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Comparative selectivity of acaricides to the predatory mites of *Phytoseiulus persimilis* and *Neoseiulus californicus* (Acari: Phytoseiidae)

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Abstract:

To address suitable acaricides, the selectivity and efficacy of five acaricides of bifenazate, cyflumetofen, pyridaben, pyridaben+clofentezine and spirodiclofen to two predacious mites *Phytoseiulus persimilis persimilis* (Athias-Henriot), *Neoseiulus californicus* (McGregor) (Acari: Phytoseiidae) and its prey *Tetranychus urticae* Koch. (Acari: Tetranychidae) were tested. The general selective toxicity ratio (G.S.T.R.) of five acarcides which combines the selectivity ratios of both LC_{50} and LC_{90} levels was estimated. Results revealed that both spirodiclofen and pyridaben +clofentezine had the highest toxicity on both predators, *P. persimilis* and *N. californicus*. The values were 1.81 and 1.69 ppm for *P. persimilis* and 2.69 and 1.66 ppm for *N. californicus* at LC_{50} and LC_{90} levels, respectively. However, cyflumetofen have the lowest toxicity values for each of *P. persimilis* and *N. californicus* with the same values of 0.001 ppm at LC_{90} levels. Based on the G.S.T.R., cyflumetofen, and bifenazate recorded harmless performances, whereas the other tested compounds recorded harm effects on the two used predators. The results of field studies showed that the greatest percent reductions of spider mite population on kidney bean plants were obtained by cyflumetofen (93.4 %) in China and pyridaben (89.3%) in Egypt. On other hand, pyridaben treatment gave the highest significantly percentage of reductions of 98.2 and 96.7 % against the two tested predators, respectively, under greenhouse conditions. However, the lowest percentage of reduction was obtained by the two treatments of bifenazate and cyflumetofen against the previous two predators with no difference effect between the two acaricides. It could be concluded that the recommended acaricides to control spider mites are bifenazate and cyflumetofen, based on the efficacy and toxicity with no or less harmful on associated predatory mites

Introduction

The two spotted spider mite *Tetranychus urticae* Koch. (Acari: Tetranychidae) is an important global agricultural pest. Its' high reproductive potential and short life cycle facilitate rapid resistance development to many acaricides often after a few applications (Stumpf and Nauen, 2001 and Van Leeuwen *et al*., 2015). Although different strategies have been adopted for *T. urticae* management (McMurtry and Croft, 1997 and O'Neal *et al*., 2015), the application of pesticides remains essential for controlling them in many agro-ecosystems from reaching economic injury (O'Neal *et al*., 2015). If used properly, pesticides could suppress high populations of the two spotted spider mite. However, pesticides treatments are responsible for the reduction of associated predatory mites.

Predatory mites in the subclass Acari, family Phytoseiidae are often effective management components of agricultural systems (Van Lenteren and Woets, 1988). *Phytoseiulus persimilis persimilis* (Athias-Henriot) and *Neoseiulus californicus* McGregor (Acari: Tetranychidae) are widely used in biological programmes throughout the world (Cho *et al*., 1995 and McMurtry and Croft, 1997). However, several studies indicated that, despite the effectiveness of phytoseiid predators for biological control of spider mites on their host plants, the predators alone may not be able to maintain spider mite populations below an economic injury level for an extended period (Kim *et al.*, 2005). Currently, great efforts are directed towards reduction in the use of traditional pesticides and towards increase in the use of integrated pest management (IPM) techniques. However, the search for pesticides that are compatible with IPM programmes is an interesting approach.

Understanding the effects of chemicals and the impact of their residues on *T. urticae* and its associated predatory mites is necessary for pest management. The selectivity of pesticides against beneficial arthropods should also be considered. Selective insecticides have several advantages over broad-spectrum insecticides including shorter pre-harvest intervals due to their lower mammalian toxicity and greater compatibility with biological control because of their less harmful effects on natural enemies. Knowledge of miticides selectivity to predatory mites is important to their utilization in IPM programmes.

Integrated pest management (IPM) is already introduced as an effective tactics against the two spotted spider mites. Several factors bended this introduction. One of them is the side effect of pesticides on the predators. In this study, the efficacy, persistence and toxicity of five chemical acaricides commonly used to control spider mites in China was investigated. Subsequently, the purpose of present experiments were onducted to find out the most effective tested acaricides under field and greenhouse conditions against mites with no or less harmful on associated predatory mites.

The main aim of the present study is to clarify the toxicity or selectivity of five acaricides against the predator *P. persimilis*, *N. californicus* and its prey *T. urticae.*The results will be useful to set up a list of recommendeded registered acaricides as a general selective toxicity ratio for integrated mite management in both Egypt and China.

Materials and methods

1. Two spotted spider mite *Tetranychus urticae* and predator cultures:

Laboratory colonies each of the two spotted spider mite *T. urticae* and the two used predatory mites, *P. persimilis* and *N. californics* were maintained under 25 ± 1 °C, 65 ± 5% RH., and a photoperiod of 16:8 (L:D) h at the Laboratory of Predatory mites, Institute of Plant Protection, Chinese Academy of Agricultural Sciences (IPP-CAAS), Beijing, China.

The strains of the predatory mites of *N. californicus* and *P. persimilis* were put on sub colony of each experimental unit. The experimental rearing unit each consisted of a 75 mm-diameter black plastic film placed on a piece of filter paper (90 mm diameter), both placed on a water saturated sponge (90 mm diameter × 60 mm height) laying in a 140 mm ×120 mm (diameter x height) plastic boxes. Each box was approximately half filled with water to isolate the rearing arena. These unites were maintained at 25ºC, 80% RH. and 16:8 L:D.

2. Miticidal formulations:

The five commercial pesticides of cyflumetofen 20%, bifenazate, (Acramite® 43%, pyridaben,(Damanling 15% EC); spirodiclofen (Envidor 240g/L SC) and pyridaben+clofentezine (5%+5%) were selected for trials because of their widespread use on fruits and vegetables in most conventional agriculture. Acaricides used with their active ingredient, trade names, mode of action, recommendeded dose and respective manufacturers are briefly shown in Table (1).

Table (1):General features and application doses of the acaricides used in the study.

Active ingredient	Trade name with formulation type	Mode of action	Application dose (mL/100 L water)	Source Supply
Cyflumetofen	Cyflumetofen 20% EC	Inhibit electron transport complex II, preventing the utilization of energy by cells.	30 mL	FMC China An Agricultural Sciences Company
Bifenazate	Acramite® 43%	Inhibit electron transport complex III, preventing the utilization of energy by cells.	35 mL	*Arysta Life Science*
Pyridaben	Pyridaben 15%	Inhibit electron transport complex I, preventing the utilization of energy by cells	150 mL	Jiangsu Huifeng Agrochemical Co., Ltd.
Pyridaben Clofentezine	Pyridaben Clofentezine SC 10% (5:5)	Incompletely defined mode of action leading to growth inhibition.	100 mL	Sichuan Guoguang Agrochemical Co., Ltd.
Spirodiclofen	Envidor® 240 SC	Inhibit acetyl coenzyme A carboxylase, part of the first step in lipid biosynthesis	30 mL	Bayer Crop Science

3. Toxicological experiments:

Direct spray technique was used to test the effect and selectivity of the tested acaricides against each of the adult females of the two-spotted spider mite, *T. urticae* and both the predators. One circular leaf disc each with 3 cm in diameter punched from the bean leaves were put in petri-dishes with 90 mm in diameter lined with water saturated cotton wool. Twenty-five adult females of the two-spotted spider mite at the same age (2 days) were transferred by aid of fine brush to the upper surface of each leaf disc to test the effect of the tested acaricides against themite.Serial concentrations for each tested acaricide were prepared in aqueous solution and four replicates for each concentration were used. The range of concentrations was chosen based on preliminary trials. Discs were sprayed with a constant amount of the toxicant solution determined by spraying pressure for three seconds by means of glass manual atomizer. Controls were sprayed only with distilled water, since distilled water was used to dilute the compounds.

On other hand, the same previous methods were followed with each of the two tested predatory mites. Ten adult females of each predatorwere transferred onto each leaf disc supplemented with *T. urticae* served as the prey of the predatory mites. There were 5 replicates for each pesticide treatment and the control.

All treatments were incubated in growth chamber under constant conditions of 25±2°c and 65±5% R.H. and 16:8 hrs L:D. The mortality counts were estimated after 24 hrs of each treatment. The criterion for mortality was considered the failure of mites to respond positively by leg movement following light prodding with a fine brush. The percentage mortality in all treatments was corrected using Abbott's (1925) formula. The toxicity lines were statistically analyzed according to the method described by Finny (1977). Toxicity lines were statically analysis using a probit procedure for the subsequent experiments to assess the lethal LC_{50}, and LC_{90}.

4. Chemical control:

4.1. Greenhouse experiment:

Greenhouse trial was conducted in Institute of Plant Protection, Beijing, China to evaluate the impact of the five pesticides considered in glasshouse trial on each of *T. urticae*, *P. persimilis* and *N. californicus* populations in a more realistic situation. Seeds of local Chinese variety of kidney bean were sown directly in 100 pots 20-cm in diameter with the rate of 5 seeds per pots, filled with soil and peatmoss in a 2:1 ratio, respectively. The potted bean plants were grown in growth chamber conditions for one week until they reached the two true leaf stage. Then, the two-spotted spider mites *T. urticae* were released onto each plant and allowed to multiply for one week. Each of five pots were placed into an individual cage (120 by 60 by 60 cm). Cages were covered with nylon fabric. On other hand, four days before the pesticide applicationseither *P. persimilis* or *N. californicus*was released onto six cages for multiplication. The average release rate was approximately a 10:1 ratio (10 twospotted spider mite to one predatory mite). Cages were used to keep both the two-spotted spider mites and two associated predatory mites from dispersing between plants.

Experimental design was a completely randomized block with three groups (18 cages for each group). Each group was including six treatment (five treated and one untreated) with three replicates for each. Groups consisted of 1) only *T. urticae* without any predatory mites, 2) 10 *P. persimilis* adults released per infested plant, 3) 10 *N. californicus* adults released per infested plant.

Five acaricides were applied using a commercial hand sprayer until run-off for each group at the recommendeded dose. The control plants were sprayed with distilled water. The effect of five acaricides on *T. urticae, P. persimilis* and *N. californicus* each were evaluated 1, 3, 5, 7, 10, and 15 days after pesticide applications by counting phytoseiid motile forms. Data are reported as means and, efficacy was evaluated according to **Henderson and Tilton (1955).**

4.2. Field experiment:

The field experiment was in carried out in each of Ismailia Agriculture Research station, Egypt and Institute of Plant Protection, Beijing, China on kidney bean (*Phaseolus vulgaris* L.) at the same period from April 28th to 12th May in 2019. The field experiments were designed according to "Guidelines for field efficacy, pesticides against two spider mites, 2018 (Egypt)".

Bean seeds were sown directly in small pots (5 cm) with the rate of 2 seeds per pots, filled with soil and peatmoss in a 2:1 ratio, respectively. The pots were kept in growth chamber for one week, then bean seedlings were transferred to field. Bean seedlings were planted in plots 7.5 by 2.5 m consisting of five rows with 0.25-m row spacing. The plots were arranged in a randomized complete block design with four replications and separated by an unplanted alley (1 m). All the normal agronomic practices were followed as usual throughout the experiment.

The experimental area was divided into six treatments including the control. Seven days before the test, each plot was infested with *T. urticae* with the same pieces of infested leaves and at the beginning of the trial, the beans in each plot was seriously infested. Each test plot was sprayed with the active ingredient at the recommendeded dose. The acaricides were sprayed with manual operated knapsack sprayer having 5 liters capacity fitted with hollow cone nozzle. The spray machine was clean completely before any acaricide was sprayed. The control plot was sprayed with water only. Forty leaves per treatment were picked up randomly for scouting of mites. Each treatment included four replicates. Only one spraying was applied. Samples were taken before treatment and then 1, 3, 5, 7 10, and 14 days after the application from treated and untreated plots. Representative samples were collected randomly after spraying with each replicate.

4.3. Statistical analysis:

Samples were examined and alive moving stages were counted recorded to one square inch of each leaf. Percentage of reduction was estimated according to the equation of Henderson and Tilton (1955).The numbers of motile forms of mites per plot were subjected to ANOVA and significant differences in means were identified by Tukey´s tests (0.05). The efficacy of acaricides was calculated by Henderson-Tilton’s formula to estimate the percentage of reductions.

To calculate the general selective toxicity ratios of the tested acaricides, the method of Abd El-Aal *et al* .(1979) with slight modified by El-Adawy *et al*. (2000), was used as follow:

The linear equation of Finney is

$Y= a + b \log x$ (1)

Where Y= probit mortality, and x = concentration.

From above equation, LC90 and LC50 can be related

$6.28= a+b \log LC_{90}$ (2)

$5.00= a+b \log LC_{50}$ (3)

Where 6.23 and 5.00 values are the probit mortality of 90 and 50 %, respectively. By subtracting equation (3) from equation (2) and tacking the antilogarithm, Equation 4 is obtained:

$LC_{90}= LC_{50} x\ 10^{1.28/b}$ (4)

Assuming that three species, *T. urticae*, *P. persimilis*, and *N. californicus* are to be compared at LC_{90} the following equation results:

$LC_{90}(mite)/ LC_{90}(predator)= LC_{50}(mite) \times 10^{1.28/b\ (mite)} / LC_{50}(predator) \times 10^{1.28/b\ (predator)}$ (5)

Or

$LC_{90}(mite)/ LC_{90}(predator)= LC_{50}(mite)/ LC_{50}(predator) \times 10^{1.28/b\ (mite) - 1.28/b\ (predator)}$ (6)

The selectivity ratio (s.r.) at LC_{90} level can be combined with LC_{50} in one parameter {general selective toxicity ratio (G.S.T.R.)} by employing the following equation:

$G.S.T.R. = (\text{experimental s.r.at LC50}) \times 10^{1.28 (\frac{bp-bm}{bpxbm}}$

Where:

G.S.T.R = general selective toxicity ratio,

s.r. = selectivity ratio

bp = slop of the toxicity line on the predator

bm = slop of the toxicity line on the mite

Results and discussion

Data in Table (2) showed that cyflumetofen was the most potent compound tested at LC_{50} (0.6 ppm) and LC_{90} (2.66 ppm) levels against the adult female of the mite *T. urticae*, followed discerningly bypyridaben (2.53 and 9.77 ppm), pyridaben+clofentezine (3.12 and

13.48 ppm), bifenazate (3.91 and 15.66 ppm) and spirodiclofen (10672.3 and 44567.48 ppm), respectively. However, pyridaben was the most potent compound tested at both levels of LC_{50} and LC_{90} against the adult female of the predatory mite of *P. persimilis*, followed discerningly bypyridaben+clofentezine, bifenazate, cyflumetofen, and spirodiclofenat LC_{90} level for the previous compound, respectively (Table, 3).

The same trend was observed with the predatory mite of *N. californicus* (Table, 4). The acaricides pyridaben+ clofentezine was the most impact compound tested at both levels of LC_{50} (1.16 ppm) and LC_{90} (8.11 ppm) against the adult female of the predator. While the lowest effective compound was spirodiclofen. The side effect of the tested five acaricides on the two predatory mites was shown in Table (5). The toxicity values varied from 0.001 to 1.81 for *P. persimilis* and 0.001 to 1.938 for *N. californicus* at LC_{50}. Whereas these values varied from 0.001 to 1.695 for *P. persimilis*and 0.001 to 1.486 for *N.californicus* at LC_{90}. The two acaricides of spirodiclofen and pyridaben+ clofentezine had the highest toxicity on the two predators of *P. persimilis* and *N. californicus* at the two former levels, respectively.

The values were 1.81 and 1.69 ppm for *P. persimilis* and 2.69 and 1.66 ppm for *N. californicus* at LC_{50} and LC_{90} levels, respectively. However, the acaricides of cyflumetofen have the lowest toxicity values at each of the levels for each of *P. persimilis and N. californicus* with the same values of0.001 ppm at LC_{90} and LC_{90} levels, respectively. The selectivity ratio of cyflumetofen, bifenazate, at LC_{50} and LC_{90} levels have values less than one for both tested two predators, which means these acaricides are safe to these predators; whereas the remaining acaricides have values greater than one at the same level. As regard to general selective toxicity ratios (Table, 5) it could be seen that all the tested acaricides have values greater than one except cyflumetofen and bifenazate.

In other findings, data (Table, 6) showed the effect of five tested chemical of acaricides on the populations of active stages of twospotted spider mite *T. urticae*on kidney bean under field conditions in China and Egypt. It revealed that all treatments reduced the mean numbers of mite population compared with untreated one. The highest percent reductions of mite's population in the whole period were obtained by the acaricide of cyflumetofen in China and pyridaben in Egypt. The obtained percentage reductions were 93.4 % by cyflumetofen, followed by pyridaben (91.3%), bifenazate (90.9%) and pyridaben+clofentezine (89.8%), with no significant difference among of these compounds. On other hand, the same trend was recorded in Egyptian field . Pyridaben application gave the highest percentage of reduction (89.3%), followed by cyflumetofen (88.7%), bifenazate (86.4%) and pyridaben+clofentezine (84.7%), with no significant difference among the compounds. However, the least percentage of reduction was obtained in spirodiclofen treatment in both field trails with an average reduction of 82.7% and 78.0% respectively. No phytotoxic symptoms were found on leaves or any other plant parts in any of the treated plots.

Results in Table (7) shows the effect of five tested compounds on the populations of the two predatory mites of the most common predators of the twospotted spider mite. The obtained results showed highly significant difference among the tested pesticides in their effect on the two predators of *P. persimilis* ($F=757.4$, $P<0.0001$) and *N. californicus* ($F=501.2$, $P<0.0001$) in the whole period. Pyridaben treatment gave the highest percentage of reductions of 98.2 and 96.7 % for two predators, respectively, without significant difference effect for the treatments between pyridaben+clofentezine and spirodiclofen. However, the least percentage of reduction was obtained by the two treatments of bifenazate and cyflumetofen for the previous two predators with no difference effect between the two acaricides.

The foregoing results clearly show that existing of two selectivity ratios to each acaricide at LC_{50} and at LC_{90} levels maybe cause disturbance in our estimation for the tested compounds. The general selective toxicity ratio resulting from combining the two former levels LC_{50} and $LC_{90,}$ is more useful. It can be relied on as a sufficient parameter to determine the least toxic acaricide against the two predatory mites*P. persimilis* and *N. californicus*. Also, to recommended the suitable acaricides to control the two-spotted spider mite throughout integrated pest management which the predator is dominant.

Broadly effective pesticides used in pest control cause side effects on natural enemies as well as predator mites, *P. persimilis* and *N. californicus.* Identifying the side effects of the pesticides on natural enemies is of importance for developing integrated control methods. Therefore, it is necessary to searching for the suitable selective pesticides that have the lowest effect on the beneficials in integrated control programs. It is possible to use the pesticides identified as harmless or not very harmful for predatory mites in production areas. It is also thought that the development of resistance in pests will be reduced based on the decrease in pesticide use (Marcic, 2012).

Alternative management strategies include the use of predatory mites along with pesticides instead of using pesticides alone in production areas (Cloyd *et al*., 2006). To identify the most selective pesticides that could be used in pest biocontrol strategies, it is very important to know the side effects of these products on the most relevant natural enemies for each specific crop.

A similar pattern of toxicity against the two-spotted spider mite has been previously reported for spirodiclofen (Marcic, 2007 and Van Pottelberge *et al.,* 2009). The results showed that the field rate of spirodiclofen was very toxic (82-96% mortality) after 7 and 21days following treatment for *T. urticae* but not for the predatory mite *Amblyseius andersoni* Chant (Acari: Phytoseiidae) (Rhodes *et al.,* 2006). They also suggested that release of phytoseiid mites after applying bifenazate at half the recommendeded rate effectively could control *T. urticae* in strawberries. Pyridaben was tested against red spider mite on marigold plants and was found to give higher mortality of nymphs over the adults (Raymond *et al*., 2010). Lee and Kim (2015) evaluated effects of 9 acaricides to the predatory mite *N. californicus*. Cyenopyrafen, spirodiclofen, spiromesifen, acequinocyl, bifenazate, flufenoxuron and cyflumetofen exhibited low toxicity to adult females and nymphs of *N. californicus* and had little effect on the reproduction and hatching of eggs deposited by treated predators. Based on the results, the seven above-mentioned acaricides are appeared to be promising candidates for use in integrated mite management program where *N. californicus* is the major natural enemy.

In contrary, Salman and Turan (2017) revealed that acequinocly, etoxazole, bifenazate and milbemectin showed high levels of toxicity on the nymphs and adults of *P. persimilis* and *N. californicus* at seventh days after applying. Kim and Yoo (2002) reported that bifenazate, acequinocyl, chlorfenapyr, flufenoxuron and fenbutatin oxide were very toxic against *P. persimilis* adults. In the field and greenhouse trails, there were fewer two spotted spider mites in the *N. californicus* treated plots compared with the *P. persimilis* treated ones. This suggests that *N. californicus* may be better for tolerance of the tested acaricides and environmental conditions than *P. persimilis.* In this study, it is also known that *P. persimilis* suppress quickly the twospotted spider mite populations under controlled conditions. Therefore, *P. persimilis* cannot survive in areas where its food is devoid. These results argued strongly that the use of various pesticides for the mite control should be carefully monitored in order to avoid deleterious side effects on the predator's complex that may result in a rapid increase of non-target insect species. Furthermore, field releases of the biological control agents such as *P. persimilis* and *N. californicus* could employ selective pesticides such as bifenazate and cyflumetofen.

Finally, results regarding side effect studies conducted with predatory mites in the pesticide lists to be updated in the future will make contribution to the early planning of an integrated mite management program. The identification of the side effects of the pesticides used will enable the use of preparations that are harmless or a little harmful to natural enemies. Thus, the feasibility of biological control will be facilitated, the use of excessive pesticide doses will be prevented, and the environment and the health of living individuals will be protected.

Table (2): Probit analysis for five acaricidal activities against adult female stage of the two spotted spider mite *Tetranychus urticae*.

Chemical Compound	Lethal concentrations [a] (95% Lower-Upper of confidence limits)		Slope [b] ± standard errors (SE)	X^2 (df; *P*-value) [c]	Heterogeneity
	LC_{50}	LC_{90}			
Bifenazate	3.91 (3.3-4.6)	15.66 (11.7-29.3)	2.12 ± 0.10	7.68 (5; *P*<0.001)	1.92
Cyflumetofen	0.60 (0.53-0.68)	2.66 (1.79-4.33)	1.98 ± 0.08	4.70 (5; *P*<0.02)	1.17
Pyridaben	2.53 (2.35-2.74)	9.77 (6.56-15.03)	2.19 ± 0.09	2.67 (5; *P*<0.01)	0.67
Pyridaben Clofentezine	3.12 (2.67-3.65)	13.48 (8.59-20.12)	2.01 ± 0.20	7.19 (5; *P*<0.001)	1.80
Spirodiclofen	10672.3 (10058.4-11323.50)	44567.48 (29542.1-70018.51)	2.06 ± 0.01	1.27 (5; *P*<0.003)	0.32

a = Delivered median lethal concentration (LC_{50}) expressed by infective propagules $ml^{-1}$and estimated by the logistic model. Mortality censored up to day 3 and 5 application. Control mortality averaged 1.1±0.2%.
b = Slope for mortality represents regression of proportion of larval mortality versus log_{10} of propagules ml^{-1}.
c = chi-squared goodness of fit test (X^2), degrees of freedom (df), and *P*-value represent the probability of slope.

Table (3): Probit analysis for five acaricidal activities against adult female stage of *Phytoseiulus persimilis*.

Chemical Compound	Lethal concentrations [a] (95% Lower-Upper of confidence limits)		Slope [b] ± standard errors (SE)	X^2 (df; *P*-value) [c]	Heterogeneity
	LC_{50}	LC_{90}			
Bifenazate	165.6 (133.8-205.1)	661.1 (432.0-987.5)	2.13 ± 0.12	7.69 (5; P<0.002)	1.92
Cyflumetofen	464.49 (373.1-578.4)	1944.55 (1388.9-3285.8)	2.06 ± 0.12	7.62 (5; P<0.001)	1.91
Pyridaben	1.51 (1.18-2.05)	7.21 (5.31-11.32)	1.94 ± 0.12	11.40 (5; P<0.001)	2.19
Pyridaben Clofentezine	2.05 (1.52-2.70)	12.87 (8.21-23.23)	1.60 ± 0.10	7.99 (5; P<0.001)	1.99
Spirodiclofen	6295.79 5147.82.40-7700.43)	32196.67 (29542.1-70018.51)	1.81 ± 0.11	5.24 (5; *P*<0.008)	1.31

Table (4): Probit analysis for five acaricidal activities against adult female stage of Neoseiulus californicus.

Chemical Compound	Lethal concentrations [a] (95% Lower-Upper of confidence limits)		Slope [b] ± standard errors (SE)	X^2 (df; *P*-value) [c]	Heterogeneity
	LC_{50}	LC_{90}			
Bifenazate	226.0 (186.7-273.6)	769.5 (536.1-1185.0)	2.41 ± 0.14	6.93 (5; *P*<0.001)	1.95
Cyflumetofen	546.75 (432.6-691.4)	2489.92 (1664.8-4160.3)	1.95 ± 0.12	7.79 (5; *P*<0.001)	1.64
Pyridaben	2.25 (1.75-2.86)	12.90 (7.51-20.84)	1.69 ± 0.11	6.55 (5; *P*<0.001)	1.74
Pyridaben Clofentezine	1.16 (0.87-1.51)	8.11 (5.07-14.91)	1.52 ± 0.10	6.97 (5; *P*<0.001)	1.22
Spirodiclofen	5506.17 (4510.68-29926.47)	29926.47 (21674.1-56704.08)	1.74 ± 0.11	4.88 (5; *P*<0.003)	1.95

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Table (5): Toxicity of five acaricides to the two spotted spider mite *Tetranychus urticae* and the two predators, *Phytoseiulus persimilis* and *Neoseiulus californicus*.

Compound	*Tetranychus urticae*			*Phytoseiulus persimilis*			Selective ratio at level		General selective toxicity ratio*	*Neoseiulus californicus*			Selective ratio at level[a]		General selective toxicity ratio*
	LC_{50}	LC_{90}	Slope	LC_{50}	LC_{90}	Slope	LC_{50}	LC_{90}		LC_{50}	LC_{90}	Slope	LC_{50}	LC_{90}	
Bifenazate	3.9	15.7	2.12	165.6	661.1	2.13	0.024	0.024	0.023	226.0	769.5	2.41	0.017	0.020	0.015
Cyflumetofen	0.6	2.7	2.0	464.5	1944.6	2.1	0.001	0.001	0.001	546.8	2489.9	1.95	0.001	0.001	0.001
Pyridaben	2.5	9.8	2.2	1.51	7.21	1.9	1.675	1.359	2.005	2.3	12.9	1.69	1.100	0.760	1.648
Clofentezine	3.1	13.5	2.0	2.1	12.8	1.6	1.6	1.486	1.055	1.16	8.11	1.5	2.690	1.665	4.396
Spirodiclofen	10672.3	44567.5	2.1	6295.8	32196.7	1.8	1.81	1.695	1.384	5506.2	29926.5	1.74	1.938	1.489	2.591

***Values greater than 1 indicate unsafe to the predator.**

Table (6): Effect of five acaricides on the percentage reduction of the two spotted spider mite *Tetranychus urticae* infesting kidney bean plants during season 2019 under field conditions of China and Egypt.

Compound	Rate of application M/100 L.Water	Percentage reduction in mite's population at indicated days after treatment (Numbers of mite /inch^2 at indicated days after treatment)													
		China							Egypt						
		0*	3	5	7	10	15	Mean	0*	3	5	7	10	15	Mean
Bifenazate		(36.3)	100.0 (0.0)	100.0 (0.0)	90.5 (4.6)	84.5 (6.6)	79.3 (10.2)	90.9 (4.3)	(11.1)	100.0 (0.0)	91.4 (1.1)	82.5 (1.6)	81.2 (3.0)	77.0 (4.1)	86.4 (2.2)
Cyflumetofen		(51.0)	100.0 (0.0)	100.0 (0.0)	93.1 (4.7)	89.8 (6.1)	84.3 (10.9)	93.4 (4.3)	(12.7)	100.0 (0.0)	93.8 (0.9)	87.6 (2.1)	83.0 (3.1)	78.9 (4.3)	88.7 (2.1)
Pyridaben		(34.3)	100.0 (0.0)	100.0 (0.0)	92.0 (3.7)	83.6 (6.6)	81.2 (8.8)	91.3 (3.8)	(9.7)	100.0 (0.0)	92.4 (0.9)	86.9 (1.8)	85.8 (2.1)	81.3 (3.1)	89.3 (1.6)
Pyridaben Clofentezine		(40.8)	100.0 (0.0)	100.0 (0.0)	90.3 (5.3)	80.2 (9.5)	78.5 (11.9)	89.8 (5.3)	(8.9)	100.0 (0.0)	90.1 (1.1)	82.3 (2.3)	79.2 (2.9)	71.8 (4.4)	84.7 (2.1)
Spirodiclofen		(25.2)	100.0 (0.0)	92.5 (2.4)	84.9 (5.1)	71.0 (8.6)	68.5 (10.8)	82.7 (5.5)	(10.7)	100.0 (0.0)	88.3 (1.2)	77.3 (2.7)	68.0 (4.1)	63.7 (5.2)	78.0 (2.8)
Untreated		(40.6)	(34.0)	(51.3)	(54.4)	(47.7)	(55.2)		(10.7)	(9.8)	(12.3)	(14.3)	(15.4)	(17.2)	(10.7)

Note: *pretreatment. Number in brackets means .

Table (7): Effect of five acaricides on the percentage reduction of the two predatory mites of *Phytoseiulus persimilis* and *Neoseiulus californicus* on kidney bean plants under greenhouse conditions.

Compound	Rate of application M/100 L.water	Percentage reduction in mite's population at indicated days after treatment (Numbers of mite /inch^2 at indicated days after treatment)													
		Phytoseiulus persimilis							*Neoseiulus californicus*						
		0*	3	5	7	10	15	Mean	0*	3	5	7	10	15	Mean
Bifenazate		(36.3)	9.1 (0.9)	0.0 (1.8)	0.0 (2.0)	0.0 (2.5)	0.0 (2.4)	1.8 (1.9)	(11.1)	1.8 (1.0)	0.2 (1.5)	0.0 (1.8)	0.0 (1.2)	0.0 (1.3)	0.4 (1.4)
Cyflumetofen		(51.0)	10.3 (1.0)	7.6 (1.9)	0.0 (2.2)	0.0 (2.7)	0.0 (2.8)	3.6 (2.7)	(12.7)	2.9 (1.2)	0.2 (1.9)	0.0 (2.3)	0.0 (1.5)	0.0 (1.7)	0.6 (1.7)
Pyridaben		(34.3)	100.0 (0.0)	100.0 (0.0)	100 (0.0)	97.2 (0.1)	93.8 (0.2)	98.2 (0.1)	(9.7)	100.0 (0.0)	100.0 (0.0)	100.0 (0.0)	92.3 (0.1)	91.1 (0.1)	96.7 (0.1)
Pyridaben Clofentezine		(40.8)	100.0 (0.0)	100.0 (0.0)	100 (0.0)	97.5 (0.1)	91.6 (0.3)	97.8 (0.1)	(8.9)	100.0 (0.0)	100.0 (0.0)	100.0 (0.0)	94.7 (0.1)	81.2 (0.4)	95.2 (0.1)
Spirodiclofen		(25.2)	100.0 (0.0)	100 (0.0)	100 (0.0)	96.3 (0.1)	88.0 (0.3)	96.9 (0.1)	(10.7)	100.0 (0.0)	100.0 (0.0)	100.0 (0.0)	91.7 (0.2)	85.1 (0.4)	95.4 (0.1)
Untreated		(1.3)	(1.3)	(2.4)	(2.7)	(3.3)	(3.1)		(10.7)	(1.4)	(2.1)	(2.6)	(1.7)	(1.9)	(10.7)

***pretreatment. Number in brackets means .**