Brazilian Journal of Biology®

ISSN 1519-6984 (Print)
ISSN 1678-4375 (Online)

Original Article

Side effects of abamectin and hexythiazox on seven predatory mites

Efeitos colaterais da abamectina e hexitiazox em sete ácaros predadores

S. S. Alhewairini[a*] and M. M. Al-Azzazy[a,b]

[a] Qassim University, College of Agriculture and Veterinary Medicine, Department of Plant Production and Protection, Qassim, Saudi Arabia
[b] Al Azhar University, Faculty of Agriculture, Agricultural Zoology and Nematology Department, Cairo, Egypt

Abstract

Use of acaricides has become a common practice to control pests all over the world including Saudi Arabia. In spite of killing the targeted pests, such insecticides also effect growth of predatory mites. Present study has been conducted to evaluate the impact of two acaricides, abamectin and hexythiazox, on seven species of predatory mites. Standard solutions of abamectin (8.4% w/v) and hexythiazox (10% w/w) were purchased and prepared for direct spray. Acaricides were tested at three serial concentrations of recommended dose (RD), half of the recommended dose (HRD) and double the recommended dose (DRD). Trials were made on eggs, nymphs and adults of the seven species of predatory mites under laboratory conditions. Effect of the applied acaricides was determined one week after the application. The results of the study revealed that all doses of hexythiazox and abamectin are toxic to the nymphs and adults of all seven species of predatory mites but to the variable extent. Furthermore, it was observed that hexythiazox and abamectin reduced the percentage of egg hatching for all seven species of predatory mites. Hexythiazox was found to be more toxic than abamectin to all seven predatory mites. Higher mortality was recorded at DRD and RD, while minimum mortality was recorded at HRD. Acaricidal effect is less severe on hatching eggs than on immatures and adults of the predatory mites. Species vary in susceptibility to acaricides and in some populations resistance has been observed. Based upon this study, it is recommended that the frequent use of acaricides against phytophagous mites should be avoided and feasibility of biological control programs should be promoted to protect the environment, health of living individuals and the non-target organisms.

Keywords: mites, acaricides, hexythiazox, abamectin, mortality.

Resumo

O uso de acaricidas se tornou prática comum para o controle de pragas em todo o mundo, incluindo a Arábia Saudita. Apesar de matar as pragas-alvo, esses inseticidas também afetam o crescimento de ácaros predadores. O presente estudo foi conduzido para avaliar o impacto de dois acaricidas, abamectina e hexythiazox, em sete espécies de ácaros predadores. Soluções padrão de abamectina (8.4% w/v) e hexitiazox (10% w/w) foram adquiridas e preparadas para pulverização direta. Os acaricidas foram testados em três concentrações seriais de dose recomendada (RD), metade da dose recomendada (HRD) e o dobro da dose recomendada (DRD). Os ensaios foram feitos em ovos, ninfas e adultos das sete espécies de ácaros predadores em condições de laboratório. O efeito dos acaricidas aplicados foi determinado uma semana após a aplicação. Os resultados do estudo revelaram que todas as doses de hexitiazox e abamectina são tóxicas para as ninfas e adultos de todas as sete espécies de ácaros predadores, mas em extensão variável. Além disso, foi observado que hexitiazox e abamectina reduziram a porcentagem de eclosão de ovos para todas as sete espécies de ácaros predadores. Verificou-se que o hexitiazox é mais tóxico do que a abamectina para todos os sete ácaros predadores. A mortalidade mais alta foi registrada no DRD e RD, enquanto a mortalidade mínima foi registrada no HRD. O efeito acaricida é menos severo em ovos para incubação do que em imaturos e adultos de ácaros predadores. As espécies variam em suscetibilidade a acaricidas, e em algumas populações foi observada resistência. Com base neste estudo, recomenda-se que o uso frequente de acaricidas contra ácaros fitófagos seja evitado e a viabilidade de programas de controle biológico seja promovida para proteger o meio ambiente, a saúde de indivíduos vivos e de organismos não visados.

Palavras-chave: ácaros, acaricidas, hexitiazox, abamectina, mortalidade.

1. Introduction

Global croplands are limited and global population is increasing rapidly. Thus, there is a continuous demand of efforts to increase crop yield, keeping in consideration food safety and the environment. One common and economical

*e-mail: hoierieny@qu.edu.sa
Received: April 23, 2021 – Accepted: July 8, 2021

way of increasing crop yield is the application of pesticides. The global utilization of pesticides is around two million tons per year. Europe consumes 45%, 25% is utilized in the USA, and 25% in the rest of the world including Saudi Arabia (Zhang, 2018). Acaricides are the pesticides that are used to kill members of the arachnid belonging to subclass acari, which includes ticks and mites. During the last few decades, worldwide use of pesticides has drastically increased to such an extent that it is effecting natural control system by killing predatory mites. To minimize toxic effects and develop integrated pest management strategies, integration of pesticides and natural enemies in a manner which is safer for other organisms is a key factor (Volkmar et al., 2008). However, not a lot of data are available on impact of pesticides on natural enemies of phytophagous mites and insects. One of the paradigms of ecotoxicology is the practical need to select a limited number of species for evaluating the environmental effects of chemicals, as data on impacts of pesticides on the environment and natural enemies have become obligatory for registration purposes in many countries. The number of laboratories involved in such tests has increased during the last decade (Haskell and McEwen, 2012).

Predatory mites of the family Phytoseiidae and Stigmeidae are important biological control agents for different phytophagous mites on various greenhouses, ornamental plants and variety of fruit crops. Their presence can even negate the need for the application of certain acaricides (Al-Azzazy, 2005; Metwally et al., 2005; Mailloux et al., 2010). In Saudi Arabia several species of phytoseiid mites are found in vegetable greenhouses and fruit orchards perennially inhabit or over winter in soft fruit crops (Al-Atawi, 2011; Fouly and Al-Rehiaya, 2011).

Neoseiulus cucumeris (Oudemans) (Acari: Phytoseiidae), *Amblyseius cydnodactylon* (Shehata and Zaherand), *Phytoseius plumifer* (Canestrini and Fanzago), *Typhlodromips swirskii* (Athias-Henriot), *Euseius scutalis* (Athias-Henriot), *Neoseiulus barkeri* (Hughes) (Acari: Phytoseiidae) and *Agistemus exsertus* (Gonzalez) (Acari: Stigmaeidae) are predatory mites of several acari pests. They play an important and influential role in either keeping phytophagous mite populations at a low level or reducing high populations and thus decreasing their pest status (Al-Azzazy, 2002; Abou-Awad et al., 2010; Mailloux et al., 2010; Shakarami and Bazgir, 2017; Li et al., 2018). Moreover, they have been extensively used for biological control of the eriophyid mite, *Aculops lycopersici* (Massee) and two-spotted spider mite, *Tetranychus urticae* (Koch) (Al-Azzazy et al., 2018) as both species have an economic importance. However, Alhewairini (2019) found that oxamyl and pyridaben can significantly affect the population of these predatory mites. Furthermore, Oliveira et al. (2020) documented that abamectin has lethal and sublethal effects on the population of *Phytoseiulus macropilis* (Banks).

Research conducted regularly on acaricides and mites with the aim of testing the side effects are of particular importance in order to develop integrated control strategy and make a final decision on the compounds to be used in these control programs (Kavousi and Talebi, 2003). Laboratory studies on side effects of acaricides on predatory mites are mostly done by estimating the median lethal concentrations or dose with some exceptional studies on field recommended/realistic dose. The missing link is the comparison of toxic doses/concentrations with the realistic field concentrations. Not only is the recommended dose one that is used against pests in the crop field and greenhouses, but also the misuse of a mixture of chemicals. As inappropriate following of the instructions can cause many health as well as environmental problems. So, for experimental purposes it is essential to use the same concentration for evaluation of the risks to non-target species and environmental hazards. Present study is aimed to determine the side effects of two acaricides (abamectin and hexythiazox) on mortality of seven predator mites, immatures and eggs.

2. Materials and Methods

2.1. Selection of region and predatory mites

This experimental work was conducted in the Laboratory of Department of Plant Production and Protection, College of Agriculture and Veterinary Medicine, Qassim University, Saudi Arabia, during the year 2018, to evaluate the side effects of two acaricides (abamectin and hexythiazox). Seven species of predatory mites, *N. cucumeris*, *A. cydnodactylon*, *P. plumifer*, *T. swirskii*, *E. scutalis*, *N. barkeri* and *A. exsertus* from the Qassim region were selected for the trials.

2.2. Selection of plants

Adult males and females of predatory mites (*N. cucumeris*, *A. cydnodactylon*, *P. plumifer*, *T. swirskii*, *E. scutalis*, *N. barkeri* and *A. exsertus*) used in this study were collected from heavily infested citrus, fig, olive, castor, strawberry, tomato and eggplant leaves at abandoned orchards and greenhouses in the Qassim region.

2.3. Preparation of solutions and recommended doses

Commercial formulations of abamectin (Abamec Gold 8.4% w/v) and hexythiazox (Rexon 10% w/w) were obtained from Montajat Pharmaceuticals and Erzam companies, respectively. The recommended doses; 15ml/100L for abamectin and 50g/100L for hexythiazox were prepared for direct spray mixture. In three different stages (eggs, immatures and adults) of seven predacious mites.

2.4. Experimental design

Side effects of two acaricides (abamectin and hexythiazox) on the predacious mites were studied on excised leaf disc in the laboratory. Leaf discs made were circular in appearance with 3cm diameter. The leaf discs were placed on a cotton bed in the Petri-dish (4cm × 2cm) facing under surface upward. The cotton bed was kept wet by soaking with water twice daily, so that the discs remained fresh. Before transferring the predacious mites to the leaf discs, they were checked under a microscope. To prevent mites from escaping, a ring of vaseline was put around the leaves. The experimental design utilized was a completely randomized design with three treatments of pesticides and one untreated group as a control (distilled water). Spray was done directly on the Petri-dishes by using a small knapsack sprayer (1 L) and three repetitions with 20 adults, Immatures and eggs per plot. After spray, untreated *T. urticae* and *A. lycopersici* were added daily to the Petri-dishes as a source of food for predators that did not die, so that the effect of the acaricides does not mix with the effect of hunger. Adults, immatures and eggs of predacious mites were counted using a stereomicroscope, to determine the initial distribution and density of the predatory mites as pre-spray counts. Observations were made after one week of the application to determine post-spray counts.

2.5 Statistical analysis

The equation of Henderson and Tilton (1955) was used to determine the mortality percentage of predatory mites (Equation 1):

$$\text{Corrected (\%)} = (1 - \frac{\text{n in Co before treatment} \times \text{n in T after treatment}}{\text{n in Co after treatment} \times \text{n in T before treatment}})*100 \quad (1)$$

Where:

n = Number of predatory mites, T = Treated, Co = Control.

The mortality rate of predatory mites was counted through direct observation. Microsoft Excel was then used to calculate the average from this data and to determine the percentage of larvae hatched from eggs. Statistically, all variables were examined with the use of one-way analysis of variance (ANOVA).

3. Results

3.1. Side effects of abamectin on immature and adult predatory mites

Results of Abamectin spray on seven species of predatory mites under laboratory conditions are given in Table 1. Mortality percentage is minimum at HRD and highest at DRD in all cases of seven species of predatory mites, both immatures and adults. Mortality percentage is more (5-10%) in immatures than the adults. Table also

Table 1. Side effects of three concentrations of abamectin on immature and adult predatory mites, *A. cydnodactylon*, *P. plumifer*, *A. exsertus*, *N. cucumeris*, *T. swirskii*, *E. scutalis* and *N. barkeri* under laboratory conditions.

Species	Conc.	No. of immature predatory mite			No. of adult predatory mite		
		Average pre-spray count	Average post-spray count *	Reduction % **	Average pre-spray count	Average post-spray count *	Reduction % **
A. cydnodactylon	Control	20.00	20.00	0.00 a	20.00	18.00	0.00 a
	HRD	20.00	15.00	25.00 b	20.00	14.00	22.30 b
	RD	20.00	9.00	55.00 c	20.00	10.00	44.50 c
	DRD	20.00	4.00	80.00 c	20.00	6.00	66.70 d
P. plumifer	Control	20.00	20.00	0.00 a	20.00	18.00	0.00 a
	HRD	20.00	14.00	30.00 b	20.00	15.00	16.00 b
	RD	20.00	8.00	60.00 c	20.00	9.00	50.00 c
	DRD	20.00	3.00	85.00 d	20.00	5.00	73.00 d
A. exsertus	Control	20.00	20.00	0.00 a	20.00	17.00	15.00 a
	HRD	20.00	13.00	35.00 b	20.00	13.00	23.00 b
	RD	20.00	5.00	75.00 c	20.00	6.00	64.80 c
	DRD	20.00	2.00	90.00 d	20.00	2.00	90.00 d
N. cucumeris	Control	20.00	18.00	10.00 a	20.00	18.00	10.00 a
	HRD	20.00	12.00	33.40 b	20.00	14.00	22.30 b
	RD	20.00	5.00	72.23 c	20.00	6.00	66.00 c
	DRD	20.00	2.00	88.90 d	20.00	3.00	83.34 d
T. swirskii	Control	20.00	20.00	0.00 a	20.00	20.00	0.00 a
	HRD	20.00	8.00	60.00 b	20.00	10.00	50.00 b
	RD	20.00	4.00	80.00 c	20.00	6.00	70.00 c
	DRD	20.00	3.00	85.00 d	20.00	4.00	80.00 d
E. scutalis	Control	20.00	20.00	0.00 a	20.00	17.00	15.00 a
	HRD	20.00	13.00	35.00 b	20.00	13.00	23.60 b
	RD	20.00	6.00	70.00 c	20.00	7.00	58.00 c
	DRD	20.00	3.00	85.00 d	20.00	4.00	74.00 d
N. barkeri	Control	20.00	20.00	0.00 a	20.00	19.00	5.00 a
	HRD	20.00	14.00	30.00 b	20.00	15.00	21.00 b
	RD	20.00	6.00	70.00 c	20.00	9.00	52.70 c
	DRD	20.00	3.00	85.00 d	20.00	5.00	73.00 d

Different letters in the horizontal rows denote significant difference between control, HRD, RD and DRD within a specie, (F-test, $P < 0.05$, $P < 0.01$). *Counts made after one-week post treatment. ** Mortality values calculated with the Henderson-Tilton equation.

indicates that highest mortality in immatures and adults is 90% against *A. exsertus.* However, in case of other six predatory mites, *A. cydnodactylon*, *P. plumifer*, *N. cucumeris*, *T. swirskii*, *E. scutalis* and *N. barkeri*, mortality percentage is more in premature than the adults.

3.2. Side effects of hexythiazox on immature and adult predatory mites

Results of hexythiazox spray on seven species of predatory mites under laboratory conditions are given in Table 2. Mortality percentage is minimum at HRD and highest at DRD in all cases of seven species of predatory mites, both immatures and adults. Mortality percentage is 100% in case of six species of predatory mites *A. cydnodactylon*, *P. plumifer*, *N. cucumeris*, *A. exsertus*, *E. scutalis* and *N. barkeri*, however, it is 85% against *T. swirskii*. In case of adults, highest mortality is 95% in case of *A. cydnodactylon* and it is minimum (80%) for *T. swirskii and A. exsertus*.

3.3. Side effects of abamectin treatment on hatching of predatory mite eggs

Side effects of abamectin spray on hatching of eggs is shown in Table 3. Hatching is 100% in control except for

Table 2. Side effects of three concentrations of hexythiazox on immature and adult predatory mites, *A. cydnodactylon*, *P. plumifer*, *A. exsertus*, *N. cucumeris*, *T. swirskii*, *E. scutalis* and *N. barkeri* under laboratory conditions.

Species	Conc.	No. of immature predatory mite			No. of adult predatory mite		
		Average pre-spray count	Average post-spray count *	Reduction % **	Average pre-spray count	Average post-spray count *	Reduction % **
A. cydnodactylon	Control	20.00	19.00	5.00 a	20.00	18.00	10.00 a
	HRD	20.00	11.00	42.20 b	20.00	12.00	40.00 b
	RD	20.00	2.00	89.50 c	20.00	3.00	85.00 c
	DRD	20.00	0.00	100.00 d	20.00	1.00	95.00 d
P. plumifer	Control	20.00	20.00	0.00 a	20.00	20.00	0.00 a
	HRD	20.00	10.00	50.00 b	20.00	12.00	40.00 b
	RD	20.00	3.00	85.00 c	20.00	5.00	75.00 c
	DRD	20.00	0.00	100.00 d	20.00	2.00	90.00 d
A. exsertus	Control	20.00	20.00	0.00 a	20.00	20.00	0.00 a
	HRD	20.00	14.00	30.00 b	20.00	17.00	15.00 b
	RD	20.00	6.00	70.00 c	20.00	10.00	50.00 c
	DRD	20.00	0.00	100.00 d	20.00	4.00	80.00 d
N. cucumeris	Control	20.00	19.00	5.00 a	20.00	18.00	10.00 a
	HRD	20.00	13.00	31.60 b	20.00	14.00	22.30 b
	RD	20.00	3.00	84.00 c	20.00	8.00	55.60 c
	DRD	20.00	0.00	100.00 d	20.00	3.00	85.00 d
T. swirskii	Control	20.00	20.00	0.00 a	20.00	20.00	0.00 a
	HRD	20.00	14.00	30.00 b	20.00	16.00	20.00 b
	RD	20.00	5.00	75.00 c	20.00	7.00	65.00 c
	DRD	20.00	1.00	95.00 d	20.00	4.00	80.00 d
E. scutalis	Control	20.00	20.00	0.00 a	20.00	18.00	10.00 a
	HRD	20.00	12.00	40.00 b	20.00	13.00	27.80 b
	RD	20.00	4.00	80.00 c	20.00	7.00	61.20 c
	DRD	20.00	0.00	100.00 d	20.00	3.00	85.00 d
N. barkeri	Control	20.00	20.00	0.00 a	20.00	17.00	15.00 a
	HRD	20.00	12.00	40.00 b	20.00	11.00	35.30 b
	RD	20.00	5.00	75.00 c	20.00	6.00	64.80 c
	DRD	20.00	0.00	100.00 d	20.00	2.00	90.00 d

Different letters in the horizontal rows denote significant difference between control, HRD, RD and DRD within a specie, (F-test, $P < 0.05$, $P < 0.01$). *Counts made after one week post treatment. ** Mortality values calculated with the Henderson-Tilton equation.

Table 3. Number of larvae hatching from eggs of the predatory mite, *A. cydnodactylon*, *P. plumifer*, *A. exsertus*, *N. cucumeris*, *T. swirskii*, *E. scutalis* and *N. barkeri* treated with three concentrations of abamectin under laboratory conditions.

Species	Conc.	No. of eggs and larvae		
		Average number of eggs pre-spray count	Average number of larvae post-spray count *	Hatching (%) **
A. cydnodactylon	Control	20.00	19.00	95.00 a
	HRD	20.00	17.00	85.00 b
	RD	20.00	15.00	75.00 c
	DRD	20.00	14.00	70.00 c
P. plumifer	Control	20.00	20.00	100.00 a
	HRD	20.00	16.00	80.00 b
	RD	20.00	14.00	70.00 c
	DRD	20.00	13.00	65.00 c
A. exsertus	Control	20.00	17.00	85.00 a
	HRD	20.00	15.00	75.00 b
	RD	20.00	12.00	60.00 c
	DRD	20.00	12.00	60.00 c
N. cucumeris	Control	20.00	20.00	100.00 a
	HRD	20.00	18.00	90.00 b
	RD	20.00	16.00	80. 00 c
	DRD	20.00	15.00	75.00 c
T. swirskii	Control	20.00	20.00	100.00 a
	HRD	20.00	18.00	90.00 b
	RD	20.00	17.00	85.00 b
	DRD	20.00	14.00	70.00 c
E. scutalis	Control	20.00	20.00	100.00 a
	HRD	20.00	18.00	90.00 b
	RD	20.00	16.00	80.00 c
	DRD	20.00	13.00	65.00 d
N. barkeri	Control	20.00	20.00	100.00 a
	HRD	20.00	17.00	85.00 b
	RD	20.00	16.00	80.00 b
	DRD	20.00	13.00	65.00 c

Different letters in the horizontal rows denote significant difference between control, HRD, RD and DRD within a specie, (F-test, $P < 0.05$, $P < 0.01$). *Counts made after one week post treatment. ** Hatching percentage calculated with Excel Microsoft program.

A. cydnodactylon and *A. exsertus* where it is 95% and 85%, respectively. At HRD hatching is more successful than at RD and DRD, however, difference is not pronounced. Lowest hatching is 60% in case of *A. exsertus* and highest 90% for *E. scutalis* and *N. barkeri*. Overall, we can infer from the experimental data that the hatching process is not severely affected when eggs are subjected to spray with abamectin as compared to the mortality percentage in case of immature and adult mites.

3.4. Side effects of hexythiazox treatment on hatching of predatory mite eggs

Side effects of hexythiazox spray on hatching of eggs is shown in Table 4. Hatching results with hexythiazox treatment are different as compared to the results with abamectin. Therefore, there is a prominent difference in hatching percentage at HRD and DRD. Only 45 percent hatching was successful in case of *T. swirskii* by using DRD and it was 85% in cases of *A. cydnodactylon, N. cucumeris and N. barkeri* when HRD was used. Overall we can infer from the experimental data that the hatching process was severely affected when eggs were subjected to spray with hexythiazox. However, its lower dose is less lethal for the hatching process.

3.5. Comparison of acaricidal action of abamectin and hexythiazox on immature and adult predatory mites

Figures 1 and 2 show comparative action of the two acaricides (abamectin and hexythiazox) on immature and adult mites, respectively. It is clear from the experimental data that hexythiazox is a more effective acaricide in killing predatory mites compared with abamectin. However, at

Table 4. Number of larvae hatching from eggs of the predatory mite, *A. cydnodactylon*, *P. plumifer*, *A. exsertus*, *N. cucumeris*, *T. swirskii*, *E. scutalis* and *N. barkeri* treated with three concentrations of hexythiazox under laboratory conditions.

Species	Conc.	No. of eggs and larvae		
		Average number of eggs pre-spray count	Average number of larvae post-spray count *	Hatching (%) **
A. cydnodactylon	Control	20.00	20.00	100.00 a
	HRD	20.00	17.00	85.00 b
	RD	20.00	15.00	75.00 c
	DRD	20.00	11.00	55.00 d
P. plumifer	Control	20.00	20.00	100.00 a
	HRD	20.00	15.00	75.00 b
	RD	20.00	11.00	55.00 c
	DRD	20.00	10.00	50.00 c
A. exsertus	Control	20.00	19.00	95.00 a
	HRD	20.00	16.00	84.20 b
	RD	20.00	11.00	55.00 c
	DRD	20.00	10.00	50.00 c
N. cucumeris	Control	20.00	20.00	100.00 a
	HRD	20.00	17.00	85.00 b
	RD	20.00	14.00	70.00 c
	DRD	20.00	13.00	65.00 c
T. swirskii	Control	20.00	20.00	100.00 a
	HRD	20.00	16.00	80.00 b
	RD	20.00	12.00	60.00 c
	DRD	20.00	9.00	45.00 d
E. scutalis	Control	20.00	20.00	100.00 a
	HRD	20.00	15.00	75.00 b
	RD	20.00	11.00	55.00 c
	DRD	20.00	10.00	50.00 c
N. barkeri	Control	20.00	20.00	100.00 a
	HRD	20.00	17.00	85.00 b
	RD	20.00	14.00	70.00 c
	DRD	20.00	12.00	60.00 d

Different letters in the horizontal rows denote significant difference between control, HRD, RD and DRD within a specie, (F-test, $P < 0.05$, $P < 0.01$). *Counts made after one week post treatments. ** Hatching percentage calculated with Excel Microsoft program.

HRD and RD abamectin is more lethal for immatures and adults in case of *T. swirskii*.

3.6. Comparison of acaricidal action of abamectin and hexythiazox on hatching of predatory mite eggs

Figure 3 shows comparative effect of the two acaricides (abamectin and hexythiazox) on hatching of eggs when treated for seven days during hatching. Hatching is 100% in control samples which were sprayed with distilled water. Data in the Figure 3 shows that hexythiazox has effected hatching more severely than the abamectin in case of all doses.

4. Discussion

Pesticides are economical, quick and most powerful tool among the pest control strategies. However, the use of pesticides for long periods leads to severe problems such as resistance in pests, outbreak of secondary pests, destruction of natural enemies and environmental hazard (Beers et al., 1998; Van Leeuwen et al., 2010). Predatory mites, present in the agricultural fields are considered to be a natural control system over phytophagus mites as they feed upon them (Oliveira et al., 2007; Cavalcante et al., 2015). Agricultural control experts are now thinking above the usage of predatory mites along with pesticides

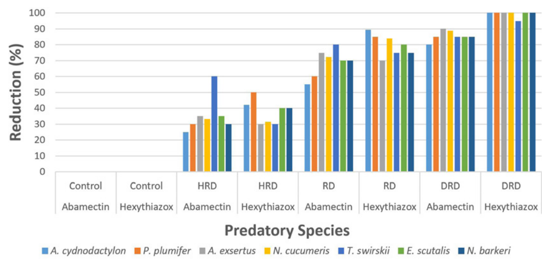

Figure 1. Side effects of three concentrations of abamectin and hexythiazox on immature predatory mites under laboratory conditions.

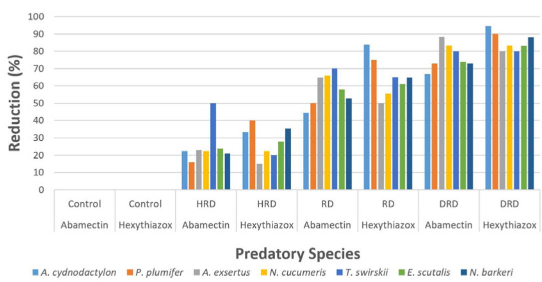

Figure 2. Side effects of three concentrations of abamectin and hexythiazox on adult predatory mites under laboratory conditions.

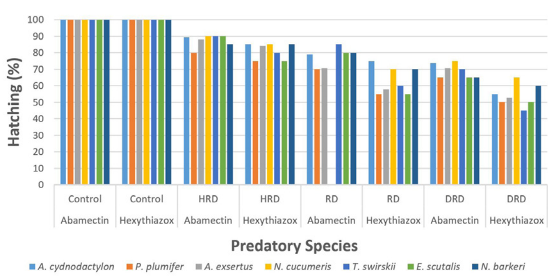

Figure 3. Number of larvae hatching from eggs of the predatory mites treated with three concentrations of abamectin and hexythiazox under laboratory conditions.

instead of using pesticides alone in greenhouses or open fields (Cloyd et al., 2006). Knowledge of the side effects of acaricides on predatory mites is therefore of fundamental importance in integrated pest management (IPM). However, limited data is available on impacts of pesticides on natural enemies of phytophagous mites and insects. (Haskell and McEwen, 2012). However, up to this date no study has examined the potential side effects of pesticides on predatory mites in Saudi Arabia. It is therefore, high time to assess the suitable pesticides to be used in IPM strategy by utilizing some pesticides with minimal toxicity to natural enemies of pests (Meena et al., 2002).

In the present study we have explored the side effects of two acaricides on seven species of predatory mites, *A. cydnodactylon*, *P. plumifer*, *A. exsertus*, *N. cucumeris*, *T. swirskii*, *E. scutalis* and *N. barkeri*. These predatory mites are quite common in Saudi Arabia and they use mites of the arachnid class as their preferred food, hence, provide biological control. The Qassim region was chosen for the collection of mites as it is among the agricultural lands of Saudi Arabia.

Trials made to study side effects of three concentrations (HRD, RD and DRD) of abamectin and hexythiazox including the control (distilled water) on eggs, immatures and adult predatory mites under laboratory conditions have indicated that mortality percentage in immature mites is higher than in adults (Tables 1 and 2). It may be due to soft or no exoskeleton leading to more adsorption of the acaricide on the surface. Hexythiazox has caused more mortality in immature and adult predatory mites (Figures 1 and 2). It is therefore recommended that to promote biological control during the growth of crops especially in greenhouses, abamectin should be a preference as an acaricide. These acaricides when sprayed on eggs had little effect on hatching as compared to their mortality in case of immature and adults (Figures 1, 2 and 3). Main output of this investigation is that the time of spray of acaricides in greenhouses and croplands should be chosen when eggs of predatory mites are at the pre-hatching stage.

5. Conclusion

Abamectin and hexythiazox are effective acaricides against mites of acari family. These acaricides disrupt natural control systems as they effectively kill predatory mites which are the natural killer of phytophagus mites. Hexythiazox is more effective than the abamectin against predatory mites. Lower mortality of predatory mites is achieved by using lower concentration of acaricides than the recommended dose. Use of lower dosage of acaricides causes less damage to predatory mites. Spray of acaricides on crops in greenhouses and open fields at the stage when its hatching time of eggs of predatory mites is more fatal. To augment biological control and avoid environmental hazards, acaricides should be used at lower concentration and at suitable time when predatory mites are at the pre-hatching stage.

Acknowledgements

The authors gratefully acknowledge Dr. Mohamed Motawei and Dr. Mohammad Al-Deghairi for revising this manuscript.

References

ABOU-AWAD, B.A., METWALLY, A.M. and AL-AZZAZY, M.M., 2010. *Typhlodromips swirskii* (Acari: Phytoseiidae) a predator of eriophyid and tetranychid mango mites in Egypt. *Acta Phytopathologica et Entomologica Hungarica*, vol. 45, no. 1, pp. 135-145. http://dx.doi.org/10.1556/APhyt.45.2010.1.12.

AL-ATAWI, F.J., 2011. Phytophagous and predaceous mites associated with vegetable crops from Riyadh, Saudi Arabia. *Saudi Journal* *of Biological Sciences*, vol. 18, no. 3, pp. 239-246. http://dx.doi.org/10.1016/j.sjbs.2011.02.004. PMid:23961130.

AL-AZZAZY, M.M. 2002. *Studies on mites associated with olive trees*. Cairo: Al-Azhar University. M.Sc. Thesis in Agriculture.

AL-AZZAZY, M.M. 2005. *Integrated management of mites infesting mango trees*. Cairo: Al-Azhar University. Ph.D. Thesis in Agriculture.

AL-AZZAZY, M.M., AL-REHIAYANI, S.M. and ABDEL-BAKY, N.F., 2018. Life tables of the predatory mite *Neoseiulus cucumeris* (Acari: Phytoseiidae) on two pest mites as prey, *Aculops lycopersici* and *Tetranychus urticae. Archiv für Phytopathologie und Pflanzenschutz*, vol. 51, no. 11-12, pp. 637-648. http://dx.doi.org/10.1080/03235408.2018.1507013.

ALHEWAIRINI, S.S., 2019. Toxic effects of oxamyl and pyridaben on seven predatory mites: a call and attention. *Pakistan Journal of Agricultural Sciences*, vol. 56, no. 4, pp. 1045-1055.

BEERS, E.H., RIEDL, H. and DUNLEY, J.E., 1998. Resistance to abamectin and reversion to susceptibility to fenbutatin oxide in spider mite (Acari: Tetranychidae) populations in the Pacific Northwest. *Journal of Economic Entomology*, vol. 91, no. 2, pp. 352-360. http://dx.doi.org/10.1093/jee/91.2.352.

CAVALCANTE, A.C.C., BORGES, L.R., LOURENÇÃO, A.L. and MORAES, G.J., 2015. Potential of two populations of *Amblyseius swirskii* (Acari: phytoseiidae) for the control of *Bemisia tabaci* biotype B (Hemiptera: Aleyrodidae) in Brazil. *Experimental & Applied Acarology*, vol. 67, no. 4, pp. 523-533. http://dx.doi.org/10.1007/s10493-015-9964-6. PMid:26387112.

CLOYD, R.A., GALLE, C.L. and KEITH, S.R., 2006. Compatibility of three miticides with the predatory mites *Neoseiulus californicus* McGregor and *Phytoseiulus persimilis* Athias Henriot (Acari: phytoseiidae). *HortScience*, vol. 41, no. 3, pp. 707-710. http://dx.doi.org/10.21273/HORTSCI.41.3.707.

FOULY, A.H. and AL-REHIAYA, S.M., 2011. Predaceous mites in Al-Qassim Region, Saudi Arabia, with description of two new laelapid species (Acari: gamasida: laelapidae). *Journal of Entomology*, vol. 8, no. 2, pp. 139-151. http://dx.doi.org/10.3923/je.2011.139.151.

HASKELL, P.T. and MCEWEN, P., 2012. *Ecotoxicology: pesticides and beneficial organisms*. Dordrecht: Kluwer Academic Publishers, 396 p.

HENDERSON, C.F. and TILTON, E.W., 1955. Tests with acaricides against the brown wheat mite. *Journal of Economic Entomology*, vol. 48, 157–16.

KAVOUSI, A. and TALEBI, K., 2003. Side-effects of three pesticides on predatory mite, *Phytoseiulus persimilis* (Acari: phytoseiidae). *Experimental & Applied Acarology*, vol. 31, no. 1-2, pp. 51-58. http://dx.doi.org/10.1023/B:APPA.0000005127.42123.98. PMid:14756400.

LI, L., JIAO, R., YU, L., HE, X.Z., HE, L., XU, C., ZHANG, L. and LIU, J., 2018. Functional response and prey stage preference of *Neoseiulus barkeri* on *Trasonemus confuses. Systematic and Applied Acarology*, vol. 23, no. 11, pp. 2244. http://dx.doi.org/10.11158/saa.23.11.16.

MAILLOUX, J., BELLEC, F.L., KREITER, L., TIXIER, M.S. and DUBOIS, P., 2010. Influence of ground cover management on diversity and density of phytoseiid mites (Acari: Phytoseiidae) in Guadeloupean citrus orchards. *Experimental & Applied Acarology*, vol. 52, no. 3, pp. 275-290. http://dx.doi.org/10.1007/s10493-010-9367-7. PMid:20480212.

MEENA, B.L., DADHICH, S.R. and KUMAWAT, R.L., 2002. Efficacy of some insecticides against ladybird beetle, *Coccinella septumpunctata* L. feeding on fenugreek aphid, *Acyrthosiphon pisum* (Harris). *Annals of Biology*, vol. 18, pp. 171-173.

METWALLY, A.M., ABOU-AWAD, B.A. and AL-AZZAZY, M.M., 2005. Life table and prey consumption of the predatory mite *Neoseiulus cydnodactylon* Shehata and Zaher (Acari: Phytoseiidae) with three mite species as prey. *Journal of Plant Diseases and Protection*, vol. 112, pp. 276-286.

OLIVEIRA, H., JANSSEN, A., PALLINI, A., VENZON, M., FADINI, M. and DUARTE, V., 2007. A phytoseiid predator from the tropics as potential biological control agent for the spider mite *Tetranychus urticae* Koch (Acari: tetranychidae). *Biological Control*, vol. 42, no. 2, pp. 105-109. http://dx.doi.org/10.1016/j.biocontrol.2007.04.011.

OLIVEIRA, H., SOTO-GIRALDO, A. and HERNÁNDEZ-GARCÍA, G., 2020. Acaricides sublethal effects are more harmful to predatory mite Phytoseiulus macropilis Banks (Acari: Phytoseiidae) than to the pest Tetranychus urticae Koch (Acari: Tetranychidae). *Boletín Científico. Centro de Museos. Museo de Historia Natural*, vol. 24, no. 2, pp. 43-52.

SHAKARAMI, J. and BAZGIR, F., 2017. Effect of temperature on life table parameters of *Phytoseius plumifer* (Phytoseiidae) fed on *Eotetranychus hirsti* (Tetranychidae). *Systematic and Applied Acarology*, vol. 22, no. 3, pp. 410-422. http://dx.doi.org/10.11158/saa.22.3.7.

VAN LEEUWEN, T., VONTAS, J., TSAGKARAKOU, A., DERMAUW, W. and TIRRY, L., 2010. Acaricide reistance mechanisms in two-spotted spider mite *Tetranychus urticae* and other important acari: a review. *Insect Biochemistry and Molecular Biology*, vol. 40, no. 8, pp. 563-572. PMid:20685616.

VOLKMAR, C., SCHUMACHER, K. and MÜLLER, J., 2008. Impact of low-input pesticides usage on spider communities with special regards to accumulated effects. Pesticides and Beneficial Organisms IOBC. *Bulletin SROP*, vol. 35, pp. 18-25.

ZHANG, W., 2018. Global pesticide use: Profile, trend, cost / benefit and more. *Proceedings of the International Academy of Ecology and Environmental Sciences.*, vol. 8, no. 1, pp. 1-27. Available from: www.iaees.org