean of Reduction%±SD	80.12±19.62^{ab}	79.88±24.07^{ab}	81.60±28.86^{a}	78.56±25.22^{ab}	59.67±25.11^{c}	68.24±28.93^{bc}
Mean residuals efficacies% (days)	82.25(15)	81.23(21)	80.61(15)	81.17(21)	65.40(9)	67.53(15)
Overall mean of reductions% in each location	80.00^{a}		80.08^{a}		63.96^{b}	

- (*): the initial effects of the tested neonics estimated at threshold limit of whitefly (5 per 10 leaves).
- Residual efficacy period (days) of the tested insecticides estimated at threshold limit of whitefly (5 per 10 leaves).
- Means followed by the same letters are not significantly different according to the $LSD_{0.05}$ of insecticides = 1.4416; $LSD_{0.05}$ of Locations = 1.7656; $LSD_{0.05}$ of interaction between insecticides & location =12.617.

Evaluation of Soil Micro-Arthropods:

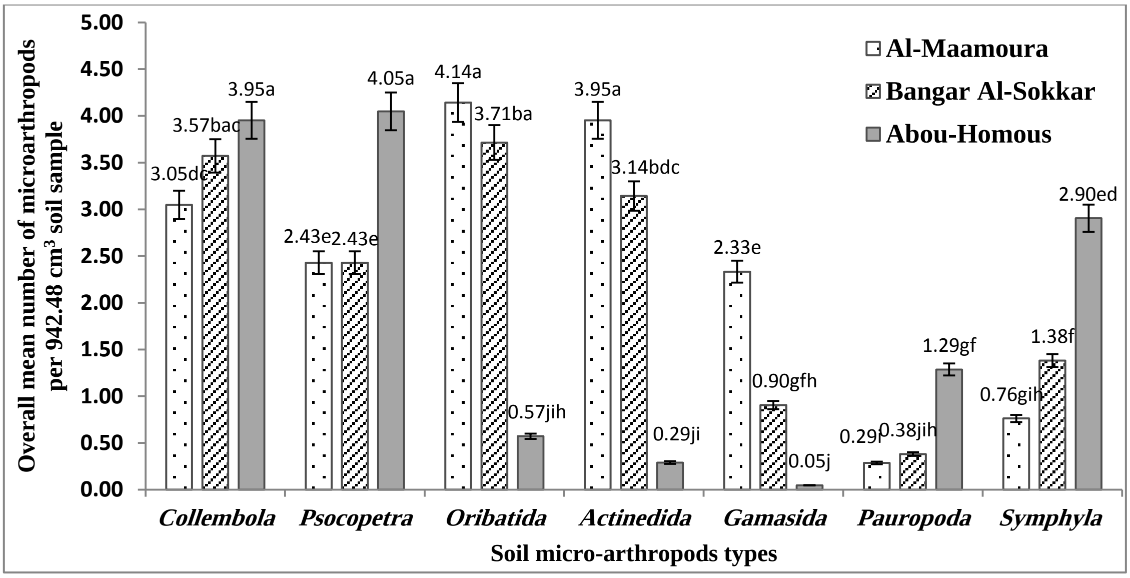
Identified Micro-Arthropods in Untreated Areas:

These taxonomic groups extracted from the selected locations comprised seven types identified as *Symphyla*, *Pauropoda*, *Gamasida*, *Collembola*, *Oribatida*, *Actinedida*, and *Psocoptera* during the two growing seasons of 2016 and 2017. Regarding to the untreated areas (control) in each selected location, the overall mean numbers for each type of the identified micro-arthropods per 942.48 cm^3 of soil samples were calculated after the seven weeks post-treatments. The distribution of the overall means numbers of these taxonomic groups were varied according to the source of tested non-target soil fauna and their depths during the two successive seasons.

Firstly, the upper depths of 0-10cm of each selected location were featured by some taxonomic groups, which had the highest significant of overall mean numbers per

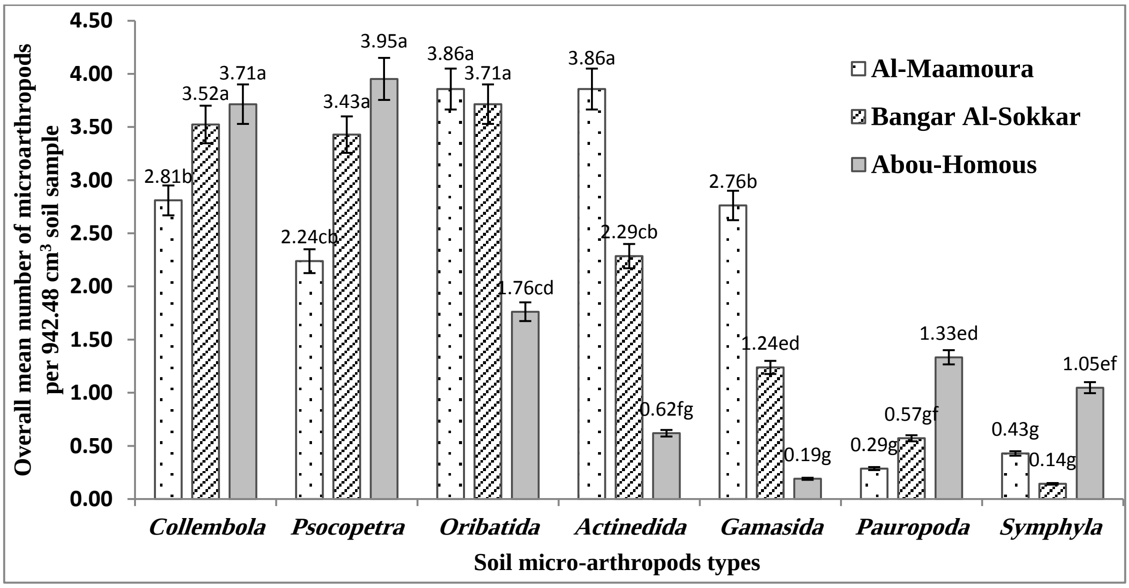
942.48 cm^3 of soil samples through the seven weeks post-treatments. Regarding to the data of season of 2016, the highest significant of overall mean numbers of micro-arthropods per 942.48 cm^3 of soil samples in location of Al-Maamoura (loamy sand soil) were 4.14 and 3.95 for *Oribatida* and *Actinedida* respectively. Meanwhile, *Psocoptera* and *Collembola* were 4.05 and 3.95 respectively in clay soil of Abou-Homous (Fig 1). In season of 2017, the highest significant of overall mean numbers of micro-arthropods per 942.48 cm^3 of soil samples in loamy sand soil of Al-Maamoura location was 3.86 for both *Oribatida* and *Actinedida* as well as *Psocopetra* and *Collembola* were 3.71 and 3.95 respectively in clay soil of Abou-Homous. Likewise, Bangar Al-Sokkar (silt loam soil) region was characterized by *Collembola*, *Poscoptera,* and *Oribatida* that reached highest significant levels of 3.52, 3.43, and 3.71 respectively (Fig 2). Noticeably, micro-arthropods of *Collembola* and *Psocoptera* in Abou-Homous (clay soil) and *Oribatida* and *Actinedida* in Al-Maamoura (loamy sand soil) almost maintained at their highest significant levels per 942.48 cm^3 of soil samples along the seasons of 2016 and 2017. All micro-arthropods of the seven identified taxonomic groups were present in the upper layer of soils samples collected from the selected locations.

Secondly, the lower depths of 10-20cm of each selected location were featured by some taxonomic groups, which had highly significant overall mean numbers per 942.48 cm^3 of soil samples through the seven weeks post-treatments. In season of 2016, high significant overall mean numbers of *Oribatida* were 1.62 and 2.62 per 942.48 cm^3 of soil samples in location of Bangar Al-Sokkar (silt loam soil) and Al-Maamoura (loamy sand soil) respectively. Meantime, clay soil samples of Abou-Homous were featured by *Collembola* and *Pscoptera* that reached 1.76 and 2.95 respectively (Fig 3). In season of 2017, the high significant of overall mean numbers per 942.48 cm^3 of soil samples of *Oribatida* and *Actinedida* were 1.43 and 1.67 in location of Bangar Al-Sokkar (silt loam soil) respectively. Meanwhile, *Oribatida* reached high significant levels of 2.14 in Al-Maamoura (loamy sand soil) samples. Likewise, *Collembola* and *Pscoptera* were 2.14 and 2.62 in clay soil of Abou-Homous respectively (Fig 4). Throughout the seven weeks post-treatments, full dissipations of *Actinedida*, *Gamasida*, *Pauropoda* and *Symphyla* continued in fauna of clay soil of Abou-Homous as well as the full dissipations of *Pauropoda* and *Symphyla* continued in Bangar Al-Sokkar (silt loam soil) and Al-Maamoura (loamy sand soil) during the two successive seasons respectively. Generally, the micro-arthropods in lower depth were almost significantly lower than those were in the upper in the tested locations and during the two successive seasons.



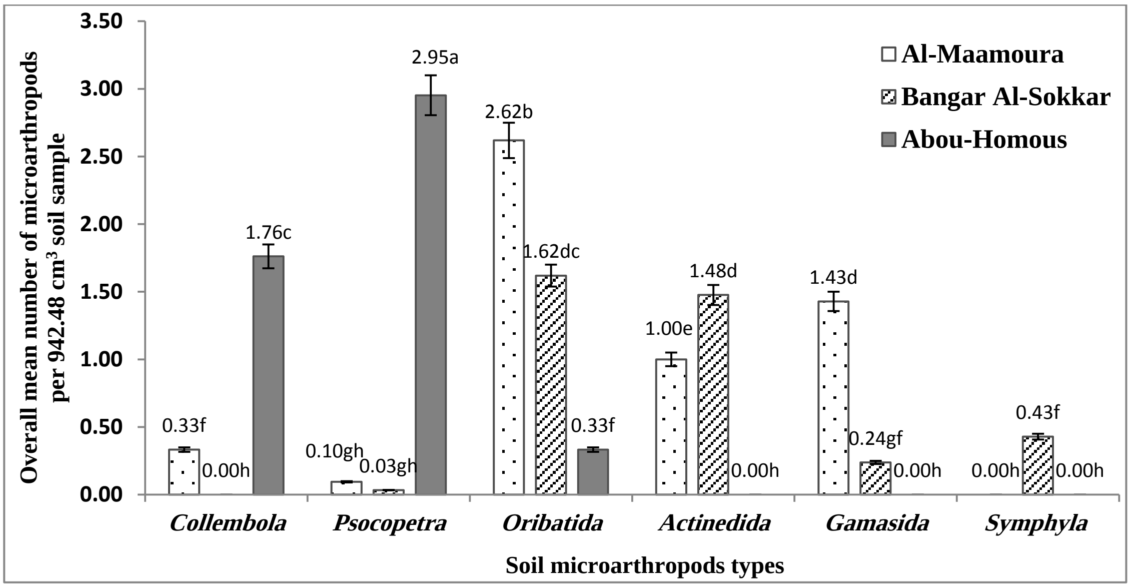
Means followed by the same letters are not significantly different according to the $LSD_{0.05}$ of interaction between micro-arthropods taxonomic groups and locations in untreated (control) areas = 0.5985

Fig.1. Overall mean number of micro-arthropod collected from the upper soil layer samples in untreated area of the tested locations during the 7 weeks post-treatments, season 2016



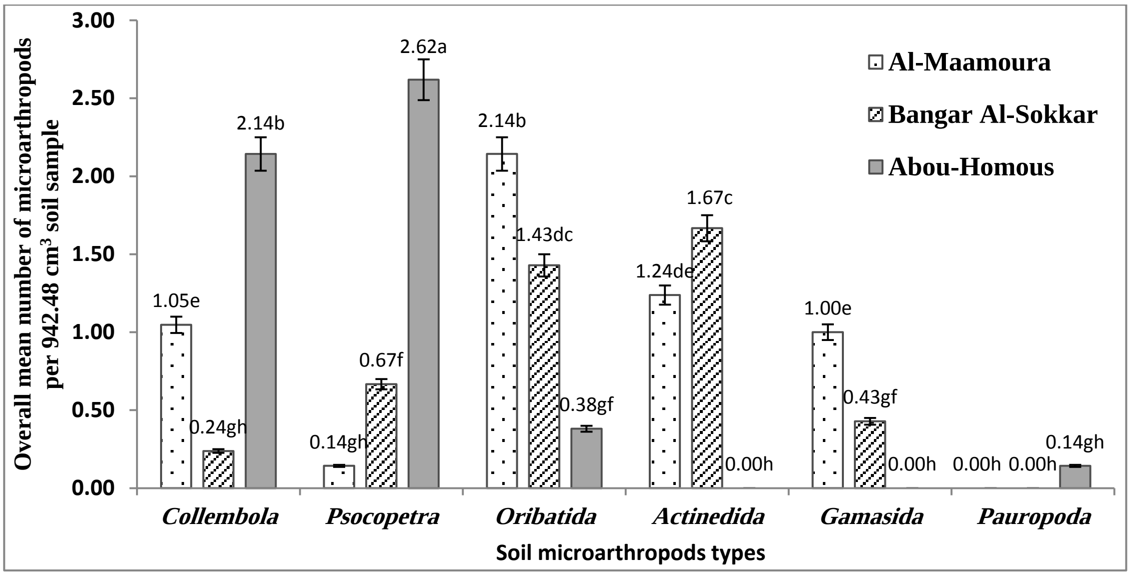
Means followed by the same letters are not significantly different according to the $LSD_{0.05}$ of interaction between micro-arthropods taxonomic groups and locations in untreated (control) areas = 0.6003.

Fig.2. Overall mean number of micro-arthropod collected from the upper soil layer samples in untreated area of the tested locations during the 7 weeks post-treatments, season 2017



Means followed by the same letters are not significantly different according to the $LSD_{0.05}$ of interaction between micro-arthropods taxonomic groups and locations in untreated (control) areas = 0.2114.

Fig.3. Overall mean number of micro-arthropod collected from the lower soil layer samples in untreated area of the tested locations during the 7 weeks post-treatments, season 2016



Means followed by the same letters are not significantly different according to the $LSD_{0.05}$ of interaction between micro-arthropods taxonomic groups and locations in untreated (control) areas = 0.3333.

Fig.4. Overall mean number of micro-arthropod collected from the lower soil layer samples in untreated area of the tested locations during the 7 weeks post-treatments, season 2017

Total Survival Populations of Neonics-Treated Micro-Arthropods:

Data of mean percentages of total survival populations of micro-arthropods in non-target soil fauna were calculated in accordance to their relative survival populations in untreated (control) areas (recovery level 100%). The monitoring of survival micro-arthropods populations throughout the seven weeks post-treatments during the two successive seasons, turn out more about the sustainability of neonic's negative effects on micro-arthropods life and probability of their recovery periods (Table 4 and 5).

In treated areas of Al-Maamoura (loamy sand soil), the mean percentages of total survival populations of soil micro-arthropods exposed to TMX at depth of 0-10 and 10-20 cm reached to their highest significant recovery levels of 102.72 and 111.11 % respectively in the season of 2016 at the 7th week post-treatments (Table 4). Likewise, in the season of 2017, the total survival populations exposed to TMX reached to their highest significant recovery levels of 113.45 and 118.25% at depths of 0-10 and 10-20 cm respectively at the 7th week post-treatments (table 5). In the same location, the mean percentages of total survival populations exposed to THI at depth of 0-10 cm failed to reach their recovery level in season of 2016 but reached recovery level of 105.65% in the season of 2017 at the 7 weeks post-treatments (Table 4 and 5). While treatment of THI in Al-Maamoura (loamy sand soil) at depth of 10-20 cm had a significant increase value of 100 and 107.14% in season 2016 and 2017 respectively at the 7th week post-treatments.

In the second location of Bangar Al-Sokkar (silt loam soil), the mean percentages of survived micro-arthropods population in treated areas with TMX had reached their highest significant values of 105.75 at the depths of 0-10 cm by the of end 7th week post-treatments. On the other hand, populations of micro-arthropods reached recovery levels of 108.33% at 10-20cm more early by the of end 6th week post-treatments in season of 2016. Moreover, total micro-arthropods population in treated areas with TMX had reached their highest significant values of 97.78 and 108.33% respectively in season of 2017 at the 7th week post-treatments. In the same location, the total survived micro-arthropods populations exposed to THI all over the 7 weeks post-treatments in both seasons of 2016 and 2017 failed to reach their recovery levels at both depths (specially the lower depths) comparing to the population in untreated areas (Table 4 and 5).

Regarding to the last location of Abou-Homous (clay soil), The data of mean percentages of total survival micro-arthropods populations exposed to TMX and THI treatments all over the 7 weeks post-treatment in both seasons had been significantly reduced at both depths. Thus, non-target soil fauna had been failed even to reach their recovery levels comparing to the untreated control (Table 4 and 5).

Table 4: Survived soil micro-arthropod's total populations exposed to thiamethoxam and thiaclopride residues via three different types of soils at two depths, season of 2016.

WAT	Total mean populations% of survived soil micro-arthropods											
	Al-Maamoura				Bangar Al-Sokkar				Abou-Homous			
	Thiamethoxam		Thiaclopride		Thiamethoxam		Thiaclopride		Thiamethoxam		Thiaclopride	
	0-10 cm	10-20 cm	0-10 cm	10-20 cm	0-10 cm	10-20 cm	0-10 cm	10-20 cm	0-10 cm	10-20 cm	0-10 cm	10-20 cm
1	97.92^{fbdec}	50.00^{mjlnk}	41.04^{mplnko}	66.67^{jih}	7.17^{utvw}	00.00^{w}	4.60^{utvw}	00.00^{w}	8.58^{utsvw}	7.87^{utsvw}	$25.76^{uptsvqro}$	$26.11^{uptsnqro}$
2	$21.81^{uptsvqrw}$	$22.22^{uptsvqrw}$	$19.44^{uptsvqrw}$	$27.78^{ptsnqro}$	$9.20^{uptsvqrw}$	12.59^{utsvrw}	00.00^{w}	00.00^{w}	00.00^{w}	5.56^{utvw}	00.00^{w}	00.00^{w}
3	1.75^{vw}	00.00^{w}	3.51^{uvw}	00.00^{w}	53.40^{jlik}	00.00^{w}	$8.64^{mptsnqro}$	00.00^{w}	00.00^{w}	00.00^{w}	00.00^{w}	00.00^{w}
4	00.00^{w}	00.00^{w}	00.00^{w}	00.00^{w}	63.94^{jihk}	$33.33^{mplnqro}$	52.46^{mjlik}	00.00^{w}	00.00^{w}	00.00^{w}	00.00^{w}	00.00^{w}
5	41.02^{mplnko}	00.00^{w}	$33.33^{mplnqro}$	00.00^{w}	[illegible]$7.79^{fbdehcg}$	67.50^{jihg}	55.96^{jlik}	$40.00^{mplnqko}$	$15.97^{utsvqrw}$	00.00^{w}	00.00^{w}	00.00^{w}
6	52.78^{mjlik}	$35.55^{mplnqro}$	48.01^{mjlnko}	$17.78^{uptsvqrw}$	92.26^{fbdec}	108.33^{bac}	76.49^{fihg}	83.33^{fdehg}	$23.19^{uptsvqrw}$	00.00^{w}	8.19^{utsvw}	00.00^{w}
7	102.72^{bdec}	111.11^{ba}	91.22^{fbdecg}	100^{fbdec}	105.75^{bdac}	127.28^{a}	34.36^{fdehcg}	83.33^{fdehg}	80.35^{fehg}	00.00^{w}	$31.91^{mplsnqro}$	00.00^{w}

- WAT: week(s) after treatment.
- 0-10 cm: upper soil depth samples & 10-20 cm: lower soil depth samples.
- Means followed by the same letters are not significantly different according to the $LSD_{0.05}$ of interaction between WAT, locations, tested insecticides and soil depths=24.16

Table 5: Survived soil micro-arthropod's total populations exposed to thiamethoxam and thiaclopride residues via three different types of soils at two depths, season of 2017.

WAT	Total mean populations% of survived soil micro-arthropods											
	Al-Maamoura				Bangar Al-Sokkar				Abou-Homous			
	Thiamethoxam		Thiaclopride		Thiamethoxam		Thiaclopride		Thiamethoxam		Thiaclopride	
	0-10 cm	10-20 cm	0-10 cm	10-20 cm	0-10 cm	10-20 cm	0-10 cm	10-20 cm	0-10 cm	10-20 cm	0-10 cm	10-20 cm
1	109.87^{bac}	150^{a}	38.97^{nkjmiohl}	58.33^{fkjmiehlg}	13.88^{nmo}	00.00^{o}	2.08^{o}	00.00^{o}	6.06^{no}	7.41^{no}	28.90^{nkjmol}	21.48^{nkmol}
2	21.81^{nkmol}	22.22^{nkmol}	19.44^{nmol}	27.78^{nkjmol}	19.20^{nmol}	00.00^{o}	00.00^{o}	00.00^{o}	00.00^{o}	5.56^{no}	00.00^{o}	00.00^{o}
3	00.00^{o}	00.00^{o}	7.47^{no}	00.00^{o}	51.84^{fnkjmiehlg}	00.00^{o}	27.70^{mkjmol}	00.00^{o}	00.00^{o}	00.00^{o}	00.00^{o}	00.00^{o}
4	00.00^{o}	00.00^{o}	00.00^{o}	00.00^{o}	73.30^{fbjdiehcg}	22.22^{nkmol}	54.94^{fkjmiehlg}	00.00^{o}	00.00^{o}	00.00^{o}	00.00^{o}	00.00^{o}
5	41.68^{nkjmiohlg}	00.00^{o}	30.66^{nkjmol}	00.00^{o}	84.43^{fbdehcg}	89.81^{fbdec}	61.95^{fkjdiehlg}	55.55^{fkjmiehlg}	19.17^{nmol}	00.00^{o}	00.00^{o}	00.00^{o}
6	66.45^{fkjdiehcg}	19.44^{nmol}	50.00^{fnkjmihlg}	22.22^{nkmol}	74.47^{fbjdiehcg}	83.33^{fbdehcg}	83.74^{fbdehcg}	91.67^{fbdec}	20.06^{nkmol}	00.00^{o}	00.00^{o}	00.00^{o}
7	113.45^{ba}	118.25^{ba}	105.65^{bdac}	107.14^{bdac}	97.78^{bdec}	108.33^{bdac}	82.31^{fbdiehcg}	86.11^{fbdec}	72.12^{fbjdiehcg}	00.00^{o}	36.18^{nkjmiol}	00.00^{o}

- WAT: week(s) after treatment.
- 0-10 cm: upper soil depth samples & 10-20 cm: lower soil depth samples.
- Means followed by the same letters are not significantly different according to the $LSD_{0.05}$ of interaction between WAT, locations, tested insecticides and soil depths = 46.95.

Generally, the obtained data of soil drainage applications of TMX at all depths were considered to be safe for micro-arthropods life by the end of the 7th week post-treatments in both of loamy sand and silt loam soils. Meantime, soil applications of THI at all depths were considered being safe for non-target soil fauna only in loamy sand soils by the end of the 7th week post-treatments. Treated non-target soil fauna with the tested neonics could restore their initial recovery levels more especially in the lower depths. On the contrary, these applications were not safe for non-target soil fauna in the clay soil of Abou-Homous region.

DISCUSSION

The total mean reductions of the adult stage of whitefly *B. Tabaci* treated with TMX as well as THI came at their highest values in Al-Maamoura (loamy sand soil) and Bangar Al-Sokkar (silt loam soil) and followed by a significant decrease in reduction values in Abou-Homous (clay soil) in the seasons of 2016 and 2017. The residual efficacies of tested neonics in soils of high portions of loamy sand and silt loam soils showed high significant residual efficacy values with high efficacy periods extended to 15 days in season of 2016 and 2017 while efficacy periods had been more shifted up to 21days for THI treatments in the season of 2017. Meanwhile, the tested neonics in clay soil had significant lower values of residual efficacies mostly not exceed 9 days in the two growing seasons. These data came in accordance with the comparing study of the efficacy of imidacloprid (IMID) and TMX at different sites found that both insecticides provided control of whitefly nymphs for 8 to 12 weeks at 9 sites on sandy soil but only 3 to 5 weeks at one site on gravelly loam soil (Schuster, 2002). Moreover, reduction percentages of adult whitefly treated with soil application of THI that reached the range of 37.8-75.4% for more than 60 days and enhance tomato plant height and yield compared to the untreated control. THI is stable to hydrolysis in soil (95–98 % recovery after 30 days) (Simon-Delso *et al*., 2014; Dong *et al*., 2017).

In this research, the data came as reasonable results to the rational chemical contents of OM and OC between these three locations. The clay soil texture compared to the other two locations had the highest contents of a relative apparent OC and OM (nearly equal two times the) more than the values of loamy sand and silt loam soils locations in the two growing seasons. Thus, the contents of the soils of OM and OC had inverse proportion with reduction percentages of whitefly population in field. It means that, high soil content of OM and OC could retard the mobility and increase the retentions of TMX and THI adjacent to root regions. The data of this research came in accordance to the studies on neonics mobility in different types of soils that exhibited a high mobility of IMID in silty kaolinite-type soil, whereas limited mobility was found in soil with high OM content (Selim *et al*., 2010). Moreover, the carbon-water partitioning coefficients (K_{oc}) that correlate with high mobility of neonics in soil (Mortl *et al*., 2016). the soil with the highest organic carbon (OC) content accelerate the total degradation or biodegradation of neonics and bio-availability of neonics was not the primary influencing factor due to their weak sorption, also soils of high content of OM could decreased the degradation of neonics due to the characteristics of sorption-desorption (Cox *et al*., 1997; Zhang *et al.,* 2018).

variations which had been found in initial effect and efficacy periods in the tested locations, indicate different types of soils, may be correlated with the different portions of (sand, silt and clay) in the soil structures which may probably rule the mobility and the elution capacity of the tested neonics. Initial effects of TMX and THI in loamy sand and in silt loam soils respectively against whitefly populations appeared early at the 3rd day post treatment in the two successive seasons. These findings were supported by laboratory studies on clodation and TMX elution profiles that considered as highly mobile and susceptible to leaching in sandy soil, but they are only moderately mobile in loam. Recoveries in effluent solution were significantly lower (27%) in the latter case compared to 69% obtained for silty soil. Similarly slow release of IMID was observed for soils with higher clay content (Toscano and Byrne, 2005). Soil mobility of clothianidin (CLO) and TMX in different soil types (sand, clay, or loam), and in pumice showed retains of these neonics in loam and clay soils, and showed ready elution through sandy soil and pumice. Elution capability of the active ingredients in sandy soil correlated with their water solubility, indicating approximately 30% higher rapidity for TMX than CLO (Mortl *et al*., 2016).

It was so important to study the toxicity of TMX and THI on non-target soil fauna as a bio-indicator for healthy agro-ecosystem. This idea was sided with the investigations on toxic effects of the tested neonics applications into the ecosystem that may imbalance the ecological equilibrium and affects the structure of the soil biota. Thus, deteriorations in neonics-exposed micro-arthropods had great modifications on some biological functions, such as soil organic matter decomposition and nutrient availability in the soil (Ferraro and Pimentel 2000).

Overall the two layers of soil, full recovery percentages of tested neonics-exposed micro-arthropods, compared to those whom were naturally settled in untreated areas, appeared at the 7th week post-treatments in Al-Maamoura soils which characterized by high portions of sand (71.20%) in both seasons of 2016 and 2017. On the other hand, full recovery percentages overall the two layers of soil of TMX exposed-micro-arthropods appeared at the 6th and 7th week post-treatments in Bangar Al-Sokkar (silt loam soils) which characterized by high portions of silt in season of 2016 and also appeared at the 7th week post-treatments in season of 2017. On contrary, soil micro-arthropods exposed to all tested neonics failed to recover and were at their minimum levels by the end of the 7th week in high clay content comparing to the other tested locations. Noticeably, most of the recovery values of soil micro-arthropods at the 7th week post-treatments in the two growing seasons in layer of 0-10cm, were significantly less than those values in layer of 10-20cm of loamy sand and silt loam soils and vice versa in clay soils. The data of this research meets the data of the foliar treatment of IMID and TMX in field where there was a significant reduction in the mean numbers of the examined micro arthropods in the layer of 0–10 cm more than 10-20 cm. The soil micro-arthropod groups showed varying mean values within the 5th week period of investigation. The results also revealed that IMID had more adverse effects on non-target soil fauna than TMX (El-Naggar and Zidan 2013). Variations of recovery levels of soil micro-arthropods in may be correlated with the different portions of (sand, silt and clay) in the soil structures which may probably affect the mobility and the elution capacity of the tested neonics. These results could be justified by laboratory studies on CLO, TMX, and IMID elution profiles that considered as highly mobile and leach in sandy soil, and pumice but only moderately mobile in loam and slow in silty and higher clay content. Moreover, recoveries of effluent solution of the active ingredients in sandy soil correlated with their water solubility, indicating a higher rapidity for TMX than CLO (Toscano and Byrne, 2005; Mortl *et al*., 2016). Furthermore, data of recovery levels of soil micro-arthropods populations in this research may be varied by OM content in the tested soils. This supposition came in agree with retardation of mobility was found in high OM content-soil OM could decreased the degradation of neonics due to the characteristics of sorption-desorption (Selim *et al*., 2010; Zhang *et al.*, 2018).

The biodegradation of the tested neonics could be accelerated in the presence of overlapping physicochemical parameters of the pH of the tested soils (in the range of alkaline conditions), high additive sources of OC and additional nutrient sources. Biodegradation in combination with soil physicochemical parameters may role the dissipations differences of TMX and THI. The optimum condition of IMID biodegradations with cometabolising bacteria occurred at neutral pH 8 and temperatures of 30◦C (Hu *et al.*, 2013). Furthermore, the magic nitro group of TMX was transformed to nitrous guanidine, desnitro/guanidine and urea metabolites by pure bacterial cultures of *Pseudomonas* sp. 1G when supplemented with 10 mM glucose under microaerophilic growth conditions (Pandey *et al.*, 2009). This could explain the rapid dissipation of TMX in more aerated soils of loamy sand and silt loam than terrible clay soil indicated by the rapid recovery of micro-arthropods in loamy sand and silt loam soils at the end of the 7th week but failure in restoring the recovery levels of micro-arthropods in clay soil. In addition, THI was hydroxylated to 4-hydroxy THI by bacterial strain *S. maltophilia* CGMCC 1.178 with a 10-fold increase in efficiency in the presence of sucrose as a carbon and energy source. 4-hydroxy THI was not found to be converted to olefin THI under acidic condition, but was simultaneously oxidised and decyanated under alkaline conditions to form 4-ketone THI imine (Zhao *et al.* 2009).

Conclusion:

Eventually, full recovery levels of micro-arthropods revealed at the end of the 7th week post-treatments in all soil's depths of loamy sand and silt loam treated with TMX and in loamy sand soil treated with THI during the two seasons. micro-arthropods failed to recover in high OM -clay soil with the tested neonics. Moreover, TMX treatments were significantly safer than THI on soil fauna in both of loamy sand and silt loam soils. Furthermore, the efficiencies of both TMX and THI via soils of loamy sand and silt loam against whitefly were significantly preferable to be recommended compared to the clay soil. However all treatments in clay soil had the least significant efficiencies, THI application was more efficient comparing to TMX.

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ARABIC SUMMERY

الآثر الابادى لتطبيقات الثياكلوبرايد والثياميثوكسام فى التربة ضد الذبابة البيضاء وتأثيراتهما على مفصليات الارجل الدقيقة فى التربة

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تم إجراء دراسات حقلية للتحقق من فاعلية مبيد الثياميثوكسام والثياكلوبريد عن طريق التربة ضد الذبابة البيضاء على شتلات الطماطم فى ثلاث أنواع مختلفة من التربة الزراعية خلال موسمين متتاليين. هذا وقد تم تحديد المعايير الفيزيائية والكيميائية فى كل نوع من أنواع التربة. وأوضحت النتائج أن أنواع التربة كانت عبارة عن رمل طفالى(المعمورة)، طفال طميي (بنجر السكر) وطينية (أبوحمض). وفى أثناء الموسمين الزراعيين لعام ٢٠١٦ و٢٠١٧، كانت التربة الطينية هي الاعلى فى محتواها من المادة العضوية (٣،٤٣ و٣،٤٨ على التوالى) وكذلك الكربون العضوي (١،٩٩ و٢،٠٣% على التوالى). سجلت النتائج أعلى نسبة إنخفاض فى تعداد الذبابة البيضاء المعاملة بمبيد الثياميثوكسام خلال عام ٢٠١٦ و٢٠١٧ حيث كانت (٧٩،٣٥ و٨٠،١٢% على التوالى) فى تربة الرمل الطفالى وفى تربة الطفال الطميي (٧٨،٣٩ و ٨١،٦٠% على التوالى) مقارنة مع نتائج التربة الطينية. وبالمثل، سجلت معاملات مبيد الثياميثوكسام أعلي نسبة خفض الآفة خلال عامى ٢٠١٦ و٢٠١٧ فى تربة الرمل الطفالى (٧٨،٠٦ و٧٩،٨٨% على التوالي) وتربة الطفال الطميي (٧٧،١٢ و٧٨،٥٦% على التوالى) مقارنة بالتربة الطينية. أمتدت بقايا فاعلية مبيد الثياميثوكسام إلى ١٥ يوم فى تربة الرمل الطفالى والطفال الطميي مقارنة بـ٩ أيام فى حالة التربة الطينية خلال الموسميين الزراعيين. ومرورا بالموسمين ٢٠١٦ و٢٠١٧، أمتدت بقايا فاعلية مبيد الثياكلوبريد فى تربة الرمل الطفالى والطفال الطميي إلى ١٥ و٢١ يوم على التوالى مقارنة بـ٩ و١٥ يوم فى التربة الطينية. كشفت نتائج التأثيرات المبدئية لمبيدات النيونيكوتينويدات محل الدراسة ضد الذبابة البيضاء عن ظهور سريع نسبيا فى اليوم الثالث من المعاملة بمبيد الثياميثوكسام فى تربة الرمل الطفالى فضلا عن مبيد الثياكلوبرايد فى التربة الطميية والطينية خلال الموسميين. كما ظهرت نتائج التأثير المبدئى عند اليوم الثالث والتاسع بعد المعاملة بمبيد الثياميثوكسام فى تربة الطفال الطميي وبمبيد الثياكلوبرايد فى تربة الرمل الطفالى خلال موسم ٢٠١٦ و٢٠١٧ علي التوالى. وأمتد التأخر فى التأثير المبدئى حتى اليوم التاسع بعد المعاملة بمبيد الثياميثوكسام فى التربة الطينية خلال الموسميين. هذا وقد ظهرت نتائج الاسترداد الكامل لتعداد مفصليات الارجل الدقيقة فى جميع أعماق التربة خلال الموسميين بنهاية الاسبوع السابع بعد المعاملة بمبيد الثياميثوكسام فى تربة الرمل الطفالى والطفال الطميي وأيضا بمبيد الثياكلوبرايد فى تربة الرمل الطفالي. وفشلت مفصليات الارجل فى الاسترداد مستوي تعدادها الطبيعى فى المساحات المعاملة بمبيدات النيونيكوتينويدات فى التربة الطينية عالية المحتوى فى المادة العضوية.