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Toxicity of Some Selected Pesticides against *Neoseiulus barkeri* (Acari: Phytoseiidae) Under Laboratory Conditions

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***Neoseiulus barkeri*, Pesticides, Biological control, LC_{50}, Compatibility**

ABSTRACT

Insect pests are the major yield decreasing factors in our agro-ecosystem. Among many pest management approaches, biological control is considered as the main strategy to address these issues including sucking pests. Different biocontrol agents are being used for the management of these sucking insect pests. *Neoseiulus barkeri* (Acari: Phytoseiidae) has been proved as an efficient acarine predator of sucking insect pests of different crops. This predator has also been reported from different localities of Pakistan. The main objective of this study was to screen out locally used pesticides *i.e.*, pyriproxyfen, acetamiprid, chlorfenapyr, diafenthiuron and thiacloprid against *N. barkeri* in order to find its compatibility with some pesticides. Leaf disc arenas were used and leaf dip bioassay was conducted. Pesticides were tested for their compatibility with *N. barkeri* at different concentrations under controlled laboratory conditions. The results showed 25%, 30%, 70%, 50% and 65% mortality occurred by tested pesticides at field relevant doses after 144 h respectively. Missing mites data indicated repellency due to pesticides, was highest at the start of experiment, and then these acclimatized on leaf discs. Thiacloprid having lowest LC_{50} value 295 and proved toxic for the predator while diafenthiuron and pyriproxyfen have higher values. The findings of the study revealed that among five tested pesticides chlorfenapyr and thiacloprid proved moderately harmful for *N.barkeri*, hence cannot be recommended in IPM module.

INTRODUCTION

Sucking insect-pests pose major threat to agriculture through reduction of crop yields per unit area (Jeschke *et al*., 2011). Whiteflies, thrips, aphids and spider mites are major threat due to their vigorous feeding behavior and source of transmission of many plant diseases (De Barro *et al*., 2011; Amna *et al*., 2012; Sarwar, 2014). For getting rid off these notorious sucking pests, the main reliance is on synthetic chemicals as the immediate control strategy. But in parallel, the injudicious use of these chemicals is causing environmental hazards, human diseases and resistance in pest species (Abang *et al*., 2013). On the other hand, biological control is considered as ecosystem friendly pest management approach (Perdikis *et al*., 2008; Sarwar and Sattar, 2016). Predatory mites proved as successful bio-control agents of sucking mite and insect pests due to many attributes (Szabo *et al*., 2014). Numerous species of phytoseiids are commercially reared as bio-control agents of sucking pests of field and covered crops (Chant and McMurtry, 2007). The predatory mite *Neoseiulus barkeri* Hughes 1948 (Phytoseiidae) has been reported from Asia, America, Australia, Africa and Europe (de Moraes *et al*., 2004). It has received considerable attention regarding its capability to control whiteflies (Nomikou *et al*., 2003), thrips (Wu *et al*., 2014) and spider mites (Jafari *et al*., 2013) and rearing trials on wide temperature range (Jafari *et al*., 2012) proved it suitable for use in augmentative biological control programs. During recent years, integrated use of phytoseiids along with compatible reduced-risk pesticides has become popular approach (Damos *et al*., 2015).

The reduced risk pesticides have less detrimental effects as they are selective, target oriented and safer for the beneficial in contrast to conventional broad spectrum pesticides. Effects of several pesticides have been reported against predatory mites in different agricultural systems (Damalas and Eleftherohorinos, 2011; Lamberth *et al*., 2013; Poliane *et al*., 2014). Acetamiprid (Poletti *et al*., 2007; Beers and Schmidt, 2014), clofentezine and phosalone (Raudonis *et al*., 2004) thiamethoxam, thiacloprid, methoxyfenozide, pyriproxyfen, indoxacarbspinosad (Biondi *et al*., 2012), fenbutatin oxide, buprofezin, fenobucarb, imidacloprid, dinotefuran, validamycin, carbendazim and sulfur (Kongchuensin and Takafuji, 2006) had non-significant effect on immature developmental stages of different phytoseiids in contrast to pyrethroids, *i.e*., esfenvalerate, fenpropathrin, and rotenone were highly toxic (Villanueva and Walgenbach,

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2005; Castagnoli *et al*., 2005). Pyrethrins and imidacloprid decreased fecundity and had negative effect against some phytoseiids and some studies revealed better performance of phytoseiids in integration with imidacloprid (Poliane *et al*., 2013).

In Pakistan, after the introduction of transgenic crops the major threat of sucking insect-pests particularly whitefly and spider mites has become very crucial (Rafiq *et al*., 2008; Ahmad *et al*., 2010) and huge investments are being spent on pesticides (Malik, 2014). By keeping in view the adverse effects of pesticides on biocontrol agents a study was planned to test pesticides at different concentration levels against *N. barkeri* (Acari: Phytoseiidae) to recommend the safer and compatible chemicals against sucking pests.

MATERIALS AND METHODS

Predatory mites culture

Native strain *Neoseiulus barkeri* (Acari: Phytoseiidae) reared under laboratory conditions since 2010 with no pesticides exposure, were used for the experimentation. The mass culture was reared on stored grain mite *Rhizoglyphus tritici* in growth chamber at 26±2°C, 65±5% R.H. and 12:12 (L:D) photoperiod. The culture was kept in small petri dishes (5.5 cm diameter) placed on water soaked foam in large petri dishes (14 cm diameter). The water served as barrier for the escape of mites.

Pesticides

The pesticides used are given in the Table I along with field relevant dose and trade names. These pesticides were purchased from local market. Serial dilutions were prepared in acetone starting from the field relevant dose, T1= Field relevant dose, T2=50%, T3=25%, T4=12.5%, T5=6.25% of field relevant doses and T6 =control (Acetone). There were four replicates for each pesticide concentrations and control.

Bioassay

Rearing arenas were prepared by using 14cm diameter petri dish along with 12cm foam soaked in water as barrier to prevent escaping of the predatory mites. Brinjal, *Solanum melongena* leaves (3 months old) were trimmed with cork borer to prepare leaf disc (1.7 cm diameter). The leaf discs were dipped individually in different concentrations for 10 seconds each and were allowed to dry at room temperature (Kongchuensin and Takafuji, 2006). These discs were placed upside down on the soaked foam. Newly emerged adult females (10 individuals) were released on each disc. Immature of *R. tritici* were offered as food on daily basis. These mites were added in the arenas to replace the consumed preys. Data on the mortality was recorded at 24 h interval basis till 144 h. The mites were considered dead if no movement in the appendages was observed on touching gently with the help of a fine needle. The absconded predators were excluded from data.

Statistical analyses

Data were analyzed statistically by calculating means, standard errors, percentages and two-way analysis of variance (ANOVA). Mortality due to pesticides was calculated by using Probit analysis and LC_{50} values were calculated with Minitab 17 Statistical Software (2010). Toxicity was evaluated according to IOBC criteria against beneficial arthropods (Jansen, 2010).

RESULTS

Pesticide at different concentrations and time intervals were tested against *N. barkeri* and harmless or slightly harmful and moderately harmful effects were observed. Highly significant mortality was observed at different concentrations (F= 41.06, 75.71, 255.34, 164.49, 192.13, df =5,108, P≤ 0.0000) and time intervals (F=10.62, 5.26, 35.42, 41.37, 24.03, df=5,108, P≤ 0.0000) for pyriproxyfen, acetamiprid, chlorfenapyr, diafenthiuron and thiacloprid respectively. Pyriproxyfen was harmless and maximum mortality (25%) was observed at field relevant dose (540 ppm) after 96 h while minimum mortality (2.50%) for 67.5 ppm after 24 h. Same value of the mortality was reported for T4, T5 after 24 and 48 h, respectively (Table II). Non-significant interaction regarding time and concentrations for mites escape (F=0.44, df =25,108,

Table I.- Pesticides along with trade names, groups, concentration in ppm and field recommended doses.

Sr. No.	Name of pesticide	Trade name	Group	Concentration in sprayable material (ppm)	Recommended dose/ acre/100ltrs. water
1	Pyriproxyfen	Priority 10.8EC	IGR	540	500 ML
2	Acetamiprid	Mospilan 20%SP	Neonicotinoid	300	150 GM
3	Chlorfenapyr	Pirate 360 G/LSC	Pyrrols	2700	75 ML
4	Diafenthiuron	Polo 50%SC	Thiourea	1000	200 ML
5	Thiacloprid	Talent 48%SC	Neonicotinoid	600	125 ML

Table II.- Effect of pyriproxyfen administered for different time period on mortality (%) of *N. barkeri* (n=10) leaf arenas.

Mortal-ity (%)	Treatment						
	T1	T2	T3	T4	T5	T6	Mean
24	7.50 ± 2.50	5.00 ± 2.89	5.00 ± 2.89	2.50 ± 2.50	2.50 ± 2.50	0.00 ± 0.00	3.75 ± 1.01D
48	15.00 ± 2.89	12.50 ± 2.50	7.50 ± 2.50	5.00 ± 2.89	2.50 ± 2.50	2.50 ± 2.50	7.50 ± 1.38C
72	20.00 ± 0.00	15.00 ± 2.89	7.50 ± 2.50	5.00 ± 2.89	2.50 ± 2.50	2.50 ± 2.50	8.75 ± 1.63BC
96	25.00 ± 2.89	17.50 ± 4.79	12.50 ± 2.50	7.50 ± 2.50	5.00 ± 2.89	2.50 ± 2.50	11.67 ± 1.97AB
120	25.00 ± 2.89	22.50 ± 2.50	12.50 ± 2.50	7.50 ± 2.50	5.00 ± 2.89	2.50 ± 2.50	12.50 ± 2.02A
144	25.00 ± 2.89	22.50 ± 2.50	15.00 ± 2.89	7.50 ± 2.50	5.00 ± 2.89	2.50 ± 2.50	12.92 ± 2.04A
Mean	19.58 ± 1.65A	15.83 ± 1.69B	10.00 ± 1.20C	5.83 ± 1.03D	3.75 ± 1.01DE	2.08 ± 0.85E	
Missing (%)							
24	12.50 ± 2.50	12.50 ± 2.50	12.50 ± 2.50	12.50 ± 2.50	12.50 ± 2.50	10.00 ± 0.00	12.08 ± 0.85A
48	15.00 ± 2.89	12.50 ± 2.50	12.50 ± 2.50	12.50 ± 2.50	12.50 ± 2.50	10.00 ± 0.00	12.50 ± 0.90A
72	15.00 ± 2.89	12.50 ± 2.50	12.50 ± 2.50	12.50 ± 2.50	12.50 ± 2.50	10.00 ± 0.00	12.50 ± 0.90A
96	17.50 ± 2.50	20.00 ± 0.00	12.50 ± 2.50	15.00 ± 2.89	12.50 ± 2.50	10.00 ± 0.00	14.58 ± 1.04A
120	17.50 ± 2.50	20.00 ± 0.00	15.00 ± 2.89	15.00 ± 2.89	12.50 ± 2.50	10.00 ± 0.00	15.00 ± 1.04A
144	17.50 ± 2.50	17.50 ± 2.50	15.00 ± 2.89	15.00 ± 2.89	12.50 ± 2.50	10.00 ± 0.00	14.58 ± 1.04A
Mean	15.83 ± 1.03A	15.83 ± 1.03A	13.33 ± 0.98AB	13.75 ± 1.01AB	12.50 ± 0.90BC	10.00 ± 0.00C	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05); T1, Field relevant dose; T2, 1/2 of field relevant dose; T3, 1/4 of field relevant dose; T4, 1/8 of field relevant dose; T5, 1/16 of field relevant dose; T6, Control.

Table III.- Effect of acetamiprid administered for different time period on mortality (%) of *N. barkeri* (n=10) leaf arenas.

Mortal-ity (%)	Treatment						
	T1	T2	T3	T4	T5	T6	Mean
24	17.50 ± 2.50	12.50 ± 2.50	7.50 ± 2.50	2.50 ± 2.50	0.00 ± 0.00	0.00 ± 0.00	6.67 ± 1.55C
48	25.00 ± 2.89	15.00 ± 2.89	10.00 ± 0.00	5.00 ± 2.89	2.50 ± 2.50	2.50 ± 2.50	10.00 ± 1.90B
72	25.00 ± 2.89	20.00 ± 4.08	12.50 ± 2.50	5.00 ± 2.89	2.50 ± 2.50	2.50 ± 2.50	11.25 ± 2.11AB
96	25.00 ± 2.89	20.00 ± 4.08	12.50 ± 2.50	5.00 ± 2.89	2.50 ± 2.50	5.00 ± 2.89	11.67 ± 2.06AB
120	27.50 ± 2.50	22.50 ± 2.50	12.50 ± 2.50	5.00 ± 2.89	2.50 ± 2.50	7.50 ± 2.50	12.92 ± 2.13AB
144	30.00 ± 0.00	22.50 ± 2.50	12.50 ± 2.50	5.00 ± 2.89	2.50 ± 2.50	7.50 ± 2.50	13.33 ± 2.23A
Mean	25.00 ± 1.20A	18.75 ± 1.39B	11.25 ± 0.92C	4.58 ± 1.04D			
Missing (%)							
24	10.00 ± 0.00	12.50 ± 2.50	12.50 ± 2.50	10.00 ± 0.00	10.00 ± 0.00	2.50 ± 2.50	9.58 ± 0.95A
48	12.50 ± 2.50	12.50 ± 2.50	12.50 ± 2.50	12.50 ± 2.50	10.00 ± 0.00	5.00 ± 2.89	10.83 ± 1.03A
72	15.00 ± 2.89	12.50 ± 2.50	12.50 ± 2.50	12.50 ± 2.50	10.00 ± 0.00	7.50 ± 2.50	11.67 ± 0.98A
96	15.00 ± 2.89	15.00 ± 2.89	12.50 ± 2.50	12.50 ± 2.50	12.50 ± 2.50	7.50 ± 2.50	12.50 ± 1.09A
120	15.00 ± 2.89	15.00 ± 2.89	12.50 ± 2.50	15.00 ± 2.89	12.50 ± 2.50	7.50 ± 2.50	12.92 ± 1.12A
144	17.50 ± 2.50	15.00 ± 2.89	15.00 ± 2.89	15.00 ± 2.89	12.50 ± 2.50	7.50 ± 2.50	13.75 ± 1.18A
Mean	14.17 ± 1.03A	13.75 ± 1.01AB	12.92 ± 0.95AB	12.92 ± 0.95AB	11.25 ± 0.69B	6.25 ± 1.01C	

For statistical and other detail see Table I.

P=0.9899) and mortality (F=1.17, df =25, 108, P=0.2823) was observed (Table II). Acetamiprid was slightly harmful and caused maximum mortality (30%) at field relevant dose (300 ppm) after 144 h, while minimum mortality (2.50%) at 18.75 and 37.5 ppm after 24 hours and so on (Table III). There was non-significant interaction regarding time and concentrations for escape (F=0.19, df =25,108, P=1.0000) and mortality (F=0.44, df =25,108, P=0.9900) (Table III). Chlorfenapyr was moderately harmful for *N. barkeri* and maximum mortality (70%) was observed at field relevant dose (2700 ppm) after 120 h while minimum mortality (5.00%) was observed at 168.75 ppm concentration after 24 h interval (Table IV). There was non-significant interaction regarding time and concentrations for escape of mites

Table IV.- Effect of chlorfenapyr administered for different time period on mortality (%) of *N. barkeri* (n=10) leaf arenas.

Mortality (%)	Treatment						
	T1	T2	T3	T4	T5	T6	Mean
24	27.50 ± 2.50fg	20.00 ± 4.08gh	10.00 ± 0.00ijk	7.50 ± 2.50jkl	5.00 ± 2.89jkl	0.00 ± 0.00l	11.67 ± 2.14D
48	50.00 ± 4.08c	40.00 ± 4.08de	27.50 ± 2.50fg	12.50 ± 2.50hij	7.50 ± 2.50jkl	2.50 ± 2.50kl	23.33 ± 3.79C
72	60.00 ± 4.08b	47.50 ± 4.79cd	30.00 ± 4.08f	17.50 ± 2.50hi	7.50 ± 2.50jkl	2.50 ± 2.50kl	27.50 ± 4.51B
96	67.50 ± 2.50ab	47.50 ± 4.79cd	32.50 ± 2.50ef	20.00 ± 4.08gh	10.00 ± 0.00ijk	5.00 ± 2.89jkl	30.42 ± 4.68AB
120	70.00 ± 4.08a	50.00 ± 4.08c	32.50 ± 2.50ef	20.00 ± 4.08gh	10.00 ± 0.00ijk	5.00 ± 2.89jkl	31.25 ± 4.90A
144	70.00 ± 4.08a	50.00 ± 4.08c	32.50 ± 2.50ef	20.00 ± 4.08gh	12.50 ± 2.50hij	7.50 ± 2.50jkl	32.08 ± 4.74A
Total	57.50 ± 3.42A	42.50 ± 2.71B	27.50 ± 1.93C	16.25 ± 1.57D	8.75 ± 0.92E	3.75 ± 1.01F	
Missing (%)							
24	7.50 ± 2.50	7.50 ± 2.50	7.50 ± 2.50	7.50 ± 2.50	10.00 ± 0.00	5.00 ± 2.89	7.50 ± 0.90B
48	7.50 ± 2.50	7.50 ± 2.50	7.50 ± 2.50	7.50 ± 2.50	10.00 ± 0.00	5.00 ± 2.89	7.50 ± 0.90B
72	10.00 ± 0.00	7.50 ± 2.50	10.00 ± 0.00	10.00 ± 0.00	10.00 ± 0.00	5.00 ± 2.89	8.75 ± 0.69AB
96	10.00 ± 0.00	10.00 ± 0.00	10.00 ± 0.00	10.00 ± 0.00	10.00 ± 0.00	7.50 ± 2.50	9.58 ± 0.42AB
120	10.00 ± 0.00	10.00 ± 0.00	12.50 ± 2.50	10.00 ± 0.00	10.00 ± 0.00	7.50 ± 2.50	10.00 ± 0.60A
144	12.50 ± 2.50	10.00 ± 0.00	12.50 ± 2.50	12.50 ± 2.50	10.00 ± 0.00	7.50 ± 2.50	10.83 ± 0.83A
Total	9.58 ± 0.73A	8.75 ± 0.69A	10.00 ± 0.85A	9.58 ± 0.73A	10.00 ± 0.00A	6.25 ± 1.01B	

For statistical and other detail see Table I.

Table V.- Effect of diafenthiuron administered for different time period on mortality (%) of *N. barkeri* (n=10) leaf arenas.

Mortality (%)	Treatment						
	T1	T2	T3	T4	T5	T6	Mean
24	20.00 ± 4.08def	15.00 ± 2.89fgh	10.00 ± 0.00hij	5.00 ± 2.89jkl	2.50 ± 2.50kl	0.00 ± 0.00l	8.75 ± 1.74C
48	37.50 ± 2.50b	25.00 ± 2.89cd	17.50 ± 2.50efg	12.50 ± 2.50ghi	7.50 ± 2.50ijk	0.00 ± 0.00l	16.67 ± 2.67B
72	45.00 ± 2.89a	35.00 ± 2.89b	25.00 ± 2.89cd	20.00 ± 0.00def	12.50 ± 2.50ghi	2.50 ± 2.50kl	23.33 ± 3.05A
96	47.50 ± 2.50a	35.00 ± 2.89b	27.50 ± 2.50c	22.50 ± 2.50cde	15.00 ± 2.89fgh	2.50 ± 2.50kl	25.00 ± 3.13A
120	50.00 ± 4.08a	37.50 ± 2.50b	27.50 ± 2.50c	22.50 ± 2.50cde	15.00 ± 2.89fgh	5.00 ± 2.89jkl	26.25 ± 3.23A
144	50.00 ± 4.08a	37.50 ± 2.50b	27.50 ± 2.50c	22.50 ± 2.50cde	15.00 ± 2.89fgh	5.00 ± 2.89jkl	26.25 ± 3.23A
Mean	41.67 ± 2.53A	30.83 ± 1.99B	22.50 ± 1.62C	17.50 ± 1.62D	11.25 ± 1.39E	2.50 ± 0.90F	
Missing (%)							
24	10.00 ± 0.00	12.50 ± 2.50	10.00 ± 0.00	12.50 ± 2.50	10.00 ± 0.00	7.50 ± 2.50	10.42 ± 0.73A
48	12.50 ± 2.50	12.50 ± 2.50	12.50 ± 2.50	12.50 ± 2.50	10.00 ± 0.00	7.50 ± 2.50	11.25 ± 0.92A
72	15.00 ± 2.89	15.00 ± 2.89	12.50 ± 2.50	12.50 ± 2.50	12.50 ± 2.50	7.50 ± 2.50	12.50 ± 1.09A
96	15.00 ± 2.89	15.00 ± 2.89	12.50 ± 2.50	15.00 ± 2.89	12.50 ± 2.50	7.50 ± 2.50	12.92 ± 1.12A
120	17.50 ± 2.50	15.00 ± 2.89	12.50 ± 2.50	15.00 ± 2.89	12.50 ± 2.50	7.50 ± 2.50	13.33 ± 1.15A
144	17.50 ± 2.50	15.00 ± 2.89	12.50 ± 2.50	15.00 ± 2.89	12.50 ± 2.50	7.50 ± 2.50	13.33 ± 1.15A
Total	14.58 ± 1.04A	14.17 ± 1.03AB	12.08 ± 0.85AB	13.75 ± 1.01AB	11.67 ± 0.78B	7.50 ± 0.90C	

For statistical and other detail see Table I.

(F=0.27, df =25,108, P=0.9998) and highly significant interaction for mortality (F=3.35, df =25,108, P≤0.0000) was observed (Table IV). Diafenthiuron also proved moderately harmful for *N. barkeri* and maximum mortality (50%) was reported at field relevant dose (1000 ppm) after 120 h, while minimum mortality (2.50%) was reported at 62.5 ppm concentration after 24 h (Table V). There was non-significant interaction regarding time and concentrations for escape of mites (F=0.20, df =25,108, P=1.0000) but a significant interaction for mortality (F=1.64, df=25, P=0.0441) (Table V). Thiacloprid was also moderately harmful for *N. barkeri* whereas maximum mortality (65%) was reported at field relevant dose (600 ppm) after 72 h while minimum mortality (2.50%) was reported at 37.5 ppm concentration after 24 h interval (Table VI). There was a non-significant interaction regarding time and concentrations for escape of mites (F=0.21, df =25,108, P=1.0000) and a highly significant interaction for mortality (F=3.68, df=25,108 P≤0.0000) (Table VI). The predatory mites escape from the arena were highly significant (F=5.51, df=5,108 P≤0.0001) (F=3.56, df=5,108, P≤0.0051) at different concentrations of pyriproxyfen and chlorfenapyr (Tables II and IV) (df=5, P≤0.0000) for acetamiprid, diafenthiuron and thiacloprid (Tables III, V and VI).

The escape of mites was found significantly different at different time intervals and remained non-significant (F=1.96, df=5,108, P=0.0907), (F=1.42, df=5,108, P=0.2218) for pyriproxyfen and diafenthiuron (Tables II and V) a significantly different (F=2.29, df=5,108, P=0.508) for acetamiprid (Table III), highly significant (F=3.20, df=5,108, P=0.0098) for chlorfenapyr (Table IV), and significant (F=2.47, df=5,108, P=0.0371) for thiacloprid (Table VI). Highest escape of predator was observed in the start of experiment, then no further escape could be due to acclimatization on leaf disc. The classification of pesticides toxicity against beneficial arthropods of our agro-ecosystem according to IOBC (International Organization for Biological Control) (Jansen, 2010) category under laboratory conditions was given in Table VIII. Probit analysis revealed LC_{50} values were varied according to all tested pesticides.

LC_{50} values after 144 h were 6314, 1280, 985, 405 and 295 for diafenthiuron, pyriproxyfen, chlorfenapyr, acetamiprid and thiacloprid respectively (Table VII). Thiacloprid was highly toxic for *N. barkeri* exhibiting the lowest LC_{50} value.

DISCUSSION

Mortality and repellent effects due to tested pesticides varied significantly for *N. barkeri* (Acari: Phytoseiidae). Pyriproxyfen at field relevant dose had least harmful effects and these outcomes are in agreement with findings of

Table VI.- Effect of thiacloprid administered for different time period on mortality (%) of *N. barkeri* (n=10) leaf arenas.

Mortality (%)	Treatment						
	T1	T2	T3	T4	T5	T6	Mean
24	22.50 ± 2.50b	17.50± 2.50de	10.00 ± 0.00e-h	7.50 ± 2.50f-i	2.50 ± 2.50hi	0.00 ± 0.00i	10.00± 1.81C
48	40.00 ± 4.08a	27.50± 2.50c	17.50 ± 2.50de	12.50 ± 2.50efg	5.00 ± 2.89ghi	2.50 ± 2.50hi	17.50± 2.90B
72	60.00 ± 4.08a	40.00± 4.08b	22.50 ± 2.50cd	12.50 ± 2.50efg	5.00 ± 2.89ghi	2.50 ± 2.50hi	23.75± 4.42A
96	65.00 ± 5.00a	42.50± 4.79b	27.50 ± 4.79c	12.50 ± 2.50efg	5.00 ± 2.89ghi	5.00 ± 2.89ghi	26.25± 4.77A
120	65.00 ± 5.00a	42.50± 4.79b	27.50 ± 4.79c	15.00 ± 2.89def	5.00 ± 2.89ghi	5.00 ± 2.89ghi	26.67± 4.73A
144	65.00 ± 5.00a	42.50± 4.79b	27.50 ± 4.79c	15.00 ± 2.89def	5.00 ± 2.89ghi	7.50 ± 2.50g-i	27.08± 4.64A
Mean	52.92 ± 3.73A	35.42± 2.48B	22.08 ± 1.90C	12.50 ± 1.09D	4.58 ± 1.04E	3.75 ± 1.01E	
Missing (%)							
24	10.00 ± 0.00	7.50± 2.50	10.00 ± 0.00	12.50 ± 2.50	7.50 ± 2.50	5.00 ± 2.89	8.75± 0.92C
48	10.00 ± 0.00	10.00± 0.00	10.00 ± 0.00	12.50 ± 2.50	7.50 ± 2.50	7.50 ± 2.50	9.58± 0.73BC
72	12.50 ± 2.50	10.00± 0.00	10.00 ± 0.00	12.50 ± 2.50	7.50 ± 2.50	7.50 ± 2.50	10.00± 0.85ABC
96	15.00 ± 2.89	12.50± 2.50	10.00 ± 0.00	12.50 ± 2.50	10.00 ± 0.00	7.50 ± 2.50	11.25± 0.92AB
120	15.00 ± 2.89	12.50± 2.50	12.50 ± 2.50	15.00 ± 2.89	10.00 ± 0.00	7.50 ± 2.50	12.08± 1.04A
144	15.00 ± 2.89	12.50± 2.50	12.50 ± 2.50	15.00 ± 2.89	10.00 ± 0.00	7.50 ± 2.50	12.08± 1.04A
Total	12.92 ± 0.95AB	10.83± 0.83BC	10.83 ± 0.58BC	13.33 ± 0.98A	8.75 ± 0.69CD	7.08 ± 0.95D	

For statistical and other detail see Table I.

Table VII.– Cumulative LC_{50} values of tested pesticides against *N. barkeri.*

Pesticides	LC_{50}	SE	95% Fiducial CI		Chi square	P Value
			Upper	Lower		
Pyriproxyfen	1279.93	478.69	478.6973	734.1133	2.130	0.546
Acetamaprid	405.292	74.45	300.3058	648.3242	4.951	0.175
Diafenthiuron	6314.55	971.60	4817.297	9102.761	0.694	0.875
Thiacloprid	295.516	22.58	254.3607	345.0062	1.259	0.739
Chlorfenapyr	985.609	82.54	832.7281	1163.507	0.222	0.974

CI, Confidence interval; P, Probability.

Table VIII.– Category of tested pesticides against *N. barkeri.*

Tested pesticides	Maximum mortality*	Standard mortality**	Categories
Pyriproxyfen	25%	0-25%	Harmless
Acetamiprid	30%,	26-50%	Slightly harmful
Diafenthiuron	50%	26-50%	Slightly harmful
Thiacloprid	65%	51-75%	Moderately Harmful
Chlorfenapyr	70%	51-75%	Moderately Harmful
—	—	>75%	Harmful

*, At field relevant dose up to 144 h; **, According to IOBC (Jansen, 2010).

Villanueva and Walgenbach (2005), who observed similar trend of mortality (1.3%), (5.0%) and missing (10.0%),(16.3%) at 105ppm after 24 and 96 h respectively, against *Neoseiulus fallacis*. Our results also matched with IOBC/wprs recommendations reported by Jansen (2010) that in field conditions pyriproxyfen at dose rate of 50grams active ingredients per hectare had moderately harmful effects against *Typhlodromus pyri*. Harmless effects of acetamiprid against *N. barkeri* were noted. These findings are in agreement with Beers and Schmidt (2014), who tested acetamiprid against *Galendromus occidentalis* at different dose rates *i.e*., 357(2X), 179(X), 18(0.1X) and 0 mg active ingredients per liter and found 36.00, 32.00, 40.00 and 0.00 percent mortality respectively. Villanueva and Walgenbach (2005) tested acetamiprid at dose rate of 115 ppm against *Neoseiulus fallacis* and observed mortality as (8.8%), (26.1%) and escape (8.8%), (17.0%) after 24 and 96 h respectively. Kongchuensin and Takafuji (2006) tested acetamiprid at 200ppm dose rate against *Neoseiulus longispinosis* and observed 60.2% mortality. These results are not in agreement to our findings which could be due to difference of species and experimental conditions. Poletti *et al*. (2007) tested acetamiprid at dose rate of 80mg active ingredients per liter against *Neoseiulus californicus* and *Phytoseiulus macropilis* and found comparatively less mortality (10.0%) and (2.0%) after 48 h. These difference of results could be attributed to difference of species and conditions. According to IOBC/wprs recommendations, acetamiprid was harmless against *Typhlodromus pyri* and *Phytoseiulus persimilis*. Our findings are in agreement with IOBC/wprs who declared acetamiprid safer against tested predatory mites. Results of our study revealed toxic effects of chlorfenpyr against *N. barkeri,* while Cloyd *et al*. (2006) observed different effects of chlorfenapyr against *Neoseiulus californicus* and *Phytoseiulus persimilis* and found (89%, 47%) survivors at 0.40 ml/2L dose rate and (85%, 52%) and at 0.81ml/2L dose rate respectively. Our results showed different mortality trend according to dose rate. Moderately toxic effect of chlorfenapyr was examined by IOBC/wprs. Its toxicity caused adverse effects on tested predatory mite and hence not recommended in IPM module. IOBC/wprs tested diafenthiuron at dose rate, 500 g active ingredients per hectare against *Typhlodromus pyri* and *Phytoseiulus persimilis* and found harmless and observed very slight toxic effects. Higher mortality percentage (50) at field relevant dose was observed. In the present results high mortality from diafenthiuron was due to formulation difference (50% SC) as compared to results of IOBC. The present study confirmed thiacloprid as toxic pesticide for predatory mites which is in agreement with findings of Vilanueva and Walgenbach (2005), who tested thiacloprid at 75ppm against *Neoseiulus fallacis* and found (2.5%) mortality and (12.5%) missing after 24 h and (14.8%) mortality and (12.4%) missing after 96 h. Similar results in our experiment regarding missing indicate repellent action of thiacloprid as same whereas high mortality in our experiment may be due to change in conditions and species under test. Our results are also in relevance to Cuthbertson *et al*. (2012), who tested thiacloprid at dose rate 0.45ml/L against four predatory mites, *Neoseiulus cucumeris, Typhlodromips montdorensis, Iphiseius degenrans* and *Amblyseius swiriskii* and found (18%, 4%, 56%, 10%) mortality after 24 h and (20%, 18%, 72%, 18%) mortality after 48 h respectively. Moreover IOBC/wprs, tested thiacloprid 480 SC against *Typhlodromus pyri* and observed slightly harmful effects. Our results are in disagreement with IOBC due to difference of species used in both cases.

CONCLUSION

Pyriproxyfen and acetamiprid were found harmless against *Neoseiulus barkeri* under laboratory conditions. These are selective pesticides and suggested to be used in recommended dose rates against their target pests. While diafenthiuron, thiacloprid and chlorfenapyr were toxic pesticides against tested predatory mite hence not recommended to be use in IPM module. However further research is still needed to study sublethal effects of these tested pesticides on further generations of this predatory mite.

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Statement of conflict of interest

Authors have declared no conflict of interest.

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