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Field Efficacy of Some Neonicotinoid Insecticides on Whitefly *Bemicia tabaci* (Homoptera: Aleyrodidae) and its Natural Enemies in Cucumber and Tomato Plants in Al-qassim Region, KSA

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ABSTRACT
The effect of three successive treatments with the recommended concentrations of the neonicotinoid insecticides, acetamiprid, imidacloprid and thiamethoxam on immature stages and adults of the whitefly, *Bemicia tabaci* (Gennadius) was investigated. Insecticide applications were conducted against whitefly infesting summer and autumn plantations of cucumber *Cucumis sativus* L. and tomato *Lycopersicum esculentum* Mille. under field conditions in Onyyzah governorate, Qassim region, Saudi Arabia. Dead and living insect individuals were counted 3, 7 and 14 days after each treatment. Tested insecticides significantly suppressed the population of immature stages and adults of whitefly *B. tabaci* living on plant leaves. Thiamethoxam showed the highest rates of efficiency against whitefly. It caused reduction in whitefly adult and immature stage populations attacking early summer cucumber by 87.5 and 82.4% after three sprays, respectively. In autumn plantations, acetamiprid, imidacloprid and thiamethoxam caused total reduction percentages in adults of *B. tabaci* of 67.3, 71.9 and 84.7%, respectively. The immature stages of the tested pest infesting autumn cucumber plants was reduced by 60.1, 72.8 and 82.1%, respectively. The tested insecticides variably affected the non target predatory insects where thiamethoxam was the most toxic compound and followed by imidacloprid and acetamiprid. Their harmful effect can be ranked from harmless to slightly harmful to predatory insects. Their side effect was significantly higher on *Orius* sp. and declined the populations of *Paederus alfierii* Koch, *Coccinella undicempunctata* (Reiche) and *Chrysoperla carnea* (Steph.).Therefore, the tested neonicotinoids could be considered promising candidates in controlling whitefly with a lower value of harmful effect on beneficial insect species.

Key words: Whitefly, *Bemicia tabaci,* predaceous insects, *Coccinella undicempunctata, Paederus alfierii, Chrysoperla carnea, orius* sp., neonicotinoid insecticides

INTRODUCTION
The whitefly, *Bemicia tabaci* (Gennadius) is one of the most intractable and worldwide damaging and injurious top hundred pest attacking a wide range of important crops, vegetables and ornamentals all over the world (Perring, 2001; Carabali *et al*., 2005; Touhidul and Shunxiang, 2007; Abdel-Baky and Al-Deghairi, 2008). Since late 1980's, the insect has risen from relative obscurity to become one of the primary insect pests of agricultural crops (Lin *et al*., 2007; Abdel-Baky and Al-Deghairi, 2008) and that may due to not only its direct damage by sucking plant phloem sap but also its transition of various viral diseases (Oliveira *et al*., 2001; Al-Deghairi, 2009). However, management of *B. tabaci* is challenging because of its intercrop movement, high reproductive potential and it's under leaf habitat (Gerling *et al*., 2001;

Al-Deghairi, 2009; Fouly *et al.*, 2011). During the last decades, chemical control using insecticides was the most efficient method to minimize whitefly damages to crop production, although such practice is hazardous to water, soil, environment and human health. That may due to the misuse of chemical insecticides. On the other hand, the increasing incidence of resistance to many conventional insecticides has led to the development of large numbers of new active compounds such as the neonicotinoids which were introduced as an alternative to the organophosphate, carbamate and pyrethroid insecticides. Recently, neonictinoides have been the fastest growing class of insecticides in modern crop protection with wide spectrum effect against sucking and certain chewing insect pests (Jeschke and Nauen, 2008). These chemical insecticides act agonistically on insect Nicotinic Acetylcholine Receptors (nAChR), blocking the necotinergic neural pathway causing accumulation of the neurotransmitter acetylcholine (Matsuda *et al.*, 2001; Tomizawa and Cassida, 2005). They are especially active on Homopteran pest species such as aphids and whiteflies and also commercialized to control many coleopteran and lepidopteran species (Nauen *et al.*, 2003). The selective toxicity of the neonicotinoid group is attributable in part to much higher affinity for the insect than the mammalian nAChR (D'Amour and Casida, 1999). Despite their increasing use in crop protection so far only limited data concerning of their side effect on non-target organisms such as natural enemies existing in the same environment (Cloyd and Bethke, 2011).

Therefore, the present protocol aims to study the effect of three neonicotinoid insecticides, acetamiprid, imidacloprid and thiamethoxam on immature stages and adults of the whitefly, *B. tabaci* infesting summer and autumn plantations of cucumber *Cucumis sativus* L. and tomato *Lycopersicum esculentum* Mille. under field conditions. On the other hand, Fouly and Al-Rehiayani (2011) surveyed the beneficial insect and mites associated with harmful arthropods especially whitefly in Saudi Arabia. Therefore, the side effect of the aforementioned neonicotinoids was also evaluated on the abundance of whitefly natural enemies, *Coccinella undecimpunctata* (Reiche), *Paederus alfierii* Koch, *Chrysoperla carnea* (Steph.) and *Orius* sp.

MATERIALS AND METHODS

Insecticides used:

- Acetamiprid (Mospilan SP 20), Chemical subclass : chloronicotinyl, International Union for Pure and Applied Chemistry (IUPAC) name: *N*-[(6-chloro-3-pyridyl)methyl]-*N*′-cyano-*N*-methyl-acetamidine. It was used at the rate of 10 ml active ingredient (a.i)100 L^{-1}. water
- Imidacloprid (Confidor SL 20), Chemical subclass : chloronicotinyl, IUPAC name : 1-(6-chloro-3-pyridymethyl)-N-nitroimidazolidin-2-ylideneamine. It was at the rate of 10 g. a.i/100 L. water
- Thiamethoxam (Actara WG 25), Chemical class : thianicotinyl, IUPAC name : 3-(2-chloro-thiazol-5-yl methyl)-5 methyl (1, 3, 5) oxidiazinon-4-ylidame-N nitroamine. It was used at the rate of 10 g a.i. 100 L^{-1}. water

Field trails

Cucumber and tomato plantations and sampling: Field experiments were carried out during two plantations, i.e. Summer and Autumn, during 2010 in a special farm in Onayzah governorate at Qassim region, Kingdom of Saudi Arabia. Cucumber *C. sativus* was planted at the middle of February and the end of August for Summer and Autumn plantations, respectively. Tomato *L. esculentum* seedlings were transplanted at the middle of March and at the middle of October for Summer and Autumn plantations, respectively. The experimental area was divided according to complete randomized block design including four replicates for each treatment as well as four replicates were left as untreated check. Each replicate was 6×7 m^2 and all plots received the normal agricultural practices. To evaluate the effectiveness of neonicotinoid insecticides against whitefly, the number of adult and immature stages were counted 24 h pretreatment and also 3, 7 and 14 days after treatment. In each plot, adult counting was made in the early morning on 25 randomly leaves per replicate collected from the bottom, middle and top of plants. The upper and lower leaf were inspected in the field where the numbers of whitefly adults were recorded. The same samples were taken to the laboratory to count the number of immature stages using binocular microscope. Reduction of population was estimated by using Henderson and Tilton (1955) to determine the initial effect and residual activity of the tested neonicotinoid insecticides.

Toxicity of neonicotinoid insecticides on natural enemies: Associated natural enemies i.e., *Chrysoperla carnea* (Steph), *Coccinella undecimpunctata* (Reiche), *Orius* spp. and *Paederus alfierii* (Koch) were counted on 100 tomato and cucumber plants in autumn plantation. Reduction percentages in population were estimated by using Henderson and Tilton (1955). Pesticides used were ranked as harmless (<25% mortality), slightly harmful (25-50% mortality), moderately harmful (51-75% mortality) and harmful (>75% mortality) according to Standards of the International Organization of Biological Control (IOBC) for semi-field or field trials (Hassan, 1985).

Statistical analysis: Data were subjected to one way ANOVA using the Micro-Computer Program COSTAT, Student-Newman Keuls Test (CoStat Sowftware, 1990) where means with the same letter aren't significantly different (p<0.05).

RESULTS

The effect of neonicotinoid insecticides on whitefly *B. tabaci*: Data showed that treatment with tested insecticides significantly suppressed the population of immature stages and adults of whitefly *B. tabaci* infesting cucumber plants growing in early summer plantation. Imidacloprid and acetamiprid caused similar reduction in adult populations of the tested whitefly which reached 94.0 and 88.6%, 84.0 and 94.6% and 80.0 and 77.7% after the first, second and third treatments, respectively (Table 1). In all cases, thiamethoxam proved to be the most effective neonicotinoid insecticide where it caused an average reduction in whitefly adult populations of 87.5%, followed by imidacloprid and acetamiprid by an average of 76.1 and 73.3% after three successive sprays, respectively (Table 2). All differences were significant (LSD p>0.05). The same trend was also

Table 1: The effect of three neonicotinoid insecticides on reduction percentage in whitefly *Bemicia tabaci* population (adults/100 leaves) of cucumber plants in early summer plantation

Insecticide	Rate of application (a.i)	Before treatment	No. of alive insect individuals and reduction% after indicated days 1st spray (X)	Av. Red. (%)	2nd spray (X)	Av. Red. (%)	3rd spray (X)	Av.Red. (%)	Mean total reduction
Acetamiprid	10 mL	181	88.66^b	66.5	94.66^b	74.5	77.76^b	79.0	73.3
Imidacloprid	10 g	201	94.00^b	68.0	84.00^b	79.6	80.00^b	80.6	76.1
Thiamithoxan	10 g	176	41.33^a	81.6	32.66^a	91.0	36.66^a	89.9	87.5
Control	---	198	289.00	---	410.00	---	405.00	---	---
LSD (p>0.05)			10.42	---	13.63	---	22.08	---	---

Active ingredient (a.i) 100 L^{-1} water, X: Average mean of alive insect individuals 3, 7 and 14 days after spray. Data were subjected to the Micro-Computer Program COSTAT, one way anova using student-newman keuls test, where means within each column having the same letter aren't significantly different (p>0.05)

Table 2: The effect of three neonicotinoid insecticides on reduction percentage in whitefly *Bemicia tabaci* population (immature stages/100 leaves) of cucumber plants in early summer plantation

Insecticide	Rate of application (a.i)	Before treatment	No. of alive insect individuals and reduction% after indicated days 1st spray (X)	Av. Red. (%)	2nd spray (X)	Av. Red. (%)	3rd spray (X)	Av.Red. (%)	Mean total reduction
Acetamiprid	10 mL	355	176.67[b]	59.7	166.2[b]	65.4	170.6[b]	62.3	62.4
Imidacloprid	10 g	411	176.33[b]	65.1	178.6[b]	68.8	169.3[b]	67.5	67.1
Thiamithoxan	10 g	406	95.66[a]	80.9	89.7[a]	84.1	91.6[a]	82.2	82.4
Control	---	420	---	---	---	---	---	---	---
LSD (p>0.05)		---	15.85	---	10.03	---	31.58	---	---

Active ingredient (a.i) 100 L^{-1} water, X: Average mean of alive insect individuals 3, 7 and 14 days after spray. Data were subjected to the Micro-Computer Program COSTAT, one way anova using student-newman keuls test, where means within each column having the same letter aren't significantly different (p>0.05)

Table 3: The effect of three neonicotinoid insecticides on reduction percentage in whitefly *Bemicia tabaci* population (adults /100 leaves) of cucumber plants in autumn plantation

Insecticide	Rate of application (a.i)	Before treatment	No. of alive insect individuals and reduction% after indicated days 1st spray (X)	Av. Red. (%)	2nd spray (X)	Av. Red. (%)	3rd spray (X)	Av.Red. (%)	Mean total reduction
Acetamiprid	10 mL	712	301.6[c]	61.8	240.6[c]	68.5	223.0[c]	71.6	67.3
Imidacloprid	10 g	604	198.7[b]	70.4	172.7[b]	73.4	187.3[b]	72.0	71.9
Thiamithoxan	10 g	622	117.3[a]	83.1	100.7[a]	85.0	97.2[a]	85.9	84.7
Control	---	830	---	---	---	---	---	---	---
LSD (p>0.05)	---	---	47.37	---	42.36	---	33.06	---	---

Active ingredient (a.i) 100 L^{-1} water, X: Average mean of alive insect individuals 3, 7 and 14 days after spray. Data were subjected to the Micro-Computer Program COSTAT, one way anova using student-newman keuls test, where means within each column having the same letter aren't significantly different (p>0.05)

observed with regard to the reduction percentages in immature stages of *B. tabaci* attacking early summer cucumber where the average reduction reached 82.4, 67.1 and 62.4% when plants were sprayed with three treatments with, thiamethoxam, imidacloprid and acetamiprid, respectively as shown in Table 2. Concerning the effect of the tested neonicotinoid insecticides on adults and immature stages of whitefly infesting cucumber plants growing in autumn, results clearly showed that acetamiprid was the least effective compound while the reduction in pest population increased significantly by using imidacloprid and reached its highest effect with thiamethoxam. After three successive treatments, acetamiprid, imidacloprid and thiamethoxam caused total reduction percentages in adults of *B. tabaci* of 67.3, 71.9 and 84.7%, respectively (Table 3). The same sequence was observed because the aforementioned neonicotinoid insecticides reduced the immature stages of the tested pest infesting autumn cucumber plants by an average of 60.1, 72.8 and 82.1%, respectively (Table 4).

Whitefly *B. tabaci* populations infesting tomato plants in early summer plantations were significantly reduced by neonicotinoid insecticides where acetamiprid reduced insect adults by an average of 63.6% while imidacloprid caused 71.5% reduction. thiamethoxam proved to be the most effective compound by reduction percentage of 82.0% after three successive sprays, respectively (Table 5). The efficiency of the three tested neonicotinoid compounds was significantly different after the 1st, 2nd and 3rd treatments (LSD = 10.75, 12.6 and 9.56) as shown in Table 5. Concerning the effect of the aforementioned insecticides on immature stages growing on tomato early summer plantation, Table 6 clearly showed that thiamethoxam was the most effective

Table 4: The effect of three neonicotinoid insecticides on reduction percentage in whitefly *Bemicia tabaci* population (immature stages/100 leaves) of cucumber plants in autumn plantation

Insecticide	Rate of application (a.i)	Before treatment	No. of alive insect individuals and reduction% after indicated days 1st spray (X)	Av. Red. (%)	2nd spray (X)	Av. Red. (%)	3rd spray (X)	Av.Red. (%)	Mean total reduction
Acetamiprid	10 mL	889	375.2[c]	60.5	377.3[c]	59.5	374.7[c]	60.2	60.1
Imidacloprid	10 g	730	218.0[b]	72.0	208.2[b]	72.8	205.0[b]	73.5	72.8
Thiamithoxan	10 g	890	173.3[a]	81.7	172.7[a]	81.5	158.7[a]	83.2	82.1
Control	---	940	---	---	---	---	---	---	---
LSD (p>0.05)	---	---	23.45	---	19.68	---	26.62	---	---

Active ingredient (a.i) 100 L^{-1} water, X: Average mean of alive insect individuals 3, 7 and 14 days after spray. Data were subjected to the Micro-Computer Program COSTAT, one way anova using student-newman keuls test, where means within each column having the same letter aren't significantly different (p>0.05)

Table 5: The effect of three neonicotinoid insecticides on reduction percentage in whitefly *Bemicia tabaci* population (adults /100 leaves) of tomato plants in early summer plantation

Insecticide	Rate of application (a.i)	Before treatment	No. of alive insect individuals and reduction% after indicated days 1st spray (X)	Av. Red. (%)	2nd spray (X)	Av. Red. (%)	3rd spray (X)	Av.Red. (%)	Mean total reduction
Acetamiprid	10 mL	132	86.67[c]	63.6	90.70[c]	63.9	86.33[c]	63.6	63.7
Imidacloprid	10 g	118	66.70[b]	68.8	58.00[b]	74.6	60.33[b]	71.5	71.6
Thiamithoxan	10 g	122	44.70[a]	79.8	41.00[a]	82.7	36.00[a]	83.5	82.0
Control	---	102	---	---	---	---	---	---	---
LSD (p>0.05)	---	---	10.75	---	12.60	---	9.56	---	---

Active ingredient (a.i) 100 L^{-1} water, X: Average mean of alive insect individuals 3, 7 and 14 days after spray. Data were subjected to the Micro-Computer Program COSTAT, one way anova using student-newman keuls test, where means within each column having the same letter aren't significantly different (p<0.05)

Table 6: The effect of three neonicotinoid insecticides on reduction percentage in whitefly *Bemicia tabaci* population (immature stages/100 leaves) of tomato plants in early summer plantation

Insecticide	Rate of application (a.i)	Before treatment	No. of alive insect individuals and reduction% after indicated days 1st spray (X)	Av. Red. (%)	2nd spray (X)	Av. Red. (%)	3rd spray (X)	Av.Red. (%)	Mean total reduction
Acetamiprid	10 mL	231	126.67[b]	59.70	130.04[c]	61.20	131.3[c]	59.50	61.30
Imidacloprid	10 g	227	119.02[b]	63.90	106.00[b]	67.90	110.2[b]	71.60	67.90
Thiamithoxan	10 g	199	65.70[a]	75.80	54.67[a]	81.20	53.3[a]	81.00	79.30
Control	---	219	---	---	---	---	---	---	---
LSD (p>0.05)	---	---	14.89	---	8.86	---	14.48	---	---

Active ingredient (a.i) 100 L^{-1} water, X: Average mean of alive insect individuals 3, 7 and 14 days after spray. Data were subjected to the Micro-Computer Program COSTAT, one way anova using student-newman keuls test, where means within each column having the same letter aren't significantly different (p>0.05)

compound and followed by imidacloprid and acetamiprid. The mean total reduction percentages in immature stages of *B. tabaci* were 79.3, 67.9 and 61.3% when plants were sprayed three times with the previous mentioned neonicotinoid insecticides, respectively. In autumn plantation, data in Table 7 showed that thiamethoxam caused the highest rate of mean total reduction in *B. tabaci* adults of 79.9% while imidacloprid and acetamiprid reduced the insects by an average of 69.8% and 62.1, respectively. By an overall view, the differences between the effect of the three tested insecticides on adult insect populations during 1st, 2nd and 3rd sprays were significant (LSD = 5.84, 5.88 and 4.94), respectively (Table 7). On the other hand, there were no significant differences between the effect of thiamethoxam and imidacloprid on immature stages of whitefly

Table 7: The effect of three neonicotinoid insecticides on reduction percentage in whitefly *Bemicia tabaci* population (adults /100 leaves) of tomato plants in autumn plantation

Insecticide	Rate of application (a.i)	Before treatment	No. of alive insect individuals and reduction% after indicated days 1st spray (X)	Av. Red. (%)	2nd spray (X)	Av. Red. (%)	3rd spray (X)	Av.Red. (%)	Mean total reduction
Acetamiprid	10 mL	198	81.0[c]	61.7	81.7[c]	62.3	79.0[c]	62.4	62.1
Imidacloprid	10 g	186	64.7[b]	67.5	60.3[b]	70.3	56.7[b]	71.5	69.8
Thiamithoxan	10 g	211	53.7[a]	76.2	41.3[a]	81.5	40.0[a]	82.1	79.9
Control	---	199	---	---	---	---	---	---	---
LSD (p>0.05)		---	5.84	---	5.88	---	4.94	---	---

Active ingredient (a.i) 100 L^{-1} water, X: Average mean of alive insect individuals 3, 7 and 14 days after spray. Data were subjected to the Micro-Computer Program COSTAT, one way anova using student-newman keuls test, where means within each column having the same letter aren't significantly different (p>0.05)

Table 8: The effect of three neonicotinoid insecticides on reduction percentage in whitefly *Bemicia tabaci* population (immature stages/100 leaves) of tomato plants in autumn plantation

Insecticide	Rate of application (a.i)	Before treatment	No. of alive insect individuals and reduction% after indicated days 1st spray (X)	Av. Red. (%)	2nd spray (X)	Av. Red. (%)	3rd spray (X)	Av.Red. (%)	Mean total reduction
Acetamiprid	10 mL	223	102.67[b]	58.5	95.67[b]	60.3	97.00[b]	61.1	60.0
Imidacloprid	10 g	207	86.20[a]	62.6	78.00[a]	63.9	70.33[a]	69.7	65.4
Thiamithoxan	10 g	288	78.00[a]	75.5	68.33[a]	78.0	60.67[a]	81.2	78.2
Control	---	268	---	---	---	---	---	---	---
LSD (p>0.05)	---	---	8.73	---	12.56	---	14.80	---	---

Active ingredient (a.i) 100 L^{-1} water, X: Average mean of alive insect individuals 3, 7 and 14 days after spray. Data were subjected to the Micro-Computer Program COSTAT, one way anova using student-newman keuls test, where means within each column having the same letter aren't significantly different (p>0.05)

B. tabaci infesting tomato in autumn plantation while both were significantly more efficient than acetamiprid. The mean total reduction percentages were 60.0%, 65.4% and 78.2% when plants were sprayed three times with acetamiprid, imidacloprid and thiamethoxam, respectively (Table 8).

The side effect of neonicotinoid insecticides on natural enemies: In Table 9, treatments with the tested neonicotinoid insecticides had a variable side toxic effect on predatory insect species living on cucumber plants in autumn plantation. Population of *Orius sp.* was the most reduced species by different compounds where 29.0% of its population was decreased by using actemiprid and followed by *C. carneae, P. alfierii* and *C. undicempunctata* by an average of 28.0, 25.4 and 25.2%. On the other hand, imidacloprid treatment reduced the population of *C. carneae* by an average of 25.9% while its efficacy increased on *C. undicempunctata*, *P. alfeirii* and *Orius* sp. where the reduction percentage reached 28.8, 31.7 and 41.1%, respectively. The same trend was noticed when these insects were subjected to thiamethoxam where it reduced their population by an average of 29.9, 32.6, 34.7 and 40.9%, respectively (Table 9). When predatory insect species were treated with the aforementioned neonicotinoid compounds, respectively (Table 9). It was also noticed that there are no significant differences between the response of both predatory insects *C. undicempunctata* and *P. alfereii* treated with acetamiprid and imidacloprid while they significantly differed with *C. carneae* and *Orius sp.* Moreover, the toxic effect of thiamethoxam was obviously higher than other compounds even the insect species under experimental conditions.

Concerning the response of the tested predatory insects living on tomato plants in autumn plantation, data in Table 10 showed an overall significant toxic side effects of tested neonicotinoid

Table 9: The effect of three neonicotinoid insecticides on reduction percentage in four predatory insect populations of cucumber plants (No. individuals/100 plants) in autumn plantation

	Rate of			No. of alive insect individuals and reduction% after indicated days						
	application	Predatory	Before							Mean total
Insecticide	(a.i)	insect	treatment	1st spray (X)	Av. Red (%)	2nd spray (X)	Av. Red (%)	3rd spray (X)	Av. Red (%)	reduction
Acetamiprid	10 mL	*Chrysopella*	109	92.7^{a}	24.8	94.0^{a}	24.6	93.3^{a}	28.5	28.0
		Coccinella	289	230.0^{c}	24.1	229.7^{c}	26.6	233.0^{c}	25.0	25.2
		Orius	201	160.0^{b}	27.5	157.3^{b}	31.1	159.6^{b}	28.5	29.0
		Paederus	295	225.6^{c}	25.6	226.6^{c}	25.7	228.7^{c}	25.0	25.4
LSD (p>0.05)			---	6.56	---	11.09	---	11.53	---	---
Imidacloprid	10 g	*Chrysopella*	76	64.0^{a}	25.5	66.0^{a}	24.1	66.0^{a}	28.1	25.9
		Coccinella	215	165.3^{c}	28.9	165.6^{c}	28.0	163.3^{c}	29.5	28.8
		Orius	189	125.3^{b}	39.7	123.7^{b}	42.4	125.7^{b}	41.1	41.1
		Paederus	246	177.0^{c}	30.1	173.3^{c}	32.0	170.7^{c}	32.9	31.7
LSD (p>0.05)			---	16.56	---	21.18	---	19.23	---	---
Thiamithoxan	10g	*Chrysopella*	79	65.0^{a}	27.2	67.0^{a}	29.5	109.0^{a}	32.9	29.9
		Coccinella	326	239.3^{d}	33.5	239.0^{d}	32.2	238.0^{b}	32.1	32.6
		Orius	232	150.7^{b}	40.9	152.0^{b}	42.4	185.0^{ab}	39.4	40.9
		Paederus	267	181.0^{c}	34.1	181.7^{c}	34.2	167.3^{ab}	35.7	34.7
LSD (p>0.05)			---	5.70	---	13.29	---	83.68	---	---
Control	---	*Chrysopella*	87	---	---	---	---	---	---	---
		Coccinella	319	---	---	---	---	---	---	---
		Orius	211	---	---	---	---	---	---	---
		Paederus	280	---	---	---	---	---	---	---

Active ingredient (a.i) 100 L^{-1} water, X: Average mean of alive insect individuals 3, 7 and 14 days after spray. Data were subjected to the Micro-Computer Program COSTAT, one way anova using student-newman keuls test, where means within each column having the same letter aren't significantly different (p>0.05)

Table 10: The effect of three neonicotinoid insecticides on reduction percentage in four predatory insect populations living on tomato plants (No. individuals/100 plants) in autumn plantation

	Rate of			No. of alive insect individuals and reduction% after indicated days						
	application	Predatory	Before							Mean total
Insecticide	(a.i)	insect	treatment	1st spray (X)	Av. Red (%)	2nd spray (X)	Av. Red (%)	3rd spray (X)	Av. Red (%)	reduction
Acetamiprid	10 mL	*Chrysopella*	88.0	83.3^{a}	19.7	78.3^{a}	21.3	51.3^{a}	19.6	20.2
		Coccinella	220.0	174.0^{d}	23.6	178.0^{d}	23.9	162.0^{d}	22.9	23.5
		Orius	189.0	139.3^{b}	32.7	142.3^{b}	32.1	139.3^{c}	32.0	32.3
		Paederus	195.0	146.3^{c}	29.3	155.0^{c}	27.2	97.3^{b}	28.7	28.4
LSD (p>0.05)		---	5.80	---	9.40	---	6.52	---	---	
Imidacloprid	10 g	*Chrysopella*	56.0	48.6^{a}	22.3	48.7^{a}	23.2	50.3^{a}	21.8	22.4
		Coccinella	207.0	164.7^{c}	24.4	164.6^{c}	25.1	165.3^{c}	23.2	24.2
		Orius	201.0	144.6^{b}	36.8	144.6^{b}	36.5	143.7^{b}	35.1	36.1
		Paederus	188.0	144.2^{b}	30.1	144.0^{b}	29.9	144.0^{b}	29.3	29.8
LSD (p>0.05)		---	8.04	---	8.04	---	10.48	---	---	
Thiamithoxan	10 g	*Chrysopella*	65.0	57.3^{a}	25.2	55.0^{a}	25.2	56.7^{a}	24.2	24.9
		Coccinella	242.0	174.7^{d}	30.2	180.0^{d}	30.0	175.3^{d}	30.4	30.2
		Orius	175.0	117.0^{b}	39.0	125.3^{b}	36.8	116.6^{b}	39.5	38.4
		Paederus	205.0	147.6^{c}	32.2	154.6^{c}	30.9	146.7^{c}	33.8	32.3
LSD (p>0.05)		---	---	7.87	---	7.97	---	11.46	---	---
Control	---	*Chrysopella*	69.0	---	---	---	---	---	---	---
		Coccinella	230.0	---	---	---	---	---	---	---
		Orius	180.0	---	---	---	---	---	---	---
		Paederus	210.0	---	---	---	---	---	---	---

Active ingredient (a.i) 100 L^{-1} water, X: Average mean of alive insect individuals 3, 7 and 14 days after spray Data were subjected to the Micro-Computer Program COSTAT, one way anova using student-newman keuls test, where means within each column having the same letter aren't significantly different (p>0.05) compounds on the non target predatory insect species. thiamethoxam showed a slightly higher toxic effect where it reduced the populations of *C. carnea, C. undicempunctata, Orius sp.* and *P. alferii* by an average of 24.9, 30.2, 38.4 and 32.3%. These values averaged 20.2, 23.5, 32.3 and 28.4% and they were 22.4, 24.2, 36.1 and 29.8% when the insects were exposed to acetamiprid and imidacloprid, respectively (Table 10). Moreover, *Orius sp.* was also the most susceptible insect to all tested compounds and followed by *P. alfierii* and *C. undicempunctata* while *C. carnea* came latest.

DISCUSSION

The effect of neonicotinoid insecticides on whitefly *B. tabaci*: The tested insecticides showed a variable adverse effect on whitefly *B. tabaci* and this may be due to the great variability in neonicotinoids characteristics influencing the movement in plant tissues such as water solubility which greatly affecting their toxicity especially on piercing sucking pest insects such as whitefly (Cloyd and Bethke, 2011). On the other hand, the tested neonicotinoid insecticides variably reduced whitefly populations living on either early summer or autumn cucumber plantation. It was also noticed that the reduction percentages in insect pest population were higher in early summer plantation than autumn and that may be due to the high temperature available in autumn plantation which extending from August to September. In other word, this period of the year has an intense sunlight and high ambient temperature reducing the toxicity of the tested compounds. These results agree with those of Zheng and Liu (1999) who stated that hydrolysis of neonicotinoid insecticides increases with increasing temperature. Contradicted results were obtained by Nauen *et al.* (1998) who noticed that imidacloprid decomposes in high temperature giving three metabolites the imidazolidine derivative, the olefin metabolite and the nitroso-derivative that were more toxic to aphids than the parent compound. The present results also clearly indicated that thiomethoxam was more toxic against whitefly than other tested compounds and that may be due to its conversion to another neonicotinoid insecticide, clothianidin which known by its long persistence and high level of toxicity on insect pests (Nauen *et al.*, 2003). Moreover, the same trend of toxicity was observed when immature stages of *B. tabaci* were treated with the same neonicotinoid insecticides. However, adult insects were more susceptible than immature stages treated with the same rates of insecticides. This may be due to soft cuticle and legible body parts as well as the bigger quantity of pesticide consumed and ingested by adults. These findings agree with those of Bethke and Redak (1997) and Van Iersel *et al.* (2000) who found that imidacloprid was more efficient on adults of silverleaf whitefly *B. argentifolii* Bellows and Perring than immature stages. In other words, imidacloprid had a median toxic action which was represented by percentage reduction in insect populations and that may be due to a level of resistance by the insects because it has been used for almost two decades.

The effect of neonicotinoid insecticides on natural enemies: The present results showed that predatory insects may be negatively affected by neonicotinoid systemic insecticides under the following circumstances, (1) when insects feed on pollen, nectar or plant tissues which contaminated with the active ingredient, (2) when they consume the active ingredient while ingesting plant sap, (3) when they feed on preys that contaminated with the active ingredient in plant sap. These findings agree with those of (Tillman and Mullinix, 2004) who showed that there is a rate of side effect of neonicotinoide insecticides applied against whitefly on non-target predatory insects. In general, *Orius sp.* proved to be the most predatory insect affected by spray with the three tested insecticides and followed by *P. alfierii, C. undicempunctata* and *C. carneae*. The present results showed that thiamethoxam was the most effective insecticides on the non-target predatory insects and followed by imidacloprid while acetamiprid was the weakest one. Similarly, studies of Iwasa *et al.* (2004) showed that nitro-substituted neonicotinoid insecticides (thiamethoxam and imidacloprid) were the most toxic to the insects than the cyano-substituted neonicotinoid (acetamiprid) which exhibited a much lower toxicity. However, the extent of neonicotinoid insecticides toxicity on natural enemies is governed by intrinsic factors such as insect movement and its speed as well as feeding habits and feeding preference (Elbert *et al.*, 1998; Rogers *et al.*, 2007). Moreover, extrinsic factors such as insecticide application method, length of exposure and properties of the product especially water solubility which governed the translocation of neonicotinoids into floral parts may also affect their toxic action. These factors could result in selective toxicity of the tested neonicotinoid insecticides to target insect pests than natural enemies. The impact of the three investigated neonicotinoids on the natural enemies associated with the target pest living on tomato and cucumber plants growing under local conditions in Qassim region, Saudi Arabia can be ranked as, harmless (<25% mortality) to slightly harmful (25-50% mortality). Therefore, such insecticides are recommended to be used against whitefly because of their low toxicity on beneficial organisms (Gohole *et al.*, 2003). Moreover, the use of natural enemies in conjunction with neonicotinoid insecticides in interiorscape environments may be too complex based on many factors which contribute to their relative toxicity to the target pests and their natural enemies.

CONCLUSION

Application of thiamethoxam and imidacloprid at three successive treatments resulted in superior whitefly control in both cucumber and tomato plantations while acetampirid occupied the last rank. It is recommended to use suitable rotation partners for neonicotinoid insecticides with different mode of action in order to avoid or delay the development of insecticide resistance among whitefly populations. Moreover, further studies with regard to the effect of neonicotinoides on different biological aspects of bio-agent organisms such as searching capacity, survival rate, food preference, reproductive potentiality and feeding capacity are highly recommended to be able to know how minimize their side effects on the biological control agents under local conditions.

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