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Efficacy of some Different Insecticides against Cotton Mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) and its Associated Predators

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ABSTRACT

The cotton mealybug, *Phenacoccus solenopsis* Tinsley is an invasive polyphagous pest species causing severe economic damage to a wide range agricultural crops. Five different toxicants of different groups were evaluated for their effectiveness in reducing mealybug incidence on cotton under both laboratory and field conditions as well as their effectiveness against its associated predators (*Chrysoperla carnea* (Steph.), *Hyperaspis vinciguerrae* Capra) under field conditions. Chlorpyrifos and Imidacloprid were the most toxic insecticides after 24h and 72h of exposure compared with Pyriproxyfen, Buprofezin and Emamectin benzoate against third instar nymphs of *P. solenopsis* under laboratory conditions. Based on field experiments, Chlorpyrifos significantly superior in reducing the cotton mealybug population followed by Imidacloprid, Pyriproxyfen, Emamectin benzoate and finally Buprofezin with average reduction between 96.24 to 43.99%. IGRs toxicants (Buprofezin and Pyriproxyfen) found to safer to the predacious insects than other toxicant groups.

Keywords: Cotton Mealybug, *Phenacoccus solenopsis,* Insecticides, Predators, *Chrysoperla carnea, Hyperaspis vinciguerrae*

INTRODUCTION

Cotton Mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) is a serious sucking pest of cotton vegetables, ornamentals and fruit trees worldwide and is known to be cryptic in nature (Mostafa *et al.*, 2018). It was described originally from the U.S. in 1898 and it remained there until 1992. Later it was reported in Central America, the Caribbean and Ecuador. In Egypt, Cotton Mealybug was recorded firstly on weeds (Abd-Rabou *et al.,* 2010) and subsequently on tomato plants as a new insect pest (Ibrahim *et al.,* 2015).

It cause damage by depleting the sap from all plant parts such as feeders on roots, root crowns, stems, twigs, leaves, flowers, and fruits. They can occasionally inject toxins, transmit viruses or excrete large amounts of honeydew stimulating the growth of sooty mould (Ben-Dov, 1994). Injured plants have discolored, wilted, produce fewer bolls of a smaller size and the deformed leaves turn yellow then dry up and eventually fall off (Eileen and Turner, 2001; Saddiq *et al*., 2014; Kousar *et al*., 2016 and Mostafa *et al*., 2018).

Biological control involving predators played an important role in suppressing mealybug pests of economically important crops. Coccinellids and Chrysopids are thought to be major predators of *P. solenopsis* (Joshi *et al.*, 2010 and Fand and Suroshe, 2015).

There is an immediate need to develop economically feasible and viable integrated pest management approach to combat the insect pests of cotton. Management of cotton mealybug chemically is difficult due to its wide host range, presence of waxy coating on the body and high reproductive potential. But the crawler stage is the most fragile and easily controllable stage in its life history. Recently some organophosphates, insect growth regulators (IGRs) and Bio-pesticides have been recommended for the control of cotton mealybug (Suresh *et al.*, 2010).

This study was conducted with the aim to evaluate the efficiency of some different insecticides classes against cotton mealybug *P. solenopsis* under laboratory and field conditions as well as assess the effect of the tested insecticides against the populations of two major natural enemies the predaceous ladybird beetles *H. vinciguerrae* and green lacewing *C. carnea* under field conditions.

MATERIALS AND METHODS

Insecticides

Commercial formulations of Renocam (Chlorpyrifos 48% EC, Jiangsu Baoling Chemical Co., Ltd, China), Imipower (Imidacloprid 35% SC, Nanjing Red Sun Co. Ltd. – China), Opal (Emamectin benzoate 5.7% EC, Shandong Dongtai Agricultural Chemistry Co., Ltd, China), Nasrfezin (Buprofezin 25% SC, Coromandel International Limited, India) and Gelester (Pyriproxyfen 10% EC, Jiangsu Rotam Chemistry Co., Ltd, China) were tested for their toxicity to *P. solenopsis* under laboratory and field conditions, beside the assessment of their toxicity to its predators *Hyperaspis vinciguerrae* and *Chrysoperla carnea* under field conditions.

Insecticidal test against *P. solenopsis* under laboratory conditions

Cotton mealybug, *P. solenopsis* was collected from unsprayed infested cotton plants (*Gossypium barbadense var.*Giza 86) at the field of Aga district, Dakahalia governorate, Egypt during summer 2017 by the authors and identified at Scale Insect Department, Plant Protection Research Institute, Agric. Res. Center, Giza, Egypt as *P. solenopsis*. The mealybug was brought to the laboratory and adult females were separated and inoculated on cotton plants, potted under laboratory conditions of 30±2^{o}C, 65±5 RH and 13:11(L: D) photoperiod. Daily examination for the morphological changes were recorded and monitored until adult stage. The newly moulted third instar nymphs were used in the laboratory experiments (Attia and Ebrahim, 2015 and Mostafa *et al.*, 2018).

Ten *P. solenopsis* third instar nymphs were transferred to a cotton leaf, placed in a culture Petri dish (9 cm in diameter) and prepared for the insecticidal treatments. Each treatment was replicated three times in addition to control. Five diluted aqueous dispersions concentrations of commercial insecticide were assessed using leaf dip bioassay (El-Zahi and Farag, 2017). Mortality recorded after 24 h and 72h of treatment and corrected by using Abotts formula (Abotts, 1925) and they are statistically analyzed to estimate LC_{50}, LC_{90} and slope values according to Finney (1971). Toxicity index was computed for different insecticides by comparing these materials with the most effective one using Sun's equation (Sun, 1950).

Field evaluation of tested insecticides against *P. solenopsis* and its associated predators

Field experiment was conducted during summer 2017 to evaluate the efficacy of five insecticides against *P. solenopsis* on the previously mentioned of cotton plants variety at the field of Aga district, Dakahalia governorate, Egypt. The experiment was laid out in a randomized block design with six treatments (five insecticides + control). Each treatment contained three replications (42 m^2 each) per plot. Twenty cotton plants were randomly selected and labelled appropriately for further observation from each replicate to count the mealybug population. A knapsack sprayer provided with one nozzle delivering 200 l water/feddan was used. According to the method described by Ahmad *et al.*, (2011), mealybugs on the top ten inches of a plant's terminal portion were counted including stems, leaves and fruiting buds irrespective of their life stage (El-Zahi and Farag, 2017). Treatments were imposed when sufficient number of mealybug population was observed in the experimental block. Observations were recorded a day before spray and three, seven, 14 and 21 days after spray. Further, the reduction percentage in the mealy bug population due to different treatments was calculated according to Henderson and Tilton (1955).

Effect of insecticides on the associated Predatorswhich identified at Scale Insect Department, Plant Protection Research Institute, Agric. Res. Center, Giza, Egypt as *H. vinciguerrae* and *C. carnea* was also recorded a day before spray and three, seven, 14 and 21 days after spray.

Statistical analysis.

The collected data were subjected for one way analysis of variance (ANOVA), and the means separated using Duncan's Multiple Range Test at P < 0.05 (Costat, 2004).

RESULTS AND DISCUSSION

Susceptibility of *P. solenopsis* to some insecticides under laboratory conditions

The potency of five toxicants representing different chemical groups was assessed under laboratory conditions against the third instar nymphs of *P. solenopsis* using the leaf-dip method (Table 1). The results indicated that Chlorpyrifos exhibited the highest degree of efficiency after 24h of initial application followed by the Imidacloprid, Pyriproxyfen, Buprofezin, while Emamectin benzoate was the least toxic one. LC_{50} values were 8.97, 272.38, 817.12, 1910.89 and 2185.302 ppm, respectively.

The efficiency order of the tested insecticides was slightly changed after 72h of treatment and Chlorpyrifos also recorded the most toxic effect followed by the Imidacloprid, Buprofezin Pyriproxyfen, and Emamectin benzoate with LC_{50} values 4.29, 50.04, 218.32, 243.33 and 317.15 respectively.

Under laboratory conditions the treatment of organophosphate insecticide Chlorpyrifos against *P. solenopsis* found to significantly superior over the rest treatments after 24h and 72h on the basis of toxicity index while, the neonicotinoid Imidacloprid treatment found to next in the order of efficacy followed by the insect growth regulators Pyriproxyfen (Juvenile hormone mimics) and Buprofezin (chitin synthesis inhibitors) then the least active one was avermectin Emamectin benzoate. This in accordance with Suresh *et al.,* (2010) who stated that among the evaluated insecticides against *P. solenopsis* Chlorpyriphos recorded overall reduction of 100 % followed by imdaclorpride (89.99%). The efficacy of Buprofezin against early and later instar nymphs of *P. solenopsis* under laboratory condition was examined and found to be more toxic to early instars than later instar nymphs. At the two lower doses (250 g a.i./ha and 312.5 g a.i./ha), its effectiveness was comparable to Chlorpyrifos 400 g a.i./ha (Patel *et al.*., 2010).

Table 1. **Susceptibility of *P. solenopsis* third instar nymphs to some insecticides using leaf-dip method under laboratory conditions**

	After 24h of treatment					After 72h of treatment				
Tested Compounds	**LC_{50} (ppm) and confidence limits at 95%**	**LC_{90} (ppm) and confidence limits at 95%**	**Slope ± SE**	**X^2**	**Toxicity index***	**LC_{50} (ppm) and confidence limits at 95%**	**LC_{90} (ppm) and confidence limits at 95%**	**Slope ± SE**	**X^2**	**Toxicity index***
Chlorpyrifos	8.97 7.93 10.34	14.84 12.43 20.00	5.863±0.91	0.75	100.00	4.29 3.29 5.38	12.21 8.92 22.27	2.822±0.53	5.24	100.00
Imidacloprid	272.38 78.78 78.30	57552.21 11840.60 1330032.22	0.551±0.11	0. 60	3.29	50.04 24.89 96.47	946.73 432.78 2836.12	1.004±0.12	3.95	8.58
Emamectin benzoate	2185.302 99.4457 71385022.00	91581410 113462.80 1.44E+19	0.278±0.084	0.25	0.41	317.15 21.50 616180.90	35188640.00 61766.25 1.42E+17	0.254±0.07	0.88	1.35
Buprofezin	1910.89 626.57 39556.78	91010.02 9131.20 1.19E+08	0.764±0.21	0.41	0.47	218.32 88.76 4642.91	6078.93 788.31 1.42E+07	0.887±0.27	1.18	1.97
Pyriproxyfen	817.12 211.70 64363.54	10145 5275.29 6.50E+09	0.612±0.184	0.15	1.1	243.33 67.73 9581.42	130936.50 4878.15 5.21E+10	0.469±0.15	0.77	1.76

***Toxicity index = LC_{50} of the most effective compound/ LC_{50} of the tested compound × 100**

The effect of insecticides on *P. solenopsis* and its associated Predatorsunder field condition

The efficacy of five insecticides was evaluated against *P. solenopsis* population under field conditions. The high variation between the mealybug populations per cotton plant before application of the tested insecticides is a common problem associated with the insecticidal treatments under field conditions. So randomly chosen of the infested cotton plants were conducted according to Hanchinal *et al.,* (2009); Ahmad *et al.*, (2011) and El- Zahi *et al.*, (2016).

All the insecticidal treatments showed significant superiority over the control in different degrees (Table 2). Of the five insecticides Chlorpyrifos proved significant superiority over the rest insecticides with pest reduction (96.24%) followed by Imidacloprid (77.82%), Pyriproxyfen (71.01%), Emamectin benzoate (54.08%), Buprofezin (43.99%) after three days of spraying. Twenty one days later the reduction in infestation increased to 99.45%, 98.32%, 93.88%, 87.10% and 82.50%, respectively. The average reduction percentages were (97.59 %), 90.14% and 81.23%, 70.80% and 66.35%, respectively.

The effectiveness of Chlorpyrifos was in confirmation with the findings of Suresh *et al.*, (2010) who reported that Chlorpyrifos proved to be one of the best insecticides for mealy bug control. Also, Ghanim and Elgohary (2015) reported that Dimethoate and Imidacloprid were the most effective insecticides against the citrus mealybug, *Planococcus citri* (Risso) under field conditions. The present results were also similar to the findings of Suresh and Kavitha (2008), who disclosed that Imidacloprid and profenophos were found to be quite effective under the laboratory conditions, but moderately effective under field conditions.

During insecticidal application, predators such as ladybird beetles *H. vinciguerrae* and *C. carnea* were found active against cotton mealybugs under field conditions. Their activities were found significantly affected as compared to control plots during all post application periods.

Application of presented pesticides had some toxic effect on *C. carnea* population (Table 3). However, Chlorpyrifos recorded the highest average reduction (69.34%) followed by Imidacloprid (59.62%), Emamectin benzoate (58.56%), Buprofezin (50.59%) and the least effective Pyriproxyfen (47.84%). Among the treatments, maximum of (78.75%) average reduction of *H. vinciguerrae* was registered in Emamectin benzoate which was on par with Chlorpyrifos (76.37%) followed by Imidacloprid (67.95%) then Pyriproxyfen (60.76%) and finally Buprofezin (41.53%).

Table 2. Efficacy of different insecticides against *P. solenopsis* population under field conditions

Insecticide	Field recommended rate*	Pre-spray	Mean number per plant and percent reduction of *P. solenopsis* — Days after insecticide treatment: 3		7		14		21		Overall Mean	
			Mean No.	% Reduc.	Mean No.	% Reduc.	Mean No.	% Reduc.	Mean No.	% Reduc.	Mean No.	% Reduc.
Chlorpyrifos	5.00 cm^3/L	299.33^{cd}	10.33^{d}	96.24	9.00^{c}	95.82	1.67^{c}	98.85	1.33^{c}	99.45	5.58^{b}	97.59
Imidacloprid	0.75cm^3/L	536.67^{b}	109.33^{c}	77.82	36.00^{bc}	90.68	16.33^{bc}	93.75	7.33^{c}	98.32	42.25^{b}	90.14
Emamectin benzoate	0.40 cm^3/L	930.00^{a}	392.33^{a}	54.08	186.67^{a}	72.12	136.33^{a}	69.89	97.33^{b}	87.10	203.17^{a}	70.80
Buprofezin	1.50 cm^3/L	195.00^{d}	100.33^{c}	43.99	46.33^{bc}	67.00	26.67^{bc}	71.91	27.67^{c}	82.50	50.25^{b}	66.35
Pyriproxyfen	0.50 cm^3/L	430.67b^{c}	114. 67^{c}	71.01	62.33^{b}	79.90	41.67^{b}	80.13	21.33^{c}	93.88	41.78^{b}	81.23
Control		241.67^{d}	222.00^{b}		174.00^{a}		117.67^{a}		196.00^{a}		177.42^{a}	
LSD $_{0.05}$		152.54	55.27		36.14		24.61		47.88		94.31	

***The used concentrations were determined based on the recommendations of Egyptian Ministry of Agriculture; The figures superscripted with same alphabets in the same columns do not significantly differ from each other as per Duncan's multiple range test**

Table 3. Toxicity of applied insecticides to adults of *C. carnea* and *H. vinciguerrae*.

Insecticide	Pre-spray	Mean population per plant and percent reduction of associated predators — Days after insecticide treatment: 3		7		14		21		Overall Mean	
		Mean No.	% Reduc.	Mean No.	% Reduc.	Mean No.	% Reduc.	Mean No.	% Reduc.	Mean No.	% Reduc.
						Chrysoperla carnea					
Chlorpyrifos	11.00^{f}	4.33^{d}	70.08	5.67^{f}	74.22	5.00^{d}	70.21	6.67^{d}	62.83	5.42^{c}	69.34
Imidacloprid	14.67^{c}	12.00^{c}	37.83	12.67^{d}	56.8	6.33^{cd}	71.72	6.67^{d}	72.13	9.42^{bc}	59.62
Emamectin benzoate	17.33^{a}	14.67^{b}	35.66	11.33^{e}	74.98	8.67^{bc}	67.21	12.33^{b}	56.39	11.75^{b}	58.56
Buprofezin	16.33^{b}	11.67^{c}	45.68	17.33^{b}	46.92	10.33^{b}	58.54	13.00^{b}	51.2	13.08^{b}	50.59
Pyriproxyfen	13.67^{d}	12.33^{c}	31.45	14.67^{c}	46.32	8.67^{bc}	58.43	10.00^{c}	55.16	11.42^{b}	47.84
Control	12.67^{e}	16.67^{a}		25.33^{a}		19.33^{a}		20.67^{a}		20.50^{a}	
LSD $_{0.05}$	0.73	1.19		1.03		2.68		1.33		4.20	
						Hyperaspis vinciguerrae					
Chlorpyrifos	9.00^{b}	1.33^{e}	90.03	4.00^{c}	74.22	8.67^{c}	68.6	9.00^{c}	72.63	5.75^{b}	76.37
Imidacloprid	9.67^{b}	4.00^{d}	72.09	8.33^{b}	50.03	9.33^{c}	68.55	6.67^{c}	81.12	7.08^{b}	67.95
Emamectin benzoate	16.00^{a}	8.00^{c}	66.26	5.33^{bc}	80.68	7.00^{c}	85.74	10.33^{c}	82.33	7.67^{b}	78.75
Buprofezin	12.33^{ab}	9.67^{b}	47.08	14.67^{a}	30.98	19.67^{b}	48.01	27.00^{b}	40.06	17.75^{a}	41.53
Pyriproxyfen	10.67^{b}	10.00^{b}	36.76	8.00^{b}	56.51	8.33^{c}	74.56	9.67^{c}	75.19	9.00^{b}	60.76
Control	9.67^{b}	14.33^{a}		16.67^{a}		29.67^{a}		35.33^{a}		24.00^{a}	
LSD $_{0.05}$	3.87	1.45		3.79		4.09		4.78		8.18	

The figures superscripted with same alphabets in the same columns do not significantly differ from each other as per Duncan's multiple range test

Physiological differences among pests and entomophagous species is the main factor affecting insecticide selectivity (Bayoun *et al,* 1995). *C. carnea* found to be more tolerant to the applied insecticides compared to *H. vinciguerrae* and this is closely parallel with Sayyad *et al.*,(2010) who reported that *C. carnea* is one of the most common natural enemies and is highly exposed to pesticides applications resulting in enhanced tolerance to pesticides. IGRs toxicants are safer to the predacious insects (*C. carnea* and *H. vinciguerrae*) than other toxicant groups (organophosphte, neonicotinoids and avermectins).

The present findings were supported by Bayoun *et al.,* (1995) Chlorpyrifos showed a high toxicity to natural enemies, and found to toxic to all instars of *C. carnea* with mortality ranging from 32 to 92% while, Emamectin benzoate was found to be intermediately toxic (Hussain *et al.,* 2012). Imidacloprid was found comparatively the most toxic to the activities of *C. carnea* up to 10 days after application of insecticides. Naranjo and Akey (2005) recommended the IGRs Pyriproxyfen and Buprofezin utilization in preference to other available insecticides as a result of their selectivity to conserve the natural enemy populations and permit biological control.

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فاعلية بعض المبيدات الحشرية المختلفة ضد بق القطن الدقيقي *Phenacoccus solenopsis* Tinsely (Hemiptera: Pseudococcidae) والمفترسات المرتبطه بها

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يعد بق القطن الدقيقى من الآفات الحشرية التي تسبب ضررا اقتصاديا للعديد من المحاصيل الزراعية. تم اختبار فاعلية عدد خمس مبيدات حشرية تنتمي لمجموعات مختلفة الفاعلية للحد من الأصابه بالبق الدقيقى على القطن تحت الظروف المعملية والحقلية وكذلك دراسة كفاءة تلك المبيدات على المفترسات المرتبطة بالآفة حقليا. كان كلوربيريفوس وإيميداكلوبريد أكثر المبيدات الحشرية سمية بعد ٢٤ ساعة و ٧٢ ساعة من التعرض مقارنة مع بيريبروإكسيفين ، بوبروفيزين و إيمامكتين بنزوات ضد حوريات الطور الثالث من *P. solenopsis*تحت الظروف المعملية .استناداً إلى التجارب الحقلية، كان الكلوربيريفوس متفوقاً بشكل ملحوظ في خفض تعداد بق القطن الدقيقي يليه إميداكلوبريد ، بيريبروإكسيفين ، إيمامكتين بنزوات وأخيراً بوبروفيزين بمتوسط انخفاض يتراوح بين ٩٦.٢٤ إلى ٤٣.٩٩٪ . وجدت المبيدات الحشرية المنتمية لمجموعة منظمات النمو الحشرية IGRs(بيريبروإكسيفين و بوبروفيزين) الأكثر أماناً للمفترسات مقارنة بالمجموعات السامة الأخرى.