FITNESS COST ASSOCIATED WITH ACARICIDES INHERITANCE RESISTANCE IN THE SPIDER MITE, *TETRANYCHUS URTICAE* KOCH

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Abstract

Tetranychus urticae caused many problems in field crops in Egypt, despite the use of acaricides that showed loss efficiency against *T. urticae* so we have studied bioassays tests for certain acaricides on some Egyptian strains of *T. urticae*. We investigated resistance levels of different acaricides from differ groups against *T. urticae*. Resistant Ratio (RR), RR_{50} = 119.62, 19.53, 17.93 and 26.38 fold for fenpyroximate, chlorfenapyr, abamectin and bifenazate, respectively. The strain showed high levels of cross-resistance to abamectin (RR 152), moderate levels of cross resistance to chlorfenapyr (RR 38.08) and low levels of cross-resistance (RR < 10) to bifenzate. Resistance coefficient (RC) values calculated for this active ingredient 2.20 (medium resistance). Sensitivity of the mite to pyrrole and avermectin active ingredient 0.152 and 0.075 (lack of resistance). Carbazate was classified as 1.14 (low resistance). All acaricides shortened the longevity and decreased the fecundity of *T. urticae* resistance strain compared with the control. Life cycle of the offspring that produced from treated *T. urticae* females was increased in all treatments compared with the control.

Key words: Fitness cost, inheritance resistance, *Tetranychus urticae*

INTRODUCTION

Tetranychus urticae Koch (Acari: Tetranychidae), is considered the main pest which threaten the quality of many crops. Its short life cycle and abundant reproductive potential facilitate rapid resistance happening to many acaricides often after applications (Devine *et al.*, 2001; Stumpf and Nauen 2001) use of repeated many acaricides for decades to control *T. urticae* continuously led to decrease the natural enemies populations that showed abundant of *T. urticae* population and resulted in appearance acaricides resistance (Kim, *et al.*, 2004). So, widely resistance has been recorded in many countries for compounds, such as organophosphates (OPs) (Anazawa *et al.,* 2003), fenpyroximate (Sato *et al.*, 2004) and abamectin (Beers *et al.*, 1998). This acaricide resistance has been a major deterrent in applied program integrated mite management in Egypt. In spite of, use fenpyroximate for short time in control *T. urticae* populations led to appear high levels of resistance (Cho *et al*. 1995), fitness cost related with acaricide resistance are where the promote of resistance to an acaricide is associated with high significant disadvantage that reduces the mite's fitness differentiate with its sensitive parallel in the population. Little studies have been done on cross-resistance types and resistance techniques in the acaricide-resistant *T. urticae*, (Kim, *et al.*, 2004) and each study is essential for the regional chosen of alternative acaricides for efficient resistance management. In this laboratory work we report on the cross-resistance types of fenpyroximate resistant *T. urticae* that considered the oldest acaricide in the local registration to three acaricides commonly used on field crops and resistance classification in Egypt. Fitness cost associated with resistance to acaricides have been reported in *T. urticae*.

MATERIALS AND METHODS

Mass rearing of spider mite strains

Abundant of *T. urticae* strains were taken from Zagazig region, Sharkia Governorate. In this study, two strains of *T. urticae* were used. The sensitive (S) strain has been preserved without offer to any acaricide in the laboratory for 4 months (Kim, *et al*., 2004). Resistant (R) strain had been created by selection pressure with 50 g litre^{-1} of acaricides for 20 successive generations. The two strains were fed on kidney bean seedlings (3 weeks after germination) in pots under the greenhouse conditions.

Bioassay test

Acaricides used in this study were obtained from plant protection research institute found in table (1), The acaricidal activity of the tested chemicals against adult females of the two strains was confirmed by a spray method technique.

Table 1. List of used acaricides

Group	Common name	Trade name	Chemical name (IUPAC)
Pyrazole	Fenpyroximate	Ortus 5% Sc	1-(6-chloro-3-pyridylmethyl)-N-nitroimidazolidin-2-ylideneamine.
Pyrrole	Chlorfenapyr	Challenger 24% Sc	4-bromo-2-(4-chlorophenyl)-1-(ethoxymethyl)-5-(trifluoromethyl) pyrrole-3-carbonitrile
Avermectin	Abamectin	Vertimec 1.8% Ec	2-[-butan-2-yl]-dihydroxy-5-hydroxy-4-methoxy-6-methyloxan-2-yl] oxy-4-methoxy-6-methyloxan-2-yl] oxy-3-tetramethylspiro [2,3-dihydropyran-trioxatetracyclopentacosa-tetraene]
Carbazate	Bifenzate	Acramite 48% Sc	propan-2-yl N-(2-methoxy-5-phenylanilino) carbamate

Leaf discs (3 cm diameter) were taken from 3-weeks-old age leaves. Adult females of *T. urticae* were delivered onto a leaf disc on a cotton pad in Petri dish (5.5 × 2 cm) the prepare four concentrations from each acaricide to calculate LC_{50} values for two strains. LC_{50} and LC_{90} values and 95% confidence limits were calculated from Probit Analysis (Finney 1971). A resistance ratio (RR) was calculated according to the formula:

$$RR = \frac{LC_{50} \text{ value for resistant strain}}{LC_{50} \text{ value for sensitive strain}}$$

RR values were classified as low (<10), moderate, (10–40), high (40–160) and extremely high resistance (>160), respectively. (Kim, *et al.*, 2004). The resistance coefficient (RC) was calculated as follows:

$$RC = \frac{LC_{95} \text{ (ppm)}}{\text{Recommended field concentration (ppm)}}$$

The following criteria were assumed to assess resistance according to (Wegorek, *et al.* 2011):
RC ≤ 1 – lack of resistance,
RC = 1.1–2 – low resistance,
RC = 2.1–5 – medium resistance,
RC = 5.1–10 – high resistance,
RC > 10 – very high resistance.

Fitness cost

A resistance strain was obtained when reared for 20 generations as explained above. These females were placed individually on plant discs, that removed after 24 hours of laying the eggs. The newly deposited eggs incubated until they become adult then calculate the life cycle of the offspring. The females placed once again on the discs of mulberry leaves to complete egg laying and calculate their longevity and fecundity. A sensitive strain was obtained after reared for 4 months and placed individually on the plant discs and followed up as previously to obtain the control treatment

RESULTS AND DISCUSION

The efficiency of 4 acaricides to the sensitive (S) and resistance (R) strains of *T. urticae* was tested by the spray technique (Table 2). The responses were differed according to the active ingredient for acaricide used. Abamectin has been one of the potent acaricide in maintained crops for a decade. The R strain was extremely resistant to fenproximate resistance ratio (RR) 119.62-fold, while, RR were 19.53, 17.93 and 26.38-fold for chlorfenapyr, abamectin and bifenzate, respectively. The R strain appeared high levels of cross-resistance to abamectin (RR 152), moderate levels of cross resistance to chlorfenapyr (RR 38.08) and low levels of cross-resistance (RR < 10) to bifenzate. Similar trends were found by (Kim *et al.*, 2004) who showed that, the strain exhibited strong positive cross-resistance among acaricides.

Table 2. Toxicity of 4 acaricides to the sensitive (S) and resistant (R) strains of *Tetranychus urticae* and cross- resistance of fenpyroximate to tested acaricides

Acaricides	Mite strains	LC_{50} (mg litre^{-1})	95% Confidence limit		LC_{90} (mg litre^{-1})	95% Confidence limit		Slope	RR_{50} (fold)
			Lower	Upper		Lower	Upper		
Fenpyroximate	S-strain	0.67	0.41	0.90	51.90	49.13	55.02	1.31	119.62
	R-strain	80.15	76.50	83.02	1010.13	1530.2	1701	1.22	
Chlorfenapyr	S-strain	1.07	0.96	2.08	2.87	2.37	3.11	0.90	19.53
	R-strain	20.90	17.69	25.12	77.11	70.50	80.23	1.24	
Abamectin	S-strain	0. 43	0.15	0.93	1.35	0.90	1.97	1.33	17.93
	R-strain	7.71	4.05	11.19	22.50	19.14	26.75	1.25	
Bifenzate	S-strain	4.28	2.68	6.50	41.72	38.99	42.75	1.71	26.38
	R-strain	112.93	98.50	120.72	283.65	265.06	300.79	1.90	
Fenpyroximate+ Chlorfenapyr	R-strain	40.75	34.15	46.11	-	-	-	1.11	38.08
Fenpyroximate+ Abamectin	R-strain	65.36	64.08	70.00	-	-	-	1.59	152.00
Fenpyroximate+ Bifenzate	R-strain	46.87	43.74	48.50	-	-	-	1.42	8.87

RR values of <10, 10–40, 40–160 and >160 were classified as low, moderate, high and extremely high resistance, respectively. According to Kim *et al*., (2004)

Table (3) indicated the only pyrazole active ingredient, to which *T. urticae* exhibited resistance was fenpyroximate. Resistance coefficient (RC) values calculated for the active ingredient 2.20 (medium resistance). Sensitivity of the mite to pyrrole and avermectin active ingredient 0.152 and 0.075 (lack of resistance). Carbazate was classified as 1.14 (low resistance). This study presents great differences between *T. urticae* resistance levels to active ingredients from different chemical groups (Zamojska *et al*., 2018) who classified the resistance levels according to resistance coefficient (RC).

Table 3. Resistance levels of *T. urticae* to acaricides

Acaricides	**F.R.C (ppm)**	**LC_{95} for R-S (ppm)**	**R.C**	**Resistance classification**
Fenpyroximate	500	1100.72	2.20	Medium resistance
Chlorfenapyr	600	91.35	0.152	Lack of resistance
Abamectin	400	30.11	0.075	Lack of resistance
Bifenzate	350	400.73	1.14	Low resistance

F.R.C = Field recommended concentration
R-st = Resistance strain
R.C. = Resistance coefficient

Data in table (4) showed the undesirable modifications in biological and reproductive aspects that generally achieved by comparing life-trait variables between sensitive (control) and resistant individuals that treated with different acaricides which, means fitness cost. The parameters evaluated were adult longevity, fecundity, fertility, and life cycle of offspring. All acaricides shortened the longevity and decreased the fecundity of *T. urticae* resistance strain compared with the control. The females that treated with fenpyroximate appeared high resistance deposited high rate of eggs, 26.88 eggs while, the lowest rate deposited eggs for abamectin 8.58 eggs that was lack of resistance. Life cycle of *T. urticae* was increased in all treatments compared with control. Insects are offered to a different pressure factors in their environment, and, in many cases for insect pests to agriculture, one of these factors is toxic insecticides (Kliot and Ghanim,2012). Coping with the toxicity of insecticides can be costly illustrated in several behavioral and physiological mechanisms such actions are costly and may affect reproduction.

Table 4. Fitness cost associated with acaricides resistance in *T. urticae*

Active ingredient	Longevity (days)	Fecundity	Fertility%	Offspring duration (days)		
				Incubation period	Immature stages	Life cycle
Fenpyroximate	11.37b	26.88b	80.31	3.95	7.75	11.70c
Chlorfenapyr	5.86d	17.39c	73.52	4.23	9.53	13.76b
Abamectin	9.42c	8.58d	67.11	4.65	11.34	15.99a
Bifenzate	13.65b	20.61c	85.23	3.22	7.38	10.60c
Control	18.54a	73.62a	98.69	3.23	6.74	9.97d

In conclusion, the results showed that resistant strain of *T. urticae* occur in Egypt. The economic effect of this strain has been accompanied with high crop losses. Some of the traditional acaricides, such as abamectin, fenpyroximate, chlorfenapyr and bifenazate have lost certain of their activity. However, recently introduced acaricides still extend suitable control of these strains, and we must take care when apply those in a proper resistance management, to safeguard their future use. Therefore, the search for alternatives to traditional pesticides and their improved application remains crucial for future spider mite control. After studying the resistance classification, we suggested that the resistance of these acaricides will increased in the future. Many biological and physiological life history characters can be studied for knowing the presence of fitness costs in a mite population; however, it is not always possible to measure these features easily. Generally, there is also no harmony in the populations chosen when comparing resistant and sensitive strains.

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تكلفة الكفاءة المرتبطة بالمقاومة الموروثة للمبيدات فى الحلم العنكبوتى*Tetranychus urticae*

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مع كثرة المشاكل التى تسببها الأكاروسات للمحاصيل الزراعية كان يستوجب استخدام المبيدات الاكاروسية بصفة مستمره ولكن مع كثرة استخدام هذه المبيدات اظهرت الاكاروسات مقاومة لهذه المبيدات مما ادى ذلك لانخفاض كفاءتها.

تم دراسة مستويات المقاومة للمبيدات الاكاروسية المختبرة التى تتبع مجاميع مختلفة ضد الحلم العنكبوتى *T. urticae*حيث اظهر المبيد الاكاروسى اورتس مقاومة واضحة بقيمة 119,62 ضعف بينما كانت قيم المقاومة 19,53 ، 17,93 و 26,38 ضعف لكلا من الشالنجر والفيرتميك والاكراميت على التوالى.

تم قياس استجابة السلالة المنتخبة مقارنة بالسلالة الحساسة وذلك للمبيدات سابقة الذكر حيث لم تظهر السلالة المنتخبة للاورتس اى مقاومة مشتركة مع الاكراميت حيث كانت نسبة المقاومة (RR) 8,87 ضعف بينما اظهر كلا من الشالنجر والفيرتميك مستويات مقاومة مشتركة واضحة حيث كانت قيم نسب المقاومة 83,08 و 152,00 ضعف على التوالى.

صنفت مقاومة السلالة الحقلية بناءا" على معامل المقاومة (RC) حيث وجد مقاومة متوسطة للاورتس بمعامل مقاومة 2,2 بينما كانت المقاومة قليلة للاكراميت 1,14 وكانت قليلة جدا للشالنجر 0,152 والفيرتميك 0,075.

كان للاستخدام المفرط للمبيدات المختبرة والمستخدمة ضد عدة أجيال من الحلم العنكبوتى تأثير سلبى فعال على حياة الافراد المختبرة حيث ادى ذلك الى تدهور فى السلوك البيولوجى للحلم وتمثل ذلك فى قلة معيشة الافراد المعاملة ونقص خصوبتها بالاضافة الى زيادة فى دورة حياة الذرية الناتجة (مدة الوصول للطور البالغ) وذلك مقارنة بالكنترول.