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Comparative toxicity study of different acaricides in laboratory preluding for field efficacy assessment against *Tetranychus urticae* (Acari: Tetranychidae)

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Abstract:

Toxicity and field studies were carried out on spirodiclofen, pyridaben, abamectin and hexythiazox against the developing stages of susceptible strain (SS) and field strains (FS) of *Tetranychus urticae* Koch. (Acari: Tetranychidae). Abamectin had the highest resistance ratios levels of 6 and 4.1 fold in adult and developmental stage respectively. In adult stage, spirodiclofen and pyridaben had 1.2 and 1.1 fold, respectively. Developmental stage had equal folds of 1.1 for spirodiclofen, hexythiazox and pyridaben. In egg stage, hexythiazox, pyridaben and spirodiclofen had 1.3, 1.2 and 1 fold, respectively. High relative resistances based on LC_{50}s of abamectin were 357 and 171 fold for pyridaben and spirodeclofin, respectively in adult stage besides, 122, 9 and 7 folds for pyridaben, spirodeclofin and hexythiazox, respectively in developmental stage. The field experiments throughout 4 weeks post treatments on green bean crop in season of 2017 showed that the highest overall reduction percentages in *T. urticae* populations were occurred in spirodiclofen (55.90 %) and pyridaben (51.72 %) compared to abamectin (49.77 %). Meanwhile, season of 2018, abamectin had the highest overall reduction percentages of 56.00 % compared to spirodiclofen (51.84 %) and pyridaben (49.40 %). Hexythiazox had the lowest overall reduction percentages of 32.53 % and 36.17 % in seasons of 2017 and 2018, respectively. The residual control activity in both seasons showed that spirodiclofen had delayed initiating effect (7- 28 DATs) > pyridaben = abamectin (4 - 21 DATs) > hexythazox (4 - 7 DATs). Eventually, our study declared that spirodiclofen, pyridaben and hexythiazox were considered to be alternatives and complementary acaricides to abamectinin controlling different developmental stages of *T. urticae*.

Introduction

Two spotted spider mite (TSSM), *Tetranychus urticae* Koch. (Acari: Tetranychidae) is an important polyphagous pest that feed on over 1100 plant species including more than 150 crops (Bensoussan *et al*., 2016 and Seal, 2006). The stylet of *T. urticae* could penetrate the plant leaf causing damage to epidermal pavement cells or without damaging through a stomatal opening. The feeding duration may extend more than 30 minutes that is enough to deplete a single mesophyll cell (Bensoussan *et al*., 2016). The accumulative effect of TSSM infestation coupled with favorable temperatures initiates serious economic losses in field grown strawberries as well as remarkable yield reductions and damages in cucumber eggplant, tomato and pepper in greenhouse and open field's worldwide (Nyoike and Liburd, 2012; Tehri *et al*., 2014; Van De Vrie *et al*., 1972 and El-Saiedy, 2015).

Spirodiclofen is a recent commercialized acaricide with a novel mode of action (of lipid synthesis inhibitor), against all developmental stages and female adults of tetranychid mite species. Spirodiclofen showed no cross-resistance in high resistance strains to at least one of organophosphates, mitochondrial electron transport inhibitors (METIs), hexythiazox and abamectin. Thus, it considered being a good alternative to these acaricides. Spirodiclofen achieved high and steady efficacy against the summer population of *Panonychus ulmi* (Koch.) (Acari: Tetranychidae) and TSSM in three vegetation seasons of cucumber (Rauch and Nauen, 2002; Marcic *et al*., 2011 and Farahani *et al*., 2018). Specifically, hexythiazox is entitled as unique ovicide with unknown mode of action to control mite growth via eggs and early developmental stages. It typically applies to bare-root plants and containerized, foliar, nonbearing and nursery canopies (United States Environmental Protection Agency (USEPA), 2007). Laboratory and field tests demonstrated that population of *P. ulmi* in an apple orchard in Pennsylvania had become highly resistant to hexythiazox during the mid-eighties of the twentieth century (Reissig and Hull, 1991). Pyridaben is a relative new selective and stoichmetric inhibitor of complex acaricide in the inner membrane of mitochondria that able to induce DNA damage and chromatin abnormalities in spermatozoa that leads to low in vitro fertilizing rate. It is used to control mites and some insects such as whitefly, aphid and thrips (Gomez *et al*., 2007 and Manas *et al*., 2013). Resistance of the *T. urticae* larvae to METIs-acaricides is an increasing problem. In a foliar spray bioassay trails, selected Japanese and English strains of *T. urticae* larvae showed a remakable resistance against pyridaben compared to the susceptible strain. Mutual crosses of homozygous and diploid females with hemizygous and haploid males in both susceptible and resistant strain revealed incompletely dominant inheritance of pyridaben resistance with slight differences between maternal and paternal inheritance. Increased oxidative metabolism of the METI-acaricides in the resistant strains could be partially suppressed in vivo by the monooxygenase inhibitor Piperonyl butoxide (Stumpf and Nauen, 2001). Abamectin belongs to avermectins which is a class of macrocyclic lactones group that produced directly by the actinomycete, *Streptomyces avermitilis* (Khalil and Abd El-Naby, 2018) or through semisynthetic modifications (Fisher and Mrozik, 1989 and Krieger, 2010). This ivermectin is known to include γ-aminobutyric acid blockade (Cohen *et al*., 2017). Some studies showed that collected *T. urticae* populations from strawberry field in Sao Paulo, Brazil recorded positive cross-resistance to abamectin and milbemectin because of the similarity in mode of action of these acaricides. This location had been frequently sprayed for about ten years and lasted by six times with abamectin before collecting these strains. Abamectin resistance seemed to be unstable in the absence of selection pressure within six months, which indicated by decreasing of resistance percentages in populations of resistant mites to levels equal or lower than 15% (Sato *et al*., 2005).

The present study investigates the toxicity of varied mode of action groups of acaricides; spirodiclofen, pyridaben, abamectin and hexythiazox against different development stages in both susceptible strain

(SS) and field strain (FS) of *T. urticae* . In addition, resistance ratio levels for each tested acaricide and relative resistance (RR) based on the most toxic acaricide were also employed. Accordingly, field studies were carried out to determine the overall reduction percentages and residual control activity for these acaricides.These field trials tried to compare the efficacy of lowest resistance acaricides as alternatives and complementary besides the other that possessing high resistance against *T. urticae* in field.

Materials and methods

1. Tested insecticides:

Table (1) showed that main group, sub-group, trade name, produced company and applied dosage of insecticides that used during the present study.

Table (1): The items of selected acaricides were demonstrated regarding to IRAC MoA classifications*(2019), trade name, produced company and applied dosage.

Common name	IRAC MoA Classification* 2019		Trade name (Formulation)	Produced company-origin	Doses 100L^{-1}
	Main group	Sub-group			
Spirodiclofen	Inhibitors of Acetyl-CoA carboxylase	Tetranoic and tetramic acid derivatives	Infedor (24 % SC)	Bayer AG - Germany	30 ml
Pyridaben	Mitochondrial complex I electron transport inhibitors	METI acaricides and insecticides	Sanmite (20 % WP)	Nissan for chemical industries., Ltd - Japan	100 mg
Abamectin	Glutamate-gated chloride channel allosteric modulators	Avermictins	Gold (1.8% EC)	El-Helb pesticides&chemical Co - Egypt	40 ml
Hexythiazox	Mite growth inhibitor affecting chitin synthase 1	Hexythiazox	Prince (10% EC)		20 ml

***Insecticide resistance action committee – Mode of action classifications.**

2. Rearing of *Tetranychus urticae* colony:

The samples of TSSM were collected from castor oil leaves, *Ricinus communis*, free of insecticides treatments. The TSSM samples were adapted according to Singh and Clare (1993) at approximate conditions of 26 ± 2 ºC, ≈70 % RH. and 12:12 light/dark cycle on green bean seedling plants, *Phaseolus vulgaris* L., in plastic pots (20 cm diameter). Under these conditions, a new susceptible mass of TSSM strain was obtained after approximate 16 successive generations. These rearing methods were carried out in integrated Plant Protection laboratory, Alexandria, Egypt. On the other hand, field strain (FS) samples were collected randomly from the infested leaves of vegetative period of *P. vulgaris* plants from Ezbit-Mohseen Al-Kobra region during season of April, 2017. These collected samples of susceptible strain (SS) and FS were submitted to toxicity assay in laboratory.

3. Laboratory studies:

The toxicity of spirodeclofin, pyridaben, Abamectin, and hexythiazox were evaluated on eggs hatchings, developmental and adult stages of *T. urticae* according to susceptibility test methods of Insecticide Resistance Action Committee (IRAC) (2009).The toxicity evaluation was carried out on *T. uratica* SS versus to FS. Mortality percentages were corrected by using formula of Abbott (1925) and subjected to probit analysis (Finney, 1971). The resistance ratio levels between FS and SS for each tested acaricide were assigned. Moreover, RR based on LC_{50} valuesof abamectin (the most toxic acaricide) in FSs were assigned compared to the other tested acaricides.

4.Field trials:

Two field experiments were achieved within the second week of April in seasons of 2017 and 2018 on the vegetative period of green bean plant at Ezbit-Mohseen Al-Kobra, Alexandria. During the period of field assessments, agriculture processing followed the optimal agronomic procedures of green bean crop. All treatments were conducted in 45 m^2 micro-plots in a randomized complete block design with four replicates. Knapsack sprayer equipment (CP3) was used for spraying the selected acaricides at their recommended field rates (FRs). Control treatment was applied by water only. The spray solution volume was 3 liter per each micro-plot. Reduction percentages and residual control activity against *T. uratica* in all treated and untreated plots were calculated at 1, 4, 7, 14, 21, and 28 days post-treatment according to Henderson and Tilton's formula (1955).

4. Statistical analysis:

All the obtained results were subjected to analysis of variance (ANOVA). Means were determined for significance at 0.05 using LSD test using SAS software (2002).

Results and discussion

1. Toxicity assay and resistance assessments on different stages of *Tetranychus urticae* under laboratory conditions:

According to data in Table (2), the values of LC_{50}s after 4 days of exposure against adult stage of *T. urticae* treated with abamectin was 0.066 mg L^{-1}in FS compared to 0.011 mg L^{-1} inSS.Therefore, abamectin possessed the highest resistance ratio levels reached to 6 folds. Whereas, LC_{50}s of spirodiclofenin FS were 11.278 mg L^{-1}compared to 9.761 mg L^{-1} in SS had resistance ratio of 1.2 folds. In addition, LC_{50}s of pyridabenin FS were 23.561 mg L^{-1} compared to 20.951 mg L^{-1}in SS had 1.1 folds. In contrast, hexythiazox had no direct toxic effect on adult stage.

On the other hand, the LC_{50}s after 4 days of exposure against developmental stage (larvae, protonymph and deutonymph) of *T. urticae* treated with abamectin were 0.495 mg L^{-1}in FS compared to 0.121 mg L^{-1} inSS. Thus, abamectin had the highest resistance ratio reached 4.1folds. Meanwhile, the resistance ratios of spirodiclofen, hexythiazox and pyridaben had the same level of 1.1 fold. Where, values of LC_{50}s for spirodiclofenin FS were 4.303 mg L^{-1} compared to 3.927 mg L^{-1}in SS. Hexythiazox had 3.607 mg L^{-1}in FS compared to 3.313 mg L^{-1}in SS and pyridaben had 60.408 mg L^{-1}in FS compared to 57.663 mg L^{-1} in SS.

The LC_{50}s against eggs stage of *T. urticae* treated with hexythiazox were 4.934 mg L^{-1}in FS compared to 3.689 mg L^{-1}in SS. While, LC_{50}s of pyridabenwere 131.116 mg L^{-1}in FS compared to 112.189 mg L^{-1}in SS and spirodiclofen 0.625 mg L^{-1}in FS compared to 0.582 mg L^{-1} in SS. Subsequently, the resistance ratios of hexythiazox, pyridaben and spirodiclofen had non varying-folds of 1.3, 1.2 and 1.1 respectively. However, abamectin had no direct toxic effect on eggs stage.

Regarding to the LC_{50} values of abamectin in FSs of adult stage, the estimated RRs of the compared tested acaricides were 357 and 171 folds for pyridaben and spirodeclofin, respectively. The resistances of abamectinin FSs of developmental stage were 122, 9 and 7 folds for pyridaben, spirodeclofin and hexythiazox, respectively. However, abamectin had no toxic effect on the egg stage.

Table (2): Toxicity of the selected acaricides against different stages of susceptible and field strains of *Tetranychus urticae* under laboratory condition after 4 days of exposure.

Stages	Tested acaricides	Strain	LC_{50} (mg L^{-1})	Confidence limits (mg L^{-1})	Slope ± SE	x^2	*Df*	Resistance ratio	Relative resistance
Adult stage	Spirodiclofen	SS	9.761	8.898-10.659	2.870±0.197	10.464	5.0	1.2	171
		FS	11.278	10.388-12.151	3.434±0.240	8.346	5.0		
	Pyridaben	SS	20.951	19.931-21.958	5.131±0.373	4.370	5.0	1.1	357
		FS	23.561	22.419-24.667	5.772±0.442	1.587	5.0		
	Abamectin	SS	0.011	0.009-0.012	1.950±0.138	10.792	5.0	6.0	1
		FS	0.066	0.056-0.078	1.449±0.109	5.265	5.0		
	Hexythiazox	SS	-	-	-	-	-	-	-
		FS	-	-	-	-	-		
Developmental stage	Spirodiclofen	SS	3.927	3.730-4.134	4.816±0.322	3.434	5.0	1.1	9
		FS	4.303	4.097-4.508	5.348±0.351	2.028	5.0		
	Pyridaben	SS	57.663	55.040-60.370	5.238±0.384	7.356	5.0	1.1	122
		FS	60.408	57.748-62.962	5.843±0.436	6.464	5.0		
	Abamectin	SS	0.121	0.112-0.131	3.004±0.217	5.304	5.0	4.1	1
		FS	0.495	0.456-0.533	3.203±0.275	9.944	5.0		
	Hexythiazox	SS	3.313	3.034-3.603	2.922±0.208	9.332	5.0	1.1	7
		FS	3.607	3.304-3.924	2.942±0.201	10.513	5.0		
Eggs stage	Spirodiclofen	SS	0.582	0.524-0.647	2.378±0.170	0.807	5.0	1.1	-
		FS	0.625	0.563-0.695	2.378±0.172	10.726	5.0		
	Pyridaben	SS	112.189	105.208-119.078	4.029±0.304	10.617	5.0	1.2	-
		FS	131.116	125.199-36.712	6.086±0.429	10.712	5.0		
	Abamectin	SS	-	-	-	-	-	-	-
		FS	-	-	-	-	-		
	Hexythiazox	SS	3.689	3.542-3.842	5.496±0.389	12.063	5.0	1.3	-
		FS	4.934	4.692-5.167	5.414±0.381	4.263	5.0		

2. Field efficacy of tested acaricides against *Tetranychus urticae*:

The obtained results in season of 2017 (Table, 3) declared that spirodiclofen and pyridaben had the highest equal overall reduction percentages on *T. urticae* populations of 55.90 and 51.72 %, respectively compared to abamectin (49.77 %) and lasted with hexythiazox (32.53 %).

Table (3): Reduction (%) of *Tetranychus urticae* population after sequent days of exposure to selected acaricides under field conditions, season of 2017.

Tested acaricides	Population numbers* before treatment	Population numbers (Reduction %) after treatment at intervals (days)						Overall mean of population numbers (Reduction %)
		1	4	7	14	21	28	
Spirodiclofen	267.50	259.75	257.50	103.50	10.00	2.00	56.00	**136.61**
		(1.84)^{i}	(2.03)^{i}	(58.74)^{f}	(95.72)^{bac}	(99.21)^{a}	(77.79)^{e}	**(55.90)^{a}**
Pyridaben	255.00	247.75	26.50	6.25	3.50	188.75	236.50	**137.75**
		(1.87)^{i}	(89.42)^{d}	(97.39)^{ba}	(98.43)^{ba}	(21.62)^{e}	(1.62)^{i}	**(51.72)^{a}**
Abamectin	297.75	278.75	14.25	2.25	103.00	180.00	273.75	**164.25**
		(5.07)^{i}	(95.13)^{bac}	(99.19)^{a}	(60.38)^{f}	(35.99)^{g}	(2.48)^{i}	**(49.77)^{ba}**
Hexythiazox	264.75	255.00	16.25	21.75	223.75	243.00	246.00	**181.50**
		(2.61)^{i}	(93.75)^{bdc}	(91.24)^{dc}	(3.19)^{i}	(2.81)^{i}	(1.44)^{i}	**(32.53)^{b}**
Control	301.25	298.25	296.00	282.50	263.00	284.50	284.00	**287.07**

***Population numbers: numbers of adult individuals of *Tetranychus urticae* /10 leaves/plot.**

. Means of reduction percentages of population of mites with the same letter are not significantly different according to the $LSD_{0.05}$ for the interaction between treatments and days after treatments.

. Means of overall reduction percentages of population in the last column with the same letter are not significantly different according to the $LSD_{0.05}$.

The obtained results in season of 2018 (Table, 4) declared that abamectin had the highest overall reduction percentages of 56.00 % compared to spirodiclofen and pyridaben which had equal reduction percentages of 51.84 and 49.40 % respectively. Lastly, hexythiazox had the lowest overall reduction percentages of 36.17 %.

Table (4): Reduction (%) of *Tetranychus urticae* population after sequent days of exposure to selected acaricides under field conditions, season of 2018.

Tested acaricides	Population numbers* before treatment	Population numbers (Reduction %) after treatment at intervals (days)						Overall mean of population numbers (Reduction %)
		1	4	7	14	21	28	
Spirodiclofen	245.50	228.50	238.25	137.00	13.00	0.00	65.25	**132.50**
		$(1.83)^{f}$	$(1.42)^{f}$	$(41.83)^{d}$	$(93.81)^{ba}$	$(100.00)^{a}$	$(72.15)^{c}$	**$(51.84)^{ba}$**
Pyridaben	239.50	215.00	35.50	8.00	3.50	207.00	217.75	**132.32**
		$(5.32)^{f}$	$(84.94)^{b}$	$(96.52)^{a}$	$(98.29)^{a}$	$(6.63)^{f}$	$(4.72)^{f}$	**$(49.40)^{ba}$**
Abamectin	285.25	245.25	10.25	2.75	82.25	154.75	207.75	**141.18**
		$(9.32)^{f}$	$(96.35)^{a}$	$(99.00)^{a}$	$(66.27)^{c}$	$(41.39)^{d}$	$(23.67)^{e}$	**$(56.00)^{a}$**
Hexythiazox	252.00	233.00	25.50	15.75	172.50	219.75	227.00	**163.64**
		$(2.48)^{f}$	$(89.72)^{ba}$	$(93.49)^{ba}$	$(19.92)^{e}$	$(5.80)^{f}$	$(5.60)^{f}$	**$(36.17)^{b}$**
Control	289.25	274.25	284.75	277.50	247.25	267.75	276.00	**273.82**

***Population numbers: numbers of adult individuals of *Tetranychus urticae*/10 leaves/plot.**

- **Means of reduction percentages of population of mites with the same letter are not significantly different according to the $LSD_{0.05}$ = 10.49 for the interaction between treatments and days after treatments.**
- **Means of overall reduction percentages of population in the last column with the same letter are not significantly different according to the $LSD_{0.05}$ = 17.71**

3. Residual control activity of the tested acaricides:

Residual control activity of treatments in both seasons (Tables 3 and 4) were statistically estimated based on comparing the mean population numbers of *T. urticae* in treated plots along the intervals of DATs with their initial populations before treatments. The data in the two seasons showed that spirodiclofen had delayed initiations at the 7th day followed by high residual control activity periods that reached more than 28 DAT. pyridaben and abamectin had the same residual control activity periods from 4 to 21 DATs. Lastly, the residual control activities of hexythazox were limited from 4 up to 7 DATs.

Generally abamectin is one of the most widely common used acaricidein controlling mites in agriculture applications by farmers due to its rapid efficacy (Yorulmaz and Kaplan, 2014; Turan *et al*., 2016 and Cagatay *et al*., 2018). Certain reports declared that abamectin does not persist or accumulate in the environment and not toxic for non-target organisms (Khalil, 2013). Moreover, quite low abamectin residues in/on treated crops leadto minimal exposure during human consumption (Lasota and Dybas, 1990 and IRAC, 2019). High RR levels in *T. urticae* populations to abamectincollected from different locations representing vegetable greenhouses as well as open fieldswere monitored (Sato *et al*., 2005; Brown *et al*., 2017 and Cagatay *et al*., 2018). These facts lead our study to find out alternative low resistance acaricides to be employed and compatible beside abamectin in controlling program against TSSM in open fields. Subsequently, a lifeline could be realized for abamectin applications in crop protection.

Data of toxicity in this research showed an observed high resistance ratio levels of field and susceptible strains of TSSM to abamectin in adult and developmental stages.These observations were supported by the resistance in *T. urticae* and control failure's reports of abamectin manifested in cotton fields of Midsouth state. Whereas, the resistance ratios of between fields and susceptible populations of TSSM in seasons of 2014 and 2015 ranged from 11.1 to 94.4 and 33.3 to 93.3 folds, respectively (Brown *et al*., 2017). Furthermore, high resistance levels to abamectin in three *T. urticae* populations collected from vegetable greenhouses in Antalya and Muğla, Turkey ranged between 223 and 404 folds compared to their susceptible populations (Cagatay *et al*., 2018).

Nevertheless, RR based on abamectin in this study showed that abamectin was more toxic in adult stages than pyridaben and spirodeclofin with 357 and 171 folds, respectively. While of toxic effect of abamectin in developmental stage transcend pyridaben, spirodeclofin and hexythiazox with 122, 9 and 7 folds, respectively. Eventually, abamectin had no toxic effect on egg stage. These results came in agree with values of RR based on abamectin in adults of *T. urticae*, presented in fenpyroximate (15 fold), spiromesifen (32 fold), chlorfenapyr (83 fold), propargite (198 fold), dicofol (376 fold) and hexythiazox (711 fold) (Kumari *et al*., 2017).

On the other hand, the obtained data of applied FRs of the tested acaricides in field trials showed that the overall reduction percentages within 4 weeks posttreatments were ordered as follows; spirodiclofen = pyridaben > abamectin > hexythiazox in season of 2017. However, varied data was recognized as abamectin > spirodiclofen = pyridaben > hexythiazox in season of 2018. Likewise, the efficacy of selective acaricides with their distinctive modes of action against the TSSM *T.urticae*, on strawberries in the potting trial from 1 to 3 weeks posttreatment, showed reductions in immature stages treated with spirodiclofen ranged from 61% to 91% and also pyridaben decreased the adults by 41% to 64% and the immatures up to 67%. Moreover, abamectin reduced the immatures by 59% within the first 2 weeks posttreatment (Niu *et al*., 2016). Therefore, the efficacy data of the tested acaricides may direct the usages of spirodiclofen and pyridaben as good alternatives beside abamectin in the insecticides resistance management (IRM) program against TSSM (Peshin *et al*., 2009).

Furthermore the field trial data in both seasons showed that spirodiclofen had delayed control activity periods (7- 28 DATs) > pyridaben = abamectin (4 - 21 DATs) > hexythazox (4 - 7 DATs). Variation of initial activity and residual control periods (lasting periods) of the tested acaricides in our field trials may be justified according to their action modes. Well known fact about abamectin that belongs to allosteric modulators of GABA chlorine channels shows its effects of paralyses, antifeeding and death to arthropods not before few days of treatment (Cagatay *et al*., 2014 and IRAC, 2019). In addition, spirodiclofen is inhibitor of acetyl-CoA carboxylase that cause desiccation followed by death in treated mites (IRAC, 2019). It has a long-lasting and stable acaricidal effect. Evaluation of spirodiclofen in Serbia on cucumber achieved high efficacy (91–98%) against *P.ulmi* and *T.urticae* with long-residual efficacy of (38–47 DAT) and (14–15DAT), in the 3rd and 1st evaluation, respectively. The trials carried out in several EU countries against *P. ulmi* on apple trees at low to medium initial infestation in summer season, showed efficacy higher than 90% throughout 26–32 DAT (Marcic *et al*., 2011 and Marcic, 2012). Pyridaben is mitochondrial complex I electron transport inhibitors. It provides residual control activity up to 45 days against all spiders and broad mites life (IRAC, 2019). Hexythiazox has slow-acting mite growth regulators that interfere with chitin synthesis and specific target site or proteins during the molting process of eggs, embryo and larval development. It possessed long residual control activity (28-45 days) (IRAC, 2019). Therefore, field trial data of residual control activities of spirodiclofen, pyridaben and hexythiazox considered them as good alternatives beside abamectin in the insecticides resistance management (IRM) program against TSSM.

The toxicity studies showed observed high resistance ratio levels between FS and SS of TSSM to abamectin in adult and developmental stages. Nevertheless, RR based on abamectin showed that abamectin was more toxic in adult and developmental stages than the tested acaricides. On the other hand, field trial tests showed that the total population reduction of TSSM and residual control activities of the tested acaricides may direct spirodiclofen, pyridaben and hexythiazox as good low resistance alternatives and to be compatible beside abamectin in IRM program against specified developmental stages of TSSM.

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