Controlling Strawberry Mites: Comparison of New Bio-Pesticides and Conventional Chemical Pesticides

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Abstract

BACKGROUND: *Tetranychus cinnabarinus* is one of the pest insects most severely influencing strawberry production. It has a high attack rate and causes severe economic losses. Laboratory toxicity tests and greenhouse experiments were carried out using 13 acaricides to determine their efficacy and potential mechanisms of action.

RESULTS: Abamectin showed the highest efficacy against *T. cinnabarinus* female mites; its LC_{50} value was 0.18 mg L^{-1} . Pyridaben, cyhalothrin, veratrine, and carbosulfan showed reasonably high efficacy; their LC_{50} values were 2.69 mg L^{-1} , 3.94 mg L^{-1} , 5.98 mg L^{-1} , and 6.75 mg L^{-1} , respectively. Less effective were hexythiazox and bifenthrin, their LC_{50} values were 9.82 mg L^{-1} and 19.09 mg L^{-1} ,

1 respectively. Other acaricides such as spirotetramat, chlorantraniliprole, chlorfenapyr,
 2 spinosad, and bifenthrin did not show good efficacy. The status of female mites
 3 treated with avermectin, pyridaben, kanghebio and cyhalothrin changed significantly
 4 under a fluorescence microscope. There were no significant differences among female
 5 mites treated with spirotetramat, chlorantraniliprole, spinosad and bifenthrin. Enzyme
 6 activity tests showed that Kanghebio and cyhalothrin obviously inhibited Ca^{2+} -
 7 adenosine triphosphatase (Ca^{2+} -ATPase), while veratrine and kanghebi obviously
 8 inhibited acetylcholinesterase (TChE) and monoamine oxidase (MAO).
 9 Cyhalothrin exerted an auxo-action on MAO. Greenhouse experiment indicated that
 10 abamectin showed the best efficacy, as well as the longest duration of efficacy,
 11 pyridaben, cyhalothrin, veratrine, and kanghebio followed, while carbosulfan,
 12 hexythiazox, and bifenthrin performed the worst.

13 **CONCLUSIONS:** Our study provided a scientific basis for chemical pesticides to be
 14 replaced by these and potentially other new bio-pesticides.

15 **Keywords:** Bio-pesticide, Chemical pesticide, Toxicity test, Greenhouse test,
 16 Mechanism of pesticide action.

17 1. INTRODUCTION

18 *Tetranychus cinnabarinus* is one of the most important pest species and is
 19 distributed worldwide. It attacks more than 100 plant species, including crops such as
 20 cotton and strawberry, vegetables, deciduous fruits, and ornamental plants¹. *T.*
 21 *cinnabarinus* causes enormous economic damage due to reductions in both the yield

1 and quality of affected crops, and is controlled by acaricide sprays^{2,3,4}. Due to
 2 acaricide resistance and environmental pollution, there is an increasing demand for
 3 sustainable, environmentally friendly control methods. For example, phytoseiid mites
 4 have been used as effective biological control with of agents of spider mites on many
 5 cultivated crops^{5, 6}. In this study, we tested the effectiveness of new bio-pesticides as
 6 alternatives to chemical pesticides for the control of strawberry mites. *Tetranychid* is
 7 an important pest that severely affects strawberry production in Pinggu district,
 8 Beijing. It can seriously damage leaves of strawberry plants, causing economic losses
 9 and potentially leading to death of the host plant.

10 Chemical pesticides are often applied to control strawberry mites. However, long-
 11 term use of one chemical can easily cause the mites to develop insecticide resistance,
 12 making them more difficult to control. Moreover, pick your own strawberry farms are
 13 an increasingly popular spring outing, so it is very important to produce strawberries
 14 free of artificial pesticides. Bio-pesticides are safe, organic, and tend not to induce
 15 resistance in target species.

16 Biological pesticides are the use of living beings and active ingredients of living
 17 beings, and natural compound of the material, the preparation of the prevention and
 18 control of plant diseases, insects and plant growth regulator. Compared with the
 19 traditional chemical pesticides, biological pesticides have some good features, as they
 20 are safe to living beings and non-target organisms, good environmental compatibility,
 21 not easy to produce resistance, easy to protect biodiversity, wide sources, etc. In

1 recent years, many new biological resources have been used, get innovative
2 production technology. Some new products come into the market⁷.

3 Relative study about the acaricidal mechanism was reported. Liang *et al.*⁸ reported
4 that the study on scopoletin toxicity to *Tetranychus cinnabarinus* and its acaricidal
5 mechanism, several target enzymes activity of nervous system and the effect on
6 acetylcholinesterase were tested. Wang *et al.*⁹ reported that the colorimetry assay to
7 test *Tetranychus cinnabarinus*' enzyme activity of few enzyme after applying the
8 acaricidal activities of *Polygonum aviculare*. The purpose of our study was to explore
9 the biological pesticides' (veratrine, kanghebio) target enzyme of strawberry mites by
10 enzymatic activity of Ca²⁺-adenosine triphosphatase, acetylcholinesterase and
11 monoamine oxidase.

12 In this study, 13 acaricides were used, including newly listed chemical pesticides
13 (spirotetramat, bifenthrin), a new botanical preparation (veratrine), and microbial
14 agents (kanghebio, spinosad). Laboratory toxicity tests and greenhouse experiments
15 were carried out in order to evaluate the control efficacy of chemical pesticides and
16 bio-pesticides, and explore the potential mechanisms by which they act.

17 2. MATERIALS AND METHODS

18 2.1. Selected Acaricides and test pest sources

19 In this experiment, 13 different acaricides were used and listed in Table 1. The
20 experiment was carried out during Jan-May 2014. The tested mites were collected

1 from strawberry greenhouses in Pinggu District, Beijing and kept in laboratories.

2 Female adult mites were used for laboratory toxicity tests.

3 **2.2. Test method**

4 **2.2.1. Laboratory toxicity test**

5 A slide-dip method^{10,11} based on the United Nations Food and Agriculture
6 Organization (UN FAO) recommended method was used in laboratory toxicological
7 experiments. The 3-cm lengths of double-sided adhesive tape were attached to the
8 slides. Female mites, each with the same size, bright color, and high activity, were
9 chosen, and the back of each mite was attached to the adhesive tape; between 15 and
10 25 mites were attached to each slide. There was a gradient of 5 concentrations of each
11 pesticide. Each slide, along with attached mites, was dipped into a pesticide, shaken,
12 removed from the pesticide after 5s, and then dried with filter paper. Then the slides
13 were put in culture dishes with gauze, and these put in an incubator with the
14 conditions used for acclimatizing the mites. The test was repeated three or four times
15 for each pesticide, and slides with mites were dipped in water as a control. The
16 number of live mites was counted after 6h, 12h, 24h, 36h, 48h, 60h, and 72h. Mites
17 were checked with a small brush under a microscope; mites which did not move were
18 considered dead.

19 **2.2.2. Greenhouse test**

20 The greenhouse test was carried out in Pinggu district, Beijing. Two greenhouses
21 (No.1 and No.2) were selected for the experiment; the variety of strawberry used was

1 Sweet Charlie. Eight acaricides (abamectin, pyridaben, cyhalothrin, veratrine,
2 carbosulfan, hexythiazox, bifentazate, and kanghebio) were tested, and all treatments
3 were repeated three times. Twenty-eight replicated plots were set up. A back-mounted
4 hand sprayer was used to spraying the acaricides. Ten strawberry plants were used in
5 each experiment, and the number of strawberry mites on 5 leaves of each plant was
6 counted before spraying. The number of remaining live strawberry mites was counted
7 after 3d, 7d, 14d, and 21d using a microscope.

8 **2.2.3. Enzyme activity test**

9 **2.2.3.1. Preparation of enzyme solution**

10 Twenty-four hours after acaricide treatment, 100 female adult mites were
11 homogenized with 0.25mL normal saline solution (NS) for 15min in a 4°C ice-water
12 bath at 2500rpm, and the resulting supernatant was collected.

13 **2.2.3.2. Enzyme source protein concentration**

14 G-250 Coomassie Brilliant Blue (5 mL) was mixed with enzyme liquid (0.2 mL) at
15 25°C. Optical density (OD) was measured three times at 595nm, and the protein
16 content was calculated according to a standard curve.

17 **2.2.4. Acetylcholinesterase (TChE) test**

18 The TChE checker board method was followed the instructions of enzyme activity
19 test kit produced by Nanjing Jiancheng Bioengineering Institute. OD was measured
20 three times at 412nm and zero set with double distilled water (DDW).

21 **2.2.5. Ca^{2+} -ATPase test**

1 The ultra-micro ATPase checkerboard method was followed the instructions of
2 enzyme activity test kit produced by Nanjing Jiancheng Bioengineering Institute. OD
3 was measured three times at 412nm and zero set with distilled water.

4 **2.2.6. Monoamine oxidase (MAO) test**

5 The monoamine oxidase checkerboard method was followed the instructions of
6 enzyme activity test kit produced by Nanjing Jiancheng Bioengineering Institute. OD
7 was measured three times at 242nm and the enzyme activity calculated.

8 **2.3. Data analysis**

9 Comparisons of rates of pest mortality and revised control efficiency were
10 conducted using one-way analysis of variance (one-way ANOVA). Significant
11 differences among means were determined using Fisher's LSD test at $P = 0.05^{12}$, and
12 all analyses were conducted in the statistical program SPSS v 19.0.

$$13 \text{ Reduced rate of pest(\%)} = \frac{\text{Cardinal number of pests before treatment} - \text{Number of pests after treatment}}{\text{Cardinal number of pests before treatment}} \times 100$$

$$14 \text{ Revised effective rate(\%)} = \frac{\text{Reduced rate of treatment section} - \text{Dropping rate of contrast section}}{100 - \text{Reduced rate of treatment section}} \times 100$$

15 **3. RESULTS**

16 **3.1. Laboratory test**

17 The acaricide most effective in control of strawberry red spider mites was 1.8%
18 abamectin, LC_{50} was 0.18 mg L^{-1} (Table 2). Following this, a group of five (15%
19 pyridaben, 2.5% lambda-cyhalothrin, 0.5% veratridine, 20% carbosulfan) had high
20 toxicity (LC_{50} = 2.69 mg L^{-1} , 3.94 mg L^{-1} , 5.98 mg L^{-1} and 6.75 mg L^{-1} , respectively).
21 The next most toxic group was 5% hexythiazox and 10% bifenazate (LC_{50} = 9.82 mg

1 L⁻¹ and 19.09 mg L⁻¹, respectively). The next group, 24% spirotetramat, 20%
 2 chlorantraniliprole and 10% chlorfenapyr, was less effective; the order of toxicity
 3 from high to low was spirotetramat>chlorantraniliprole>chlorfenapyr. The least
 4 effective group was 2.5% spinosad and 43% bifenthrin with LC50= 117.73mg L⁻¹
 5 and 146.22mg L⁻¹, respectively.

6 We tested 13 acaricides, including chemical agents (e.g., abamectin, bifenthrin) a
 7 botanical pesticide (veratrine) and a microbial agent (kanghebio). The most effective
 8 was abamectin. Three new acaricides (veratrine, kanghebio and bifenthrin) had
 9 variable effectiveness. Veratrine and kanghebio were more effective than bifenthrin.
 10 Six acaricides with high efficacy were identified: abamectin, pyridaben, cyhalothrin,
 11 carbosulfan, hexythiazox, and bifenthrin.

12 The status of female mites 24h after acaricide was determined under a fluorescence
 13 microscope. The status of female mites treated with abamectin, pyridaben, kanghebio
 14 and cyhalothrin changed significantly; they curled up in convulsions, and their
 15 activity was low. Female mites treated with kanghebio became black. Female mites
 16 treated with veratrine, carbosulfan, hexythiazox and bifenthrin, curled their feet and
 17 had low activity, but no convulsions. After treatment with chlorfenapyr, mites were
 18 black, with curled feet and no convulsions or significant change in the activity. There
 19 were no significant differences among female mites treated with acaricide
 20 (spirotetramat, chlorantraniliprole, spinosad, and bifenthrin) and those treated with
 21 water as a control. Figure 1 showed the proportional reduction in numbers of live

mites 6 h to 72 h after the slide-dip test. Abamectin and pyridaben had the most rapid reduction in mite numbers (i.e., 6h after the test), while spinosad, chlorfenapyr, chlorantraniliprole and bifenthrin had little effect after 6h. Pyridaben and carbosulfan showed the greatest reductions in mite numbers at 24h and 48h after the test. Bio-pesticides (veratrine, spinosad, and kanghebio) performed worse than chemical pesticides. Most acaricides' effectiveness grew noticeably 12h after the test, and all of them killed some mites between 1d and 3d.

Figure 2 showed the status of female mites 24 h after acaricide application under a fluorescence microscope. The status of female mites treated with abamectin, pyridaben, kanghebio and cyhalothrin (panels A, B, C and D, respectively) was greatly changed—many were curled up in convulsions and activity was low. Female mites treated with kanghebio (C) became black. Panels E, F, G, and H show female mites treated with veratrine, carbosulfan, hexythiazox, and bifenthrin, respectively. Mites had curled feet and low activity but no convulsions. Panel K (treatment with chlorfenapyr): mite black, foot curled, no convulsions, no significant change in activity. Compared to the control (water, Panel CK), female mites treated with spirotetramat, chlorantraniliprole, spinosad and bifenthrin (Panels I, J, L, and M, respectively) showed no significant change in status.

3.2. Greenhouse test

The same treatments were applied in No.1 and No. 2 greenhouses over the same period. The overall trend was consistent with the laboratory test (Table 3 and 4). Two new bio-pesticides showed better control efficacy than chemical pesticides in

1 greenhouse tests. Of the eight acaricides, abamectin showed the best efficacy, while
 2 Pyridaben, kanghebio, cyhalothrin, veratrine, carbosulfan, hexythiazox, and bifenthrin
 3 also showed good efficacy. The results of experiments in No.1greenhouse were
 4 consistent with those from No.2 greenhouse, and these results were in agreement with
 5 those of the laboratory test. However, better control was achieved in No.2 greenhouse
 6 than in No.1greenhouse. This was possibly due to moister conditions in No.2
 7 greenhouse, which were not suitable for red spider outbreak, while conditions were
 8 more suitable for red spider in the No. 1 greenhouse. Eight acaricides were effective
 9 in prevention and control, and the efficacy of the biological agents veratrine and
 10 kanghebio was good. Combined with laboratory results, this suggests that the
 11 biological acaricides veratrine and kanghebio, which are low in toxicity and high
 12 effective, could be applied greenhouses to control red spider.

13 **3.3. Determination of enzyme activity**

14 Enzyme activity tests were carried out to explore possible mechanisms of action.
 15 Kanghebio and cyhalothrin obviously inhibited Ca^{2+} -adenosine triphosphatase (Ca^{2+} -
 16 ATPase), while veratrine and kanghebi obviously inhibited acetylcholinesterase
 17 (TChE) and monoamine oxidase (MAO). Cyhalothrin exerted an auxo-action on
 18 MAO.

19 Enzyme activity results were shown in table 5. Three acaricides showed different
 20 effects on TChE, Ca^{2+} -ATPase and MAO. Kanghebio and cyhalothrin obviously
 21 inhibited Ca^{2+} -ATPase, while the two Bio-pesticides (veratrine and kanghebio)
 22 obviously inhibited TChE and MAO. Cyhalothrin showed auxo-action on MAO.

Figure 3 shows the inhibiting effects of three acaricides on AChE. The bio-pesticides (veratrine, kanghebio) had the same inhibiting effect on AChE, veratrine and kanghebio's inhibiting effects were greatest at high concentrations and cyhalothrin's inhibiting effect was lowest at low concentrations.

Figure 4 shows the inhibiting effects of three acaricides on ATPase. Kanghebio had the greatest inhibiting effect, followed by cyhalothrin, while veratrine had the least inhibiting effect.

Figure 5 shows the inhibiting effect on MAO of two acaricides (veratrine and kanghebio). At high concentrations veratrine had an obviously inhibiting effect, enzyme activity approached zero. Cyhalothrin hadauxo-action on MAO, and this was greatest at high concentrations of cyhalothrin.

4. DISCUSSION

Strawberry mite infestations often occur during fruiting, mites can rapidly develop resistance to numerous acaricides, this adaptation can give rise to rapid population increases^{13,14}. The dominant species of spider mite is *T. cinnabarinus*, which can greatly influence the quality and yield of strawberry crops.

The results showed as follows: of the 13 acaricides tested, those with better efficacy in the control of strawberry mites were Abamectin, Pyridaben, cyhalothrin, veratrine, and kanghebio. Veratrine and kanghebio are bio-pesticides and were as effective as conventional acaricides. They are environment-friendly and effective acaricides with low toxicity. Next, 0.5% of the recommended doses of veratrine and kanghebio are

1 100mlha⁻¹ and 150mlha⁻¹, respectively. It is recommend that pesticide be applied in
2 early stages of insect attack, spraying once every 3d during severe infestations and
3 spraying once every 7d after insect numbers decrease, then spraying once every 10d
4 for prevention.

5 Spider mites were sensitive to abamectin and have not become resistant to
6 abamectin in the Pinggu area. Some reports¹⁵⁻¹⁹suggest that strawberry mites have
7 developed pesticide resistance. Therefore, we do not recommend abamectin as a long-
8 term option for controlling mites. Of the chemical acaricides, pyridabenand
9 cyhalothrin showed high efficacy and may have unwanted effects on bees during
10 strawberry flowering. They are WHO Class II and not environmentally friendly, so
11 we do not recommend that they be widely applied in the field.

12 Carbosulfan and hexythiazox have relatively lower toxicity and were ineffective at
13 low concentrations. This finding suggests the dosage should be increased to improve
14 the efficacy. Such acaricides that do not meet the requirements of low toxicity and
15 high efficacy are not useful for preventing strawberry spider mites in greenhouses.

16 Combining the results of the laboratory test with those of the greenhouse
17 experiment, we recommend two bio-pesticides (veratrine and kanghebio) and one
18 chemical pesticide (cyhalothrin) to control female adult mites, explore the possible
19 role targets by acetylcholinesterase checkerboard, ultramicroatpase checkerboard and
20 monoamine oxidase checkerboard. The results showed that the two bio-pesticides
21 (veratrine and kanghebio) inhibited Ca²⁺-ATPase, TChE and MAO. The chemical

1 pesticide (cyhalothrin) inhibited Ca^{2+} -ATPase, TChE and had auxo-action on MAO.

2 We speculate that Ca^{2+} -ATPase and TChE inhibition is the mechanism by which these
3 acaricides act.

4 The results obtained in our study show that the bio-pesticides veratrine, kanghebio
5 are effective control agents both in laboratory tests and greenhouse experiments.

6 Furthermore, they are environmentally friendly acaricides, with low toxicity and high

7 efficacy. This research provides a strong basis for using bio-pesticides in place of

8 conventional chemicals to control strawberry spider mites, and provides useful

9 insights into the biological mechanisms by which acaricides act. However, we need to

10 further study their efficacy at different mite developmental stages and clarify the

11 mechanisms of action of these bio-pesticides.

12 **5. CONCLUSION**

13 In summary, two new bio-pesticides and several chemical pesticides were

14 compared using laboratory toxicity tests and greenhouse experiments. The bio-

15 pesticides showed better control efficacy than chemical acaricides in greenhouse tests.

16 These bio-pesticides have developed a good reputation in international markets in

17 recent years due to their safety, organic nature, environmental friendliness, and lack

18 of propensity to induce pesticide resistance, among other advantages. Our study

19 provides a scientific basis for chemical pesticides to be replaced by these and

20 potentially other new bio-pesticides.

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Table 1. 13 different acaricides were used in this experiment.

Acaricides	Manufacturers
10% Bifenthrinemulsifiable concentrate	Langfang Pesticides Medium-scale Trial Manufac under IPP-CAAS
1.8% Abamectinemulsifiable concentrate	Beijing C. A. H. Bio-technology Co., Ltd.
15% Pyridabenemulsifiable concentrate	Jiangsu Kwin Co., Ltd.
5% Hexythiazoxwetable powder	IPP pesticide factory of CAAS
20% Carbosulfanemulsifiable concentrate	FMC Corporation
2.5% Lambda-cyhalothrinemulsifiable concentrate	Syngenta Crop Protection Co., Ltd.
24% Envidor suspending agent	Bayer Crop Science China Co., Ltd.
2.5% Spinosad suspending agent	Dow Chemical Company
20% Chlorantraniliprole suspending agent	USA Dupont Group Chemical Co., Ltd.
10% Chlorfenapyr suspending agent	BASF SE
0.5% Veratrine soluble liquid	Jianhua Plant Pesticide Plant,Handan City, Hebei
43% Bifenazate suspending agent	Chemtura Inc.
Kanghebio	Korea Bio Co., Ltd.

Table 2. Toxicity of 13 acaricides on adult female strawberry mites using the slide-dip method in laboratory tests.

Acaricide	Slope $\pm$ SE	LC ₅₀ (ng a.i.adult ⁻¹)	95% confidence interval (ng a.i.adult ⁻¹)	χ^2 (df)	Relative toxicity index
Abamectin	1.29 $\pm$ 0.15	0.18	0.14–0.25	1.23(16)	0.0012
Pyridaben	0.79 $\pm$ 0.10	2.69	1.55–4.48	2.35(19)	0.0184
Cyhalothrin	1.85 $\pm$ 0.35	3.94	3.01–5.11	5.68(16)	0.0269
Veratrine	1.68 $\pm$ 0.20	5.98	4.83–7.53	12.57(13)	0.0409
Carbosulfan	1.53 $\pm$ 0.19	6.75	5.24–8.85	1.90(16)	0.0462
Hexythiazox	2.18 $\pm$ 0.28	9.82	7.89–11.79	5.48(19)	0.0672
Bifenthrin	1.17 $\pm$ 0.25	19.09	11.79–27.49	2.33(16)	0.1306
Envidor	1.84 $\pm$ 0.34	40.19	30.98–52.49	4.44(16)	0.2749
Chlorantraniliprole	0.96 $\pm$ 0.17	60.50	38.74–92.85	3.45(16)	0.4138
Chlorfenapyr	2.89 $\pm$ 0.54	75.84	65.31–91.40	4.22(16)	0.5187
Spinosad	0.92 $\pm$ 0.16	117.73	77.47–197.82	2.09(16)	0.8052
Bifenazate	1.97 $\pm$ 0.21	146.22	120.82–180.02	4.98(13)	1.00
Kanghebio	1.18 $\pm$ 0.19	4.15 $\times 10^7$	2.54 $\times 10^7$ – 5.73 $\times 10^7$	1.12(13)	

Table 3. Reductions in insect density and corrected mortality results for 8 acaricides

from the experiment in Greenhouse 1.

Acaricide	Reduction in insect density (%)				Correctedmortality (%)			
	7d	14d	21d	28d	7d	14d	21d	28d
1.8% Abamectin EC	91.93	93.57	95.75	97.14	98.28ab	98.77ab	99.34a	99.68a
15% Pyridaben EC	92.63	94.75	95.63	96.03	98.44a	99.08a	99.31a	99.50a
Kanghebio	84.30	88.08	90.46	91.45	96.87bc	98.01abc	98.59ab	98.97ab
2.5% Cyhalothrin EC	81.29	83.03	84.20	88.63	95.92c	96.65bc	97.41b	98.50bc
0.5% Veratrine SL	80.91	81.58	83.64	84.19	95.85c	96.41bc	97.31b	97.91bc
20% Carbosulfan EC	77.06	78.48	80.38	81.04	95.02c	95.78c	96.88b	97.57c
5% Hexythiazox WP	76.33	77.87	78.57	79.28	94.91c	96.21bc	96.68b	97.30c
10% Bifenthrin EC	49.63	32.46	15.55	11.13	89.02d	84.37d	86.45c	88.48d

Table 4.Reductions in insect density and corrected mortality results for 7 acaricides

from the experiment in Greenhouse 2.

Acaricide	Reduction in insect density %				Correctedmortality %			
	7d	14d	21d	28d	7d	14d	21d	28d
1.8% Abamectin EC	94.03	95.03	96.80	98.14	97.90a	98.75a	99.42a	99.86a
15% Pyridaben EC	93.54	95.62	96.23	97.27	97.73a	98.90a	99.32a	99.61ab
Kanghebio	86.20	88.81	90.46	91.80	95.36b	97.53ab	98.37ab	98.90bc
2.5% Cyhalothrin EC	82.59	84.18	86.09	90.18	93.73bc	95.94bc	97.37bc	98.52cd
0.5% Veratrine SL	82.56	83.57	85.39	86.04	93.76bc	95.85bc	97.22bc	97.89cde
20% Carbosulfan EC	77.40	79.59	80.60	81.52	91.89c	94.77bc	96.44bc	97.29de
5% Hexythiazox WP	75.46	76.75	76.75	77.03	91.23c	94.28c	95.80c	96.60e
10% Bifenthrin EC	50.45	35.10	17.33	5.85	82.17d	80.22d	84.59d	86.10f

Table 5. Enzyme activity of female adult mites 24h after treatment with acaricides

by acetylcholinesterase checkerboard, ultramicroatpase checkerboard and monoamine oxidase checkerboard.

Acaricide	Ca ²⁺ -ATPase(<i>Umgprot⁻¹</i>)		TChE(<i>Umgprot⁻¹</i>)		MAO(<i>Umgprot⁻¹</i>)	
	Dose(<i>mg a.i. L⁻¹</i>)		Dose(<i>mg a.i. L⁻¹</i>)		Dose(<i>mg a.i. L⁻¹</i>)	
	2.5	0.625	500	125	100	25
0.5% Veratrine EC	4.9481	5.5596	0.0204	0.0990	0.0000	0.0034
Kanghebio	0.9043	1.5281	0.0205	0.0997	0.0091	0.0101
2.5% Cyhalothrin EC	1.4034	3.1075	0.0353	0.1457	0.0341	0.0265
CK(DDW)	6.5490		0.1605		0.0114	

Figure 1. Reductions in numbers of adult female mites following treatment with one of 13 acaricides in slide-dip laboratory tests (6–96h).

Figure 2. The status of female adult mites 24 h after acaricide application, viewed under a stereo fluorescence microscope.

Note: Treated with A(Abamectin), B(Pyridaben), C(Kanghebio), D(Cyhalothrin), E(Veratrine), F (Carbosulfan), G(Hexythiazox), H(Bifenthrin), I(Envidor), J(Chlorantraniliprole), K(Chlorfenapyr), L(Spinosad), M(Bifenazate), CK(Water).

Figure 3. Acetylcholinesterase activity of female adult mites 24h after treatment with one of three acaricides.

Figure 4. Ca^{2+} -ATPase activity of female adult mites 24h after treatment with one of three acaricides.

Figure 5. Monoamine oxidase activity of female adult mites 24h after treatment with one of three acaricides.

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