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Monitoring of resistance to pyrethroid and neonicotinoid insecticides of *Aphis gossypii* (Hemiptera: Aphididae)

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Abstract:

Resistance to several insecticides belonging to tow groups in the four field strains of the cotton aphid, *Aphis gossypii* Glover (Hemiptera: Aphididae) collected from Behera, Dakahlia, Menofia, Skarkia and Beni-Suif Governorates during 2008-2010 at cotton seasons was investigated using slide-dipping method. The insecticides used in this study belong to pyrethorids (Es-fenvalerate, deltamethrin, lambda-cyhalothrin, fenpropathrin, alpha-cypermethrin) and neonicotinoids (imidacloprid, acetamiprid, thiamethoxam). The results indicated that the pyrethroid, deltamethrin recorded low levels of resistance during 2008-2010 cotton growing seasons (Resistance ratio (RR) rang between 2.5-10.3-fold), but the other pyrethroids exhibited high levels of resistance in most of the field strains during 2008-2010 cotton growing seasons, lambda-cyhalothrin (RR rang between 9 - 44.7-fold), es-fenvalerate (RR rang between 2.9- 23.5-fold), fenpropathrin (RR rang between 5.6- 27.3-fold), alpha-cypermethrin (RR rang between 12.6 - 26-fold). All tested neonicotinoids were still effective insecticides against most of field strains, where resistance levels were low or moderate during 2008-2010 cotton growing seasons (RR rang between 1.7-11.9-fold), except for thiamethoxam which showed high resistance in Dakahlia (RR 20.5-fold) in 2009 cotton growing season.

Introduction

The cotton aphid, *Aphis gossypii* Glover (Hemipetra: aphididae) is one of the most important piercing sucking pests in cotton fields in Egypt. The grower is usually used the chemical pesticides in controlling the cotton aphid pest. As such applications are frequent, the role of most of the abundant natural enemies is eliminated particularly after the aphis develop resistance to these insecticides (Godfrey *et al.*, 2009), thus making subsequent treatments inefficient and leading to an increase in aphid population levels (Godfrey and Fuson, 2001).

In Egypt, several insecticides of different chemical groups are used against cotton pests. Pyrethroid resistance in *A. gossypii* has previously been documented in many parts of the world, such as Pakistan (Ahmed *et al.*, 2003) and Australia (Herron and Wilson, 2004). The neonicotinoid imidacloprid has been used on cotton for control cotton aphid in Egypt since 1997,

while the neonicotinoid acetamiprid, thiamethoxam and diotefuran have been used for controlling aphid pests on vegetable since 2002, 2003 and 2004, respectively. Resistance in cotton aphids to neonicotinoids have been reported by Wang *et al.* (2001 and 2002) and Yu *et al.* (2004). Resistance to these compounds was also obtained on *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) (Karunker *et al.*, 2008); *Nilaparvata lugens* (Stål) (Hemiptera: Delphacidae) (Wen *et al.*, 2009)*; A. gossypii* (Tabacian *et al*., 2011 and Jam *et al.*, 2014); *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae) , *Earias insulana* (Boisduval) (Lepidoptera : Noctuidae) , *A. gossypii* and *B. tabaci* (Nour El-Hoda *et al*., 2012) and *A. gossypii* and *B. tabaci* (Ghelani, 2014) .

The present work presents a survey of the resistance to the insecticides commonly used in Egypt for the control of the cotton aphid, *A. gossypii* field populations collected from certain Governorates, namely Behera, Dakahlia, Menofia and Beni-Suef during 2008 - 2010 cotton growing seasons to determine the levels of resistance of certain tested insecticides that showed the least levels of resistance accompanied by the high toxic action. It is hoped that such approach might help to developing a safer programme for aphid control.

Materials and methods

1. Monitoring of resistance to insecticides in the field strains of the cotton aphid, *Aphis gossypii* during cotton growing seasons (2008-2010):

1.1. The laboratory strain of the cotton aphid, *Aphis gossypii*:

Susceptible strain of *A. gossypii* was obtained from a cotton field population at Fayoum Governorate, then, reared entirely unexposed to any insecticides at the Central Agricultural Pesticides Laboratory for ten generations under constant conditions of 27± 2º C and 55 ± 5 % R.H. This strain was used for all bioassay investigations and regarded as a reference strain in studies on monitoring resistance and biochemical determinations.

1.2.Field strains of the cotton aphid, *Aphis gossypii:*

Field strains of *A. gossypii* were collected from selected cotton fields at Behara, Dakahlia, Menofia and Beni-Suef Governorates during the early cotton growing seasons of 2008-2010 (3-seasons). Aphid strains were collected insmediately befor the commencement of spray season early (May).

1.3. Bioassay of the tested insecticides against the cotton aphid, *Aphis gossypii*:

Slide-dipping technique (Dittrich, 1962) was used to obtain concentration mortality lines of the tested insecticides against the adult stage of *A. gossypii*. Five different concentrations of each tested insecticide were prepared by dilution in water. By means of a fine brush, ten adult aphids were affixed to a piece double face scotch tap then stuck tightly to glass a slide on the dorsal part. Slides were then dipped in the prepared insecticide aqueous solutions for ten seconds. Three replicates were used for each concentration. Mortality counts were recorded 2 hours after treatment and the percentages of mortality wewe corrected according to Abbott,s formula (1925) and mortality data were subjected to statistical analysis as described by Busvine (1957). The rates of resistance were expressed as resistance ratios (RR) at LC_{50} value of the field strains as compared with the LC_{50} value of the laboratory.

Resistance ratio (RR) = LC_{50} of the field strains / LC_{50} of the laboratory strain

1.4. Insecticides used:

1.4.1. Pyrethroid insecticides: deltamethrin (Decis, 2.5% EC), fenpropathrin (Fenithrin, 30 % EC), esfenvalerate (Sumi-alfa, 5% EC), alpha-cypermethrin (Alfa-cyper,10% EC), lambda-cyhalothrin (Karate, 2.5% EC).

1.4.2. Neonicotinoid insecticides: imidacloprid (Imidor, 20% EC, imidacloprid (Confidor, 20% SL),

Thiamethoxam (Actara, 25% WG), acetamiprid (Mospilan 20% WP).

Results and discussion

1. Monitoring resistance to insecticides in the field strains of the cotton aphid, *Aphis gossypii* during three seasons:

1.1. Pyrethroid insecticides:

Table (1) showed the levels of resistance to certain pyrethroid insecticides in four field strains of *A. gossypii* collected from Behera, Dakahlia, Menofia and Beni-Suef Governorates during 2008-2010 cotton growing seasons. From data Deltamethrin was the highest effective pyrethroid and recorded the least levels of resistance for most tested field strains. (Resistance ratios ranged 2.5-10.3-fold). As for Es-fenvalerate, Behera strain, resistance levels were low in all seasons (resistance ratios ranged between 2.9 and 4.4-fold), but Dakahlia strain showed a high resistance level in both 2008 and 2009 (11.3 and 11.8-fold). In Menofia and Beni-Suef strains resistance to es-fenvalerate trended to increase the cotton growing seasons of 2008-2010. (6.1, 7.8 and 15.4-fold) and (14.9, 11.3 and 23.5-fold), respectively. As for lambda-cyhalothrin, expect for Beni-Suef strain that showed a low level of resistance in 2008 (4.0-fold), very high resistance levels were observed in the other tested four field strains during 2008-2010 cotton growing seasons resistance ratios ranged 9.7-44.7-fold). The highest level of resistance was observed in Dakahlia strain (44.7-fold) followed by that of Beni-Suef strain (32.6-fold), then Menofia strain (15.4-fold) and finally Behera strain (12.8-fold). As a matter of fact, Behera strain exhibited relatively low levels of resistance to fenpropathrin in 2008 and 2009 (5.6 and 4.3-fold, respectively), and a similir trend of resistance occurred in the cases of lambda-cyhalothrin, fenpropathrin and alpha-cypermethrin during all considered the cotton growing seasons. On the other hand, high levels of resistance were recorded for both fenpropathrin and alpha-cypermethrin resistance ratios ranged (13.9-27.9-fold) and (12.6-26.0-fold), respectively.

Table (1): Resistance to pyrethroid insecticides on the cotton aphid, *Aphis gossypii* collected from certain Governorates during 2008, 2009 and 2010 cotton growing seasons.

Insecticide	Season	Behera			Dakahlia			Menofia			Beni-Suef		
		Slope	LC_{50} ppm	RR*	Slope	LC_{50} ppm	RR*	Slope	LC_{50} ppm	RR*	Slope	LC_{50} ppm	RR*
Deltamethrin Decis 2.5% EC	Lab. strain	1.53	2.22	-----	1.53	2.22	-----	1.53	2.22	-----	1.53	2.22	-----
	2008	1.56	11.59	5.2	1.01	16.44	7.4	1.53	17.73	8	1.58	19.57	8.8
	2009	1.09	15.51	7	1.41	14.76	6.7	1.09	14.55	6.6	2.61	22.9	10.3
	2010	1.7	5.65	2.5	1.68	8.57	3.9	1.17	20	9	2.48	16.1	7.3
Lambda-cyhalothrin Karate 20 %EC	Lab. strain	1.71	5.89	-----	1.71	5.89	-----	1.71	5.89	-----	1.71	5.89	-----
	2008	1.8	65.03	11	1.51	83.1	14.1	2.14	57	9.7	1.42	23.3	4
	2009	2.11	75.55	12.8	1.85	131.18	22.3	1.39	122.02	20.7	1.52	91.21	15.5
	2010	1.68	69.81	11.9	1.56	263	44.7	1.55	90.78	15.4	1.73	192	32.6
Esfenvalerate Sumi-alpha 5%EC	Lab. strain	1.73	4.04	-----	1.73	4.04	-----	1.73	4.04	-----	1.73	4.04	-----
	2008	1.46	11.82	2.9	2.11	45.62	11.3	1.6	24.63	6.1	0.9	60.15	14.9
	2009	2.28	9.27	2.3	2.36	47.78	11.8	1.98	31.46	7.8	2.01	45.78	11.3
	2010	1.34	17.68	4.4	1.43	22.75	5.6	1.25	62.3	15.4	1.07	94.97	23.5
Fenpropathrin Fenethrin, 30 % EC	Lab. strain	1.19	12.99	-----	1.19	12.99	-----	1.19	12.99	-----	1.19	12.99	-----
	2008	1.56	72.11	5.6	1.19	194.9	15	1.7	141.99	10.9	1.38	337.11	26
	2009	1.92	55.5	4.3	2.1	315.57	24.3	1.14	229.36	17.7	1.95	310.1	23.8
	2010	1.16	180.55	13.9	1.77	297.32	22.9	1.69	283.75	21.8	1.9	362.07	27.9
Alpha-cypermethrin Alpha-cyper, 10 % EC	Lab. strain	1.96	8.94	-----	1.96	8.94	-----	1.96	8.94	-----	1.96	8.94	-----
	2008	1.57	150.66	16.9	2.54	131.34	14.7	1.79	112.23	12.6	1.66	128.05	14.3
	2009	1.44	181.55	20.3	2.39	166.44	18.6	1.6	127.17	14.2	1.33	214.34	24
	2010	1.96	148.96	16.7	1.89	176.9	19.8	1.57	113.89	12.7	1.16	232.3	26

RR* (Resistance ratio) = LC_{50} of the field strain / LC_{50} of the laboratory strain

In conclusion, the results emphasize that the pyrethroid deltamethrin reflected a low to moderate of resistance, while the other pyrethroids (es-fenvalerate, fenpropathrin, alpha-cypermethrin and lambda-cyhalothrin) exhibited high levels of resistance in most of the considered field strains for 2008-2010 cotton growing seasons. Such conclusions are agreeing with the results of Singab (2007) who monitored of resistance to pyrethroids in field strains of *A. gossypii* in 2005-2007 cotton growing seasons in Gharbia and Fayoum Governorates and reported that field strains exhibited low levels of resistance to deltamethrin, and high level of resistance to fenpropathrin. Similar observations given by Ahmed *et al.* (2003) who reporting that field populations of *A. gossypii* collected from cotton field from 1997 to 2000 in Pakistan showed very high levels of resistance to the pyrethroids cypermethrin, alpha-cypermethrin, fenpropathrin and lambda-cyhalothrin, while the levels of resistance to deltamethrin were relatively lower than the levels of resistance to other pyrethroids. In contrast, Gubran *et al.* (1992) mentioned that the field strains of *A. gossypii* collected from cotton fields in Sudan during 1988-1990 was highly resistance to both fenvalerate and deltamethrin. The same pattern of high resistance to fenvalerate and deltamethrien was also reported from China by Subbaratinam and Redhika (2005).

1.2. Neonicotinoid insecticides:

Table (2) showed the levels of resistance to the tested neonicotinoid insecticides in 4 field strains of *A. gossypii* collected from Behera, Dakahlia, Menofia and Beni-Suef Governorates in 2008-2010 cotton growing seasons. Imidacloprid (represented by Confidor) was effective against the 4 considered field strains but recorded the least levels of resistance compared to the other tested neonicotinoid insecticides (resistance ratios ranged 1.7-4.7-fold). As for, Beni-Suef strain low resistance levels were recorded compared to the other strains in 2008-2010 (2.0, 2.3 and 2.1-fold), respectively. In Menofia strain resistance increased with the progrems of seasons, although it was still low level in 2008-2010 (1.9. 3.1 and 3.7-fold, respectively), In Behera and Dakahlia strains, resistance fluctuated between a low level in 2008 (2.5 and 1.7-fold) and a moderate level in 2009 (4.7 and 4.1-fold) and a low level in 2010 (2.9 and 2.8-fold), respectively.

For the other formulation of imidacloprid (Imidor), resistance in 2008 season was high for Behera strain (9.3-fold) while for Menofia, Dakahlia and Beni-Suef strains it showed moderate levels of resistance (4.7, 5.6 and 6.2-fold, respectively). In 2009, resistance level to Imidor increased for Menofia and Dakahlia strains (6.7 and 7.3-fold, respectively) while for Behera and Beni-Suef strains they declined (7.9 and 3.5-fold, respectively). In 2010, the all considered field strains exhibited a noticeable decline in resistance levels, 2.9, 3.4, 5.0 and 5.9-fold for Menofia, Dakahlia, Behera and Beni-Suef.

The same trend of resistance to imidacloprid was also observed with acetamiprid during 2008-2010 cotton growing seasons. Relatively higher resistance levels were obtained with Confidor, (resistance ratios 1.7-6.3-fold). However, Menofia strain showed comparatively higher levels of resistance but these levels still remained as moderate (2.8, 5.8 and 6.3-fold) for 2008, 2009 and 2010, respectively. The other tested field strains showed low level of resistance in 2008, (resistance ratios were 1.7, 2.3 and 2.8-fold for Beni-Suef, Dakahlia and Behera strains, respectively), but increased slightly in 2009 (3.0, 3.7 and 3.3-fold, respectively) and increased in 2010 for Beni-Suef and Behera strains (4.2 and 4.8-fold, respectively). In 2010, no significant changes in resistance were observed for Dakahlia strain, (3.7-fold).

For thiamethoxam, low levels of resistance were recorded in Menofia, Behera and Beni-Suef strains in 2008 season (2.2, 2.8 and 3.7-fold, respectively), while in Dakahlia strain showed resistance moderate level was (6.0-fold). In 2009, resistance level increased and resistance ratios recorded 11.9, 5.7, 4.6 and 20.5-fold for Menofia, Behera, Beni-Suef and Dakahlia strains, respectively. In 2010, further increase in resistance was observed in Beni-Suef (8.1-fold) and Behera (6.5-fold) while no change in resistance took place in Menofia strain (11.5-fold) and Dakahlia strain showed a decline in resistance level that remained still relatively high (14.0-fold).

The above results suggested that all tested neonicotinoids were except thiamethoxam effective against *A. gossypii*, with low to moderate resistance level except. Thiamethoxam, on the other hand, showed high resistance in both Dakahlia and Menofia strain. Similar results were reported by Nauen *et al*. (2003) and Denholm *et al*. (2002) who mentioned that neonicotinoids are active against numerous sucking and biting insects including aphids, whiteflies, thrips, leaf miners, beetles and some lepidopterous species. Denhlom *et al*. (2002) found that neonicotinoids showed good activity against the insect pests resistant to other classes of insecticides concluding organophosphates, carbamates, pyrethroids and chlorinated hydrocarbons. Singab (2007) further indicated that low to moderate levels of resistance to the neonicotinoids imidacloprid, acetamiprid, thiamethoxam and dinotefuran were observed on filed strains of *A. gossypii* in 2005-2007 cotton growing seasons. Godfrey *et al*. (2009) added that the repeated applications of any neonicotinoid against *A. gossypii* can develop in resistance to all neonicotinoids.

Table (2): Resistance to neonicotinoid insecticides in *Aphis gossypii* collected from certain Governorates during 2008, 2009 and 2010 cotton growing seasons.

Insecticide	Season	Behera			Dakahlia			Menofia			Beni-Suef		
		Slope	LC_{50} ppm	RR*	Slope	LC_{50} ppm	RR*	Slope	LC_{50} ppm	RR*	Slope	LC_{50} ppm	RR*
Imidacloprid Confidor, 20 % SL	Lab. strain	2.17	7.35	------	2.17	7.35	------	2.17	7.35	------	2.17	7.35	------
	2008	1.47	18.68	2.5	2.04	12.49	1.7	1.74	13.83	1.9	1.72	14.72	2
	2009	2.2	34.73	4.7	1.46	30.42	4.1	1.86	22.54	3.1	1.57	17.21	2.3
	2010	1.44	21.29	2.9	2.53	20.8	2.8	1.3 9	27.46	3.7	2.02	15.25	2.1
Imidacloprid Imidor, 20 % EC	Lab. strain	1.62	3.63	------	1.62	3.63	------	1.62	3.63	------	1.62	3.63	------
	2008	1.54	33.57	9.3	1.9	16.54	5.6	1.88	17.15	4.7	1.75	22.36	6.2
	2009	1.72	28.71	7.9	2.64	26.41	7.9	1.66	24.17	6.7	2.01	12.62	3.5
	2010	2.22	18.06	5	1.66	12.45	3.4	1.73	10.51	2.9	1.75	21.31	5.9
Aceamiprid Mospilan, 20 % SP	Lab. strain	2.23	5.61	------	2.23	5.61	------	2.23	5.61	------	2.23	5.61	------
	2008	2.23	15.5	2.8	1.78	13.06	2.3	1.83	15.47	2.8	1.93	9.69	1.7
	2009	1.46	18.53	3.3	1.92	20.71	3.7	2.01	32.4	5.8	1.8	17.04	3
	2010	1	26.91	4.8	2.33	18.97	3.4	1.49	35.26	6.3	1.19	23.26	4.2
Thiamethoxam Actara, 25 % WG	Lab. strain	1.91	8.84	------	1.91	8.84	------	1.91	8.84	------	1.91	8.84	------
	2008	1.37	24.36	2.8	1.21	53.12	6	1.64	19.15	2.2	1.66	32.97	3.7
	2009	1.85	50.78	5.7	1.19	181.19	20.5	2.1	105.32	11.9	1.07	40.74	4.6
	2010	1.02	57.64	6.5	1.2	123.9	14	1.15	101.34	11.5	0.88	71.33	8.1

* RR (Resistance ratio) = LC_{50} of the field strain / LC_{50} of the laboratory strain

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