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JOURNAL OF PLANT PROTECTION RESEARCH Vol. 53, No. 4 (2013)

DOI: 10.2478/jppr-2013-0056

FIELD EVALUATION OF IMIDACLOPRID AND THIAMETHOXAM AGAINST SUCKING INSECTS AND THEIR SIDE EFFECTS ON SOIL FAUNA

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Received: April 18, 2013
Accepted: October 14, 2013

Abstract: This work was carried out at Sakha Agriculture Research Station, Kafr El-Sheikh, Egypt during the 2010 and 2011 cotton growing seasons to evaluate the effectiveness of imidacloprid and thiamethoxam, used separately as seed treatments and foliar applications at the recommended rate against the sucking insects: thrips, *thrips tabaci* (lind), jassid, *Empoasca* spp., whitefly, *Bemicia tabaci*, and cotton aphid, *Aphis gossypii* (Glover.). The side effects of both insecticides on soil fauna was investigated as well. The experimental results showed the following trends: Seed treatment with imidacloprid and thiamethoxam protected cotton seedlings from thrips for at least 6 weeks from the onset of seed planting. Also, both insecticides induced a fast initial effect (after one week of treatment) on whitefly (immature stages). This fast initial effect then gradually decreased to reach a moderate effect according to the general mean of percent reduction. The two tested insecticides exhibited a moderate initial reduction in the population of whitefly (mature stages) and jassids during the two seasons and then this gradually decreased. Imidacloprid had a better efficiency against this sap sucking pest than thiamethoxam. Treatments with imidacloprid and thiamethoxam as foliar applications were highly effective against aphids, up to 14 days in the case of jassids, while the effect was moderate on the whitefly population (mature and immature stages). Imidacloprid had more initial and residual effect than thiamethoxam against jassids. For all soil arthropod groups implicated in this investigation, the used pesticide and depth, significantly affected their mean numbers. The least number of soil arthropods was sampled from the 10–20 cm layer treated with pesticides compared with the 0–10 cm layer. The control plot at both depths recorded the highest number of soil arthropods sampled. Collembola was most abundant while Psocoptera, Oribatida, Actinedida, and Gamasida were least abundant. Pesticide application increased the overall Collembola density compared to the control plots, while it decreased overall Psocoptera, Oribatida, Actinedida, and Gamasida density compared to the control plots. In case of the foliar treatment, there was a reduction in the mean number of examined micro-arthropods either under plants or between plants, in both depths. The reduction in the number of soil arthropods was significantly more in the 0–10 layer. The reduction was more significant between plants than under plants. The most influenced micro-arthropod was Oribatida. The results also revealed that imidacloprid had more adverse effects on soil fauna than thiamethoxam.

Key words: cotton, neonicotinoid insecticides, soil fauna, sucking insects

INTRODUCTION

Cotton is considered the most important crop in Egypt. Cotton plants are liable to be attacked by several pests throughout their life spans *i.e.* early in the season, during seedling stage, mid-season, and in the late season during the fruiting stage. In recent years, thrips, aphids, whiteflies, and jassids have become deleterious pests in cotton planted fields. They suck the sap of plant tissues and green leaves in the early season, making it sometimes necessary to re-sow (Salama *et al*. 2006). Therefore, the use of systemic insecticides as seed dressing is considered one of the most effective components in the Integrated Pest Management Programs in different crops.

Neonicotinoid insecticides represent the fastest growing class of insecticides introduced to the market since the launch of pyrethroids (Nauen and Bretschneider 2002). The current market share of this class is well above 600 million Euro per year, including imidacloprid as the biggest selling insecticide worldwide (Jemec *et al*. 2007). Another neonicotinoid commercialized since the introduction of imidacloprid, is thiamethoxam (Tomizawa and Casida 2003). Neonicotinoid insecticides are compounds acting agonistically on insect nicotinic acetylcholine receptors (nAChR). They are especially active on hemipteran pest species such as aphids, whiteflies, and plant hoppers, but also commercialized to control many coleopteran and some lepidopteran pest species (Nauen *et al*. 2003). The benefits of using systemic insecticides over contact insecticides is that in most cases they provide continuous plant protection through most of the growing

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season without the need for repeated applications. In addition, systemic insecticides are not susceptible to ultraviolet light degradation or ''wash off'' during watering, and the risk of overexposure to applicators is minimized (Herbert *et al*. 2008). The effectiveness of imidacloprid and thiamethoxam applied separately, against sucking insects on cotton was studied by several authors (Zidan *et al*. 2008; El-Seady 2009; El-Zahi and Aref 2011).

It is likely, that insecticides applied to the fields for pest control contaminate the soil. Non-target soil fauna are an important part of the soil environment, but such fauna be harmed by insecticides. Soil fauna are involved in many aspects of organic matter decomposition, partial regulation of microbial activities, nutrient cycles and crumbly structure. Disturbances caused by pollutants in the soil result in both qualitative and quantitative changes in fauna, which affect soil functioning (Cortet *et al*. 1999). Soil microarthropods are often used as bioindicators of agricultural soil quality (Cortet *et al*. 2002). However, very little information is available about the ecotoxicological effects of pesticides on soil fauna. Since pesticides are not 100% specific, they cause lethal and sublethal effects within non-target species (Adamski and Ziemnicki 2004; Adamski *et al*. 2007) and their lethality may show stage-dependence (Charmillot *et al*. 2001). Therefore, our experiments were carried out in a cotton field under real agricultural conditions to assess the effectiveness of these chemicals, used separately, as seed treatments and as foliar applications at the recommended rates against sucking insects. We examined the effects of these chemicals on soil fauna as well.

MATERIALS AND METHODS

Insecticides used

1 – Imidacloprid: (*E*)-1-(6-chloro-3-pyridylmethyl)-*N*-nitroimidazolidin-2-ylideneamine. Two formulations were tested; Gaucho 7% W.S., applied as seed treatment at 7 gm/kg seeds, and Best 25% W.P., applied as foliar treatment at 75 gm/100 l water. They were obtained from Bayer Co.

2 – Thiamethoxam: (*EZ*)-3-(2-chloro-1,3-thiazol-5-ylmethyl)-5-methyl-1,3,5-oxadiazinan-4-ylidene(nitro)amine. Two formulations were tested; Cruiser 70% W.S., applied as seed treatment at 2 gm/kg seeds, and Actara 25% W.G., applied as foliar treatment at 20 gm/100 l water. They were obtained from Syngenta AGCo.

Experimental design

The experiments were carried out at the Farm of the Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt during the 2010 and 2011 cotton growing seasons. The experimental area was divided into equal parts of 175 m^2 each. Seeds of the cotton variety Giza 86 had lint removed and were spread on clean plastic sheets moistened and mixed in thoroughly. This was repeated for each insecticide. The treated seeds were left to dry, then directly planted in the soil. Every treatment as well as the untreated plots, were replicated four times in a completely randomized block design. The area of each replicate was one kirate (175 m^2). The planting was carried out in the third and the last week of April during the 2010 and 2011 seasons, respectively. Six to eight seeds were delivered/hole into the upper 4–6 cm of soil. All normal agricultural practices were followed without any pesticide treatments during the experimental period, which extended to about 7 week after planting. Samples of 25 seedlings were chosen at random from each replicate early in the morning at 2, 3, 4, 5, 6, and 7 weeks after planting. The number of certain sucking pests was counted. The percentage of the reduction of the insect population was calculated according to the following equation:

% R = [(No. of insects in the control – No. of insects in the treatment)/No. of insects in the control] × 100

For foliar treatment, imidacloprid and thiamethoxam were diluted with water (200 l/fed). Each was sprayed using a knapsack sprayer with one nozzle. Spraying took place on July 20, 2010 and July 23, 2011 for the tested compounds in the two seasons, respectively. To evaluate the efficiency of these insecticides, 25 cotton leaves per replicate were chosen randomly from the bottom, middle, and the top of the cotton plants (2 + 1 + 2 leaves per plants, respectively). The upper and lower leaf surfaces were examined carefully and aphid, jassid, and whitefly adult counts were recorded in the field. Whitefly immature counts were done in the laboratory under a binocular microscope. Leaf sampling and insect counting were made just before the spraying and at 2, 5, 8, 11, and 14 days after the spraying. The reduction percent of the population was estimated by using Henderson and Tilton's equation (1955) to determine the initial effect (after 2 days of spraying) and the residual effect of the tested insecticides.

Soil samples

Treatment and sample collection

Soil samples were collected at intervals of 1, 2, 3, 4, and 5 weeks after sowing the insecticide-treated seeds, and 1, 7, and 14 days after the insecticide-foliar application. Samples were drawn from two depths, *i.e.* 10 and 20 cm under and between plants, collected in polyethylene bags, and labeled accordingly (Rajagopal *et al*. 1990). The samples were then moved to the laboratory where the multifaceted extractor (Berlese Tullgren Funnel) was adopted. Extraction methods were designed to suit behaviors and body structures of the organisms (Wallwork 1970). The Berlese Tullgren funnel extractor was best for extracting soil microarthropods. This extractor proved to be about 90% efficient (Hopkin 1997). The soil micro-arthropods were collected and put into containers with 70% alcohol within 48 hours. All experiments were replicated with three independent sets.

Sorting and preservation

After the organisms were extracted and collected, they were immediately sorted under a binocular dissecting microscope. Sorting involved removing individuals from the lot by using a sucking pipette. Individual species were then placed in separate specimen bottles with 70% alcohol for preservation and were later mounted and used for identification.

Preparation of slides

As a result of the small size of the organisms involved, it was necessary to mount them on slides for examination. The method of making permanent slides described by Hopkin (2007) was adopted to mount the organisms in Canada balsam.

Identification of collected soil micro arthropods species

Identification was carried out at the National Research Center, Giza, Egypt. Species were identified under stereo binocular microscope. The number and type of soil micro-arthropods extracted from each treatment were recorded, and the data obtained were analyzed.

Statistical analysis

Data were analyzed by one-way analysis of variance and Duncan's multiple range test (Duncan 1955) using SPSS (version 16.0; SPSS Inc. Chicago, IL, USA).

RESULTS AND DISCUSSION

Efficiency of imidacloprid and thiamethoxam used separately against sap sucking insects on early-stage cotton plants

The insecticidal activity of imidacloprid and thiamethoxam applied as a seed dressing against thrips, jassid, and whitefly on cotton seedlings were evaluated under field conditions. Data presented in table 1 summarize the effect of imidacloprid and thiamethoxam, used separately, in suppressing the thrips, jassid, and whitefly populations on cotton seedlings during the 2010 and 2011 seasons. It is obvious that imidacloprid and thiamethoxam induced a fast initial effect. The reduction in the thrips population was 91.3 and 87.5% for imidacloprid, and 88.06 and 81.5% for thiamethoxam, in the 2010 and 2011 seasons, respectively. The residual effect of these insecticides extended up to 7 weeks after the imidacloprid treatment (% reduction after 7 weeks from the sowing date was 55.5 and 52.0 during the two seasons). The residual effect extended up to 6 weeks after the thiamethoxam treatment (% reduction after 6 weeks from the sowing date was 54.3 and 52.8 during the two seasons), after 7 weeks of treatment the effect then decreased to reach 48.2 and 44% during the two seasons. Concerning the effect of the same compounds on jassid, as shown in table 1, the initial effect was 70 and 73% for imidacloprid in 2010 and 2011, respectively. The effect then decreased gradually to reach 22.7 and 25% reduction, respectively, after 7 weeks. Thiamethoxam showed the same trend of results as imidacloprid but the effect was less than that produced by imidacloprid. Thiamethoxam caused a 60.0 and 66.66% reduction in the 2010 and 2011 seasons, respectively. Thiamethoxam then decreased to record a 18.2 and 16.7% reduction, respectively, after 7 weeks. In the case of whitefly (mature stages), the data is presented in table 1, and shows that the two tested insecticides, used separately, exhibited a moderate initial reduction in population. Imidacloprid caused a 60 and 66.7% initial reduction in population (after one week of treatment) in the 2010 and 2011 seasons, respectively, and decreased gradually to reach 9.7 and 24.0%, respectively, after 7 weeks. Thiamethoxam showed the same trend, where it induced a 55.0 and 53.3% initial reduction on the population (after one week of treatment) in the 2010 and 2011 seasons, respectively, then decreased to record a 6.5 and 16.0% reduction after 7 weeks in the two seasons. Regarding whitefly (immature stages), the data presented in the same table showed that imidacloprid as well as thiamethoxam induced a fast initial effect. The reduction in the population was 87.5 and 83.3% for imidacloprid, and 75.0 and 66.7%, respectively (after one week of treatment), for thiamethoxam in the 2010 and 2011 seasons. The effect decreased gradually to reach a 40 and 45% reduction after 7 weeks for imidacloprid, and a 30 and 36.7% reduction for thiamethoxam in the two seasons, respectively. It is an important to mention that, the efficiency of both individually tested insecticides against the immature stages of whitefly was more than the effect on the mature stages of whitefly. This may be due to the fact that adults usually visit cotton plants early in the morning to feed and then the adults leave the seedlings to hide in the surrounding crops. Thus, the adults are in contact with the treated seedlings for a relatively short time to feed, while the immature stages were found to be in almost continuous contact with the treated seedlings for a long time, and consequently picked up more toxicants (El-Dewy 2006).

It was noticed that imidacloprid had a better efficiency against sap-sucking pests than thiamethoxam because it is highly systemic especially through the root system. Thiamethoxam is absorbed by the tissues and transported via the vascular system, right up to the last leaf. Thus, it is disastrous for pests like aphids and others feeding on the juices of plants, while natural enemies go unharmed (Anonymous 1992).

Our results agreed fully with the previous findings of many investigators who evaluated the efficiency imidacloprid as well as thiamethoxam on early cotton-sucking pests. Aioub *et al*. (2002) mentioned that imidacloprid protected cotton seedlings from sap-sucking insects (whitefly and thrips) for at least 10 weeks from the onset of seed planting, but was not able to protect cotton seedlings from the attack of both jassids and mites. Dhandapani *et al*. (2002) indicated that imidacloprid controlled those sucking pests attacking cotton (thrips and jassid) for up to 8 weeks after sowing. El-Dewy (2006) revealed that imidacloprid as well as thiamethoxam had relatively fast initial effects with long residual action against thrips and immature stages of whitefly, with a moderate effect on jassids and adults stages of whitefly. El-Naggar (2006) reported that imidacloprid as well as thiamethoxam were effective against thrips for 7 weeks after planting. Also, El-Seady (2009) found that imidacloprid was effective against jassids and whiteflies for 6–7 weeks after cultivation.

Efficiency of imidacloprid and thiamethoxam against sap sucking insects on cotton plants during the late season

The insecticidal activity of imidacloprid and thiamethoxam applied separately, as a foliar treatment against sucking insects is shown in tables 2–5. Data presented in table 2 elucidate the effect (reduction percent) of imidacloprid as well as thiamethoxam on aphid popula-

Table 1. Insecticidal activity of imidacloprid and thiamethoxam applied as seed treatments against some sucking pests on cotton plants during the 2010 and 2011 seasons

Season	Interval	Average number of sucking insects/25 cotton seedling and the percentage of the reduction after different periods of sowing																			
		Thrips tabaci					*Empoasca* spp.					*Bemisia tabaci* (mature stage)					*Bemisia tabaci* (immature stage)				
		control	imidacloprid		thiamethoxam		control	imidacloprid		thiamethoxam		control	imidacloprid		thiamethoxam		control	imidacloprid		thiamethoxam	
		M.N.	M.N.	% R	M.N.	% R	M.N.	M.N.	% R	M.N.	% R	M.N.	M.N.	% R	M.N.	% R	M.N.	M.N.	% R	M.N.	% R
2010	2 weeks	92	8	91.3	11	88.1	10	3	70.0	4	60.0	20	8	60.0	9	55.0	8	1	87.5	2	75.0
	3 weeks	205	25	87.8	30	85.4	20	9	55.0	10	50.0	35	20	42.3	22	37.1	10	2	80.0	3	70.0
	4 weeks	358	77	78.5	88	75.4	18	11.0	38.9	12	33.3	30	20	33.3	22	26.7	16	5	68.8	6	62.5
	5 weeks	125	36	71.2	40	68.0	68	45	33.8	47	30.9	40	29	27.5	33	17.3	30	12	60.0	16	46.7
	6 weeks	35	13	62.9	16	54.3	20	15	25.0	16	20.0	60	50	16.7	55	8.3	15	7	53.3	9	40.2
	7 weeks	27	12	55.5	14	48.2	22	17	22.7	18	18.2	35	28	9.7	29	6.5	20	12	40.0	14	30.0
	Average	14.3^{a}	28.5^{b}	74.3 ±12.85	33.0^{b}	69.9 ±1483	26.2^{a}	16.2	40.9 ±1675	17.2^{a}	35.4 ±154	36.66^{a}	25.8^{a}	31.7 ±16.53	28.3^{a}	25.2 ±16.97	16.5^{a}	6.5^{a}	64.9 ±15.97	8.3^{a}	54.02 ±26.96
2011	2 weeks	54	7	87.5	10	81.5	15	4	73.33	5	66.6	15	5	66.7	7	53.3	6	1	83.3	2	66.7
	3 weeks	170	36	78.8	41	75.9	30	12	60.0	14	533	35	13	62.8	17	51.4	20	6	70.0	7	65.0
	4 weeks	108	32	70.4	35	68.5	45	22	51.1	25	44.4	40	20	50.0	25	37.5	18	6	66.3	8	55.5
	5 weeks	45	15	66.7	17	62.2	70	39	44.3	44	37.4	24	14	41.7	17	29.7	30	13	56.7	15	50.0
	6 weeks	36	14	61.1	17	52.8	18	11	38.9	13	27.3	18	11	38.9	21	16.0	40	19	52.3	23	42.5
	7 weeks	25	12	52.0	14	44.0	24	18	25.0	20	16.7	25	19	24.0	21	16.0	60	33	45.0	38	36.7
	Average	73.0^{a}	19.5^{b}	69.3 ±11.39	22.5^{b}	64.2 ±12.89	33.66^{a}	17.33^{b}	48.77 ±15.37	19.3^{ab}	42.8 ±16.39	26.2^{a}	13.7^{b}	47.4 ±14.54	16.8^{a}	35.02 ±13.92	29.0^{a}	17.0^{ab}	62.4 ±12.59	15.5^{b}	52.7 ±10.99

M.N. – mean number
% R (percent of reduction) = [(M.N. in the control – M.N. in the treatment)/ M.N. in the control] × 100
For every insect, values across each row having the same superscript letter (s) were not significantly different ($p > 0.05$)

Table 2. Effect of imidacloprid and thiamethoxam applied as foliar treatment against the cotton aphid, *Aphis gossypii* during the 2010 and 2011 cotton seasons

Insecticides	Rate per fed* [gm/100 ml]	Season	No. of aphid/100 cotton leaves after spraying at indicated days						% initial kill 2 days after spraying	% residual effect at indicated days after spraying				Mean of reduction % ± SD	Mean of residual effect [%]
			before spraying	2	5	8	11	14		5	8	11	14		
Imidacloprid	75	2010	615	100	80	100	135	14	89.60	93.34	92.95	91.80	92.18	92.57±1.29	91.97
Thiamethoxam	20	2010	590	150	135	95	145	175	83.74	88.39	93.20	90.80	94.88	91.82±3.91	90.20
Control	–	2010	700	1,095	1,368	1,615	1,870	110	–	–	–	–	–	–	–
Imidacloprid	75	2011	800	95	55	78	120	2,548	93.31	96.6	96.47	95.48	92.17	95.18±1.77	94.82
Thiamethoxam	20	2011	620	165	120	100	125	185	85.02	90.34	94.16	93.92	94.65	93.29±3.63	91.64
Control	–	2011	850	1,510	1,720	2,350	2,820	98	–	–	–	–	–	–	–

*Feddan = 4,200 m^2

Table 3. Effect of imidacloprid and thiamethoxam applied as foliar treatment against mature stages of whitefly, *B. tabaci* during the 2010 and 2011 cotton seasons

Insecticides	Rate per fed* [gm/100 ml]	Season	No. of whitefly/100 cotton leaves after spraying at indicated days						% initial kill 2 days after spraying	% residual effect at indicated days after spraying				Mean of reduction % ± SD	Mean of residual effect [%]
			before spraying	2	5	8	11	14		5	8	11	14		
Imidacloprid	75	2010	320	120	105	100	70	60	70.94	72.88	76.93	78.5	79.96	77.07±3.09	75.84
Thiamethoxam	20	2010	280	150	120	127	80	84	58.48	64.57	66.52	71.88	67.93	67.73±3.49	65.87
Control	–	2010	310	400	375	315	280	290	–	–	–	–	–	–	–
Imidacloprid	75	2011	560	200	255	205	150	80	72.70	77.96	80.38	83.15	84.13	81.4±4.09	79.66
Thiamethoxam	20	2011	515	230	330	270	210	140	65.83	68.99	71.91	72.51	69.79	70.8±2.38	69.81
Control	–	2011	600	785	1,240	1,120	890	540	–	–	–	–	–	–	–

*Feddan = 4,200 m^2

Table 4. Effect of imidacloprid and thiamethoxam applied as foliar treatment against the immature stages of whitefly, *B. tabaci* during the 2010 and 2011 cotton seasons

Insecticides	Rate per fed* [gm/100 ml]	Season	No. of whitefly/100 cotton leaves after spraying at indicated days						% initial kill 2 days after spraying	% residual effect at indicated days after spraying				Mean of reduction % ± SD	Mean of residual effect [%]
			before spraying	2	5	8	11	14		5	8	11	14		
Imidacloprid	75		530	220	170	150	120	110	67.79	71.69	72.31	73.87	76.32	73.55±2.8	72.40
Thiamethoxam	20	2010	475	280	230	190	140	110	54.26	57.27	60.87	65.99	67.43	62.80±5.01	61.16
Control	–		450	580	510	460	390	320	–	–	–	–	–	–	–
Imidacloprid	75		370	120	80	60	45	35	71.23	72.97	74.52	77.70	80.73	76.48±3.39	75.43
Thiamethoxam	20	2011	420	210	135	95	70	55	55.65	59.82	64.46	69.44	73.32	66.78±6.36	64.54
Control	–		550	620	440	350	300	270	–	–	–	–	–	–	–

*Feddan = 4,200 m²

Table 5. Effect of imidacloprid and thiamethoxam applied as foliar treatment against the jassid, *Empoasca* spp. during the 2010 and 2011 cotton seasons

Insecticides	Rate per fed* [gm/100 ml]	Season	No. of jassid/100 cotton leaves after spraying at indicated days						% initial kill 2 days after spraying	% residual effect at indicated days after spraying				Mean of reduction % ± SD	Mean of residual effect [%]
			before spraying	2	5	8	11	14		5	8	11	14		
Imidacloprid	75		69	4	10	6	4	5	94.68	87.71	92.29	93.54	90.42	90.99±12.41	91.73
Thiamethoxam	20	2010	85	13	21	25	28	31	85.96	79.50	73.93	63.29	51.78	67.13±4.76	70.89
Control	–		78	85	92	88	70	59	–	–	–	–	–	–	–
Imidacloprid	75		115	10	14	17	8	3	93.21	86.77	81.52	89.39	94.90	88.15±4.796	89.10
Thiamethoxam	20	2011	110	22	25	26	29	30	84.37	75.29	70.45	59.81	46.73	63.07±12.9	67.33
Control	–		125	160	115	100	82	64	–	–	–	–	–	–	–

*Feddan = 4,200 m²

tions at 2 days (the initial kill), and 5, 8, 11, and 14 days after spraying, and the mean of the reduction percent during the 2010 and 2011 cotton seasons. It is obvious that imidacloprid was more effective causing an 89.6 and 93.3% initial kill and a 91.97 and 94.82% reduction as the general mean of the effect in 2010 and 2011, respectively, while thiamethoxam recorded an 83.74 and 85.02% initial kill and a 90.2 and 91.64% reduction as the general mean of the effect in the 2010 and 2011 seasons. In the case of whitefly (mature stages), data presented in table 3 revealed that imidacloprid as well as thiamethoxam had a moderate effect. Imidacloprid gave a 70.94 and 72.7% initial kill, and a 75.84 and 79.66% reduction as the general mean of effect in the 2010 and 2011 seasons, respectively, while thiamethoxam caused a 58.48 and 65.83% initial kill, and a 65.87 and 69.81% reduction as the general mean of the effect in the two seasons. As for whitefly (immature stages) data in table 4 indicated the same trend of efficacy. Imidacloprid induced a 67.79 and 71.23% initial kill and a 72.4 and 75.43% reduction as the general mean of the effect in the 2010 and 2011 seasons respectively. Thiamethoxam caused a 54.26 and 55.65% initial kill and a 61.16 and 64.54% reduction as the general mean of the effect in the two seasons.

With regard to the jassid, data presented in table 5 showed that imidacloprid had better efficiency against jassids than thiamethoxam, whereas imidacloprid caused a 94.68 and 93.21% initial kill and a 91.73 and 89.10% reduction as the general mean effect, in the 2010 and 2011 season, respectively. Thiamethoxam gave an 85.96 and 84.37% initial kill and a 70.89 and 67.33% reduction as the general mean of the effect, in the two seasons. The obtained results are in agreement with those of several investigators. Misra (2002) found that imidacloprid as well as thiamethoxam proved significantly superior in controlling aphids and jassids. Sharaf *et al*. (2003) reported that confidor and Best also induced the highest initial activity on immature stages of whitefly. Confidor and Best induced the highest initial and residual activity on mature stages. Razaq *et al*. (2003) illustrated that thiamethoxam as well as imidacloprid were effective against jassids (*Amrasca biguttula* Ishida) at 72, 168, and 240 h after spraying. Khattak *et al*. (2004) found that thiamethoxam (Actara) as well as imidacloprid (confidor) reduced the mean percent population of whiteflies even 240 h after spraying. Aslam *et al*. (2004) mentioned that confidor (imidacloprid) was the most effective on jassids, and was effective up to 7 days on thrips. Asi *et al*. (2008) found that imidacloprid was effective against whiteflies and jassids up to 168 h after spraying. Dhawan *et al*. (2008) mentioned that thiamethoxam was the most effective against cotton aphids under screen house conditions. Also, El-Zahi and Aref (2011) found that thiamethoxam and imidacloprid were the most effective against cotton aphids under field conditions. In contrast to our findings, Zidan *et al.* (2008) found that thiamethoxam was effective against whitefly (adults) for 15 days after treatment. El-Zahi (2005) reported that imidacloprid proved to be the most effective against aphids causing a 98.17% reduction as the general mean of the effect. El-Dewy (2006) mentioned that imidacloprid (confidor) proved to be a superior compound against aphids, jassids, and whitefly (adult).

Impact of imidacloprid as well as thiamethoxam on soil fauna

The mean number of the soil micro-arthropod group sampled in case of seed treatment is presented in table 6. The soil micro-arthropod groups showed varying mean values within the 5-week period of investigation. For all soil arthropod groups implicated in this investigation, the pesticide used and the depth, significantly affected the mean numbers of these soil arthropods. The least number of soil arthropods was sampled from the 10–20 cm layer treated with pesticides, compared with the 0–10 cm layer while the control plot at both depths recorded the highest number of soil arthropods sampled. Collembola was most abundant while Psocoptera, Oribatida, Actinedida, and Gamasida were least in abundance, as shown in table 6. Pesticide application increased overall Collembola density, compared to the control plots, while it decreased overall Psocoptera, Oribatida, Actinedida, and Gamasida density, compared to the control plots. In the case of the foliar treatment, there was a reduction in the mean numbers of the examined micro arthropods either under plants or between plants at both depths (Table 7). The reduction in the number of soil arthropods was significantly more in the 0–10 layer. The reduction was more significant between plants than under plants. The most influenced micro-arthropod was Oribatida. The results also revealed that imidacloprid had more adverse effects on soil fauna than thiamethoxam.

One possible reason for the initial decrease in the number of soil arthropods as observed in the plots treated with pesticide, was the toxic effects of imidacloprid as well as thiamethoxam that were applied to the affected plots. When a pesticide is added to agricultural land, changes in the structure of the microbial community tend to precede changes in the composition of the plant or invertebrate community. The acarina group that feed directly on soil fungi and bacteria may, therefore, be more susceptible to pollution than predatory or phytophagous groups which are further removed from the effects of the pollutant (Cole *et al*. 2001). As Collembola live in close association with the soil micro-flora and fauna, it is likely that they will give an earlier indication of ecosystem disturbance than predatory groups. Furthermore, Collembola are better suited than larger more mobile invertebrates (*e.g*. Coleoptera) in small plot agricultural field trials (Cole *et al*. 2001). Badejo and Akintola (2006) have emphasized that most soil fauna, especially the orbited mites, enjoy the better conducive micro-environment within the top 5 cm of soil.

Collembola form an important component of terrestrial soil food webs and reach densities of tens of thousands of individuals per square meter (Coleman *et al*. 2004). They drive nutrient cycling and availability for plants by feeding on soil bacteria and fungi (Filser 2002; Partsch *et al*. 2006). Thereby, they affect a multitude of ecosystem characteristics including microbial biomass and functioning, litter decomposition, plant productivity, competition, community composition, and also plant herbivore infestation above the ground (Cole *et al*. 2006; Partsch *et al*. 2006; Schütz *et al*. 2008). However, up till now, the impacts of Collembola have only been documented in laboratory studies, whereas experiments in the field are lacking.

Table 6. Effect of imidacloprid and thiamethoxam applied as seed treatment on some beneficial soil fauna

Taxonomic group	Mean number of individuals/100 gm soil at different intervals post application, and soil depths											
	1st Week											
	under plants						between plants					
	control		thiamethoxam		imidacloprid		control		thiamethoxam		imidacloprid	
	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
Collembola	0.67	0.67	7.33	2.33	1.00	0.67	2.33	1.33	10.67	4.67	6.00	3.33
Psocoptera	0.33	0.0	0.33	0.0	0.33	0.0	0.33	0.0	0.33	0.0	0.33	0.0
Oribatida	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Actinedida	1.33	0.67	0.67	0.33	1.00	0.66	3.00	1.00	1.33	0.66	1.00	0.33
Gamasida	1.67	0.67	0.67	0.66	0.33	0.67	2.00	1.00	1.67	0.33	1.00	0.67
Total	4.00	2.01	9.00	3.32	2.66	2.00	7.66	3.33	14.00	5.66	8.33	4.33
% of the control	100.00	100.00	225.00	165.00	66.50	99.50	100.00	100.00	182.80	170.00	108.70	130.00
	2nd Week											
Taxonomic group	under plants						between plants					
	control		thiamethoxam		imidacloprid		control		thiamethoxam		imidacloprid	
	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
Collembola	6.00	1.67	20.33	10.33	13.00	10.33	8.67	2.67	15.67	7.67	15.67	4.67
Psocoptera	2.00	0.67	0.0	0.0	0.67	0.0	0.33	0.0	0.0	0.0	0.0	0.0
Oribatida	6.00	3.33	3.00	1.00	9.00	3.67	4.33	1.00	2.67	1.00	3.00	0.67
Actinedida	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gamasida	9.00	3.33	3.33	1.33	4.33	2.33	1.67	0.33	0.33	0.0	1.00	0.0
Total	23.00	9.00	26.66	12.66	27.00	16.33	15.00	4.00	18.67	8.67	19.67	5.34
% of the control	100.00	100.00	115.90	140.70	117.40	181.40	100.00	100.00	124.50	216.80	131.10	133.50
	3rd Week											
Taxonomic group	under plants						between plants					
	control		thiamethoxam		imidacloprid		control		thiamethoxam		imidacloprid	
	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
Collembola	19.67	12.00	27.00	14.00	22.33	13.33	9.67	5.67	14.33	6.67	11.00	6.67
Psocoptera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oribatida	7.67	3.33	4.00	1.33	1.67	1.33	3.67	1.67	3.33	0.67	2.33	1.67
Actinedida	9.67	1.33	6.67	1.67	1.67	1.00	9.00	3.67	6.00	1.33	7.33	2.33
Gamasida	4.33	2.00	1.00	1.33	2.67	2.33	1.00	0.0	0.33	0.0	0.67	0.0
Total	41.34	18.66	38.67	18.33	28.24	17.99	23.24	11.01	23.99	8.67	21.33	10.67
% of the control	100.00	100.00	93.50	98.80	68.30	96.40	100.00	100.00	103.20	78.70	91.80	96.90

Taxonomic group	under plants						between plants					
	control		thiamethoxam		imidacloprid		control		thiamethoxam		imidacloprid	
	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
	4th Week											
Collembola	4.33	4.67	13.33	6.33	9.33	4.67	5.00	4.33	17.67	6.33	14.33	4.67
Psocoptera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oribatida	7.33	3.00	1.67	1.33	6.0	2.33	2.33	1.33	2.67	1.00	2.00	1.33
Actinedida	8.33	4.00	4.00	2.33	7.33	3.33	3.33	1.33	2.33	1.33	2.67	1.00
Gamasida	4.67	0.0	2.33	0.0	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	10.66	6.99	22.67	8.66	19.00	7.00	24.66	11.67	21.33	9.99	25.99	10.33
% of the control	100.00	100.00	212.70	123.90	178.20	100.10	100.00	100.00	86.50	85.60	105.30	88.50
	5th Week											
Taxonomic group	under plants						between plants					
	control		thiamethoxam		imidacloprid		control		thiamethoxam		imidacloprid	
	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
Collembola	11.00	2.00	13.00	4.33	9.33	3.00	3.33	1.33	9.33	1.67	6.33	1.33
Psocoptera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oribatida	3.33	2.67	2.33	2.33	3.00	2.67	1.67	0.0	1.33	0.0	1.67	0.0
Actinedida	4.67	1.33	3.33	0.67	3.33	1.67	3.00	1.67	2.00	1.33	1.67	1.67
Gamasida	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	19.00	6.00	18.66	7.33	15.66	7.34	8.00	3.00	12.66	3.00	9.67	3.00
% of the control	100.00	100.00	98.80	122.10	82.40	122.80	100.00	100.00	158.30	100.00	120.80	100.00

Table 7. Effect of imidacloprid and thiamethoxam applied as foliar treatments on some beneficial soil fauna

Taxonomic group	Mean number of individuals/100 gm soil at different intervals post application, and soil depths											
	1 day											
	under plants						between plants					
	control		thiamethoxam		imidacloprid		control		thiamethoxam		imidacloprid	
	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
Psocoptera	1.67	1.67	1.33	1.00	1.00	1.00	2.33	2.00	1.00	1.00	0.67	1.33
Oribatida	11.33	1.67	1.67	1.00	0.33	0.0	6.00	3.67	0.33	0.0	0.0	0.0
Actinedida	8.00	3.00	6.33	2.33	7.00	3.33	8.67	7.67	2.67	2.33	3.33	2.33
Total	21.00	6.34	9.33	4.33	8.33	4.33	17.00	13.34	4.00	3.33	4.00	3.66
% of the control	100.00	100.00	44.40	68.30	39.70	68.30	100.00	100.00	23.50	25.00	23.50	27.40
	1st Week											
	under plants						between plants					
Taxonomic group	control		thiamethoxam		imidacloprid		control		thiamethoxam		imidacloprid	
	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
Psocoptera	3.00	1.33	1.00	0.33	1.0	0.67	4.67	3.67	1.00	0.33	1.67	1.00
Oribatida	3.00	2.00	0.67	1.00	0.67	0.33	2.67	1.00	0.33	0.0	0.33	0.0
Actinedida	1.00	0.33	1.00	0.0	0.33	0.0	2.00	1.00	1.67	0.67	0.0	0.0
Total	7.00	3.66	2.67	1.33	2.00	1.00	9.34	5.67	3.00	1.00	2.00	1.00
% of the control	100.00	100.00	38.10	36.30	28.9	27.30	100.00	100.00	32.10	17.60	21.40	17.60
	2nd Week											
	under plants						between plants					
Taxonomic group	control		thiamethoxam		imidacloprid		control		thiamethoxam		imidacloprid	
	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
Psocoptera	2.33	1.33	2.33	1.33	1.67	1.67	3.67	2.33	1.67	1.67	1.67	1.67
Oribatida	2.67	1.67	1.33	1.00	2.33	1.00	3.33	1.00	3.67	0.33	2.67	0.33
Actinedida	4.67	1.67	4.00	1.67	3.33	1.00	5.00	3.00	2.33	1.00	2.67	0.33
Total	9.67	4.67	7.66	4.00	7.33	3.67	12.00	6.33	7.67	3.00	7.01	2.33
% of the control	100.00	100.00	79.20	85.70	75.80	78.60	100.00	100.00	63.90	47.40	58.40	36.80

The Collembolan group exhibited the greatest tendency of recolonisation in the treated areas while Acarina was least, as shown in table 6. This may have been facilitated by two factors. It might be that either the pesticide affected the parasites or predators that parasitise or prey on these groups of soil fauna, or the toxicity of the pesticide was reduced considerably, thus leading to an initial rapid increase in their numbers as shown in table 6. The effect of pesticides on the soil mesofauna is complex because of the action of the pesticides on both predacious and non-predacious groups. The increase in the populations of Collembolan and mites after the use of pesticides, is mainly because of the mortality of predacious mites (Veeresh and Rajagopal 1989). The toxicity of the pesticide could lead to the death of the soil arthropod either by asphyxiation or through systemic poisoning when arthropods consume the toxicant along with their food. The reduction in the mean arthropod number could also result when the applied pesticide creates harsh environmental conditions that could make the soil micro-arthropod embark on downward or horizontal migrations in order to escape from the hazards caused by the application.

For various species, which contribute to the circulation of matter, the soil is the actual habitat, where they meet their needs. Soil mesofauna is represented (among others) by mites (Acari), springtails (Collembola), and small insects (mainly larvae of Diptera and Coleoptera), which play very important roles in the process of litter decomposition and humus formation. A decline in their abundance extends this process in time. As a consequence, the circulation of matter is impaired. A long-term decline in the biological activity of the soil leads to a decrease in soil fertility and increases the threat of soil erosion (Addison *et al*. 2003). Although the majority of applied pesticides settle down on the plant canopy, some of the sprayed chemicals reach the soil and affect the animals and organisms inhabiting it. Since pesticides are not 100% specific, they cause lethal and sub-lethal effects within non-target species (Adamski and Ziemnicki 2004; Adamski *et al*. 2007).

The detrimental effects of insecticide application on soil fauna most likely were due to contact poisoning. By contrast, reduced predator densities in insecticide subplots were likely due to both direct poisoning and indirect effects from a decreased availability of prey, particularly Collembola which are known to be an essential component of soil food webs (Coleman *et al*. 2004; Oelbermann *et al*. 2008).

The present outcomes agree with the results of Rajagopal *et al*. (1990) who reported that insecticides such as chloropyrifos, carbosulfan, phorate, and isofenphos showed a significant effect on non-target soil fauna, which included mainly mites and Collembolans. The present results are also supported by Kip *et al*. (2002), who reported that pesticide-free cornfields had significantly higher soil invertebrate densities than the soil invertebrate densities in the treated cornfields. Entering the pesticides into the ecosystem may imbalance the ecological equilibrium. These deleterious effects greatly modify some biological functions, such as soil organic matter decomposition and nutrient availability in the soil, by reduction of the diversity of soil biota (Ferraro and Pimentel 2000).

Our results are in agreement with those obtained by Frouz (1999), who observed that pesticide applications affect the environmental condition, thus affecting the number of micro-arthropods present in such treated areas. Cortet and Poinsot-Balaguer (1998) observed that atrazine had a positive, rather than a negative effect on Collembola colonizing maize litter bags.

CONCLUSION

To sum up, it can be concluded that imidacloprid as well as thiamethoxam as seed treatments were very effective against thrips for at least 6 weeks from seed planting and had an initial effect on immature stages of whitefly. The effect then decreased to reach a moderate initial effect on mature stages of whitefly and jassids and this then decreased to finally reach a weak effect. Both of the two insecticides, used separately, as foliar treatments were highly effective against aphids for 14 days while they caused a moderate effect on the whitefly population (mature and immature stages). As regards the jassid, imidacloprid was more effective in terms of the initial and residual effect than thiamethxam. The obtained results are important in the integrated management programs of cotton insects. This investigation clearly revealed that the re-colonization ability of soil arthropods in soils treated with pesticides follows a natural cycle and the ease with which is predicated among other factors on the persistence nature of the pesticide, the level of application, and the availability of a diluting agent to the pesticide. Hence, agriculturists, and farmers should have a clear understanding of the nature of the pesticides they apply and must endeavour to apply the pesticides according to the formulation and in the appropriate quantity so as to avoid distortion and destruction of the ecosystem.

ACKNOWLEDGEMENT

We would like to thank Dr. Mahmoud Elkeblawy, Plant Protection Research Institute, Giza, Egypt, for his great help in the investigation and identification of soil fauna.

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