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Original Article

Toxicity of acaricides to kanzawa spider mite *Tetranychus kanzawai* Kishida (Acari: Tetranychidae)

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ABSTRACT

Kanzawa spider mites *Tetranychus kanzawai,* are among the most widespread and serious pests that infest economically important crops such as cassava. It is important to screen the toxicity of the available agrochemicals with acaricidal effects because chemical control remains an integral part in the management of these pests. This study presents the results of laboratory-based experiments that examined how *T. kanzawai* responded to six acaricides, namely abamectin, emamectin benzoate, fenpyroximate, hexythiazox, spirotetramat, and chlorfenapyr through leaf disk assay. Diluted concentrations of each of the six acaricides were prepared at 0.0001, 0.001, 0.01, 0.1, 1, 10, 100, and 1000mg of active ingredient per liter of solution. The study revealed that among the six registered acaricides in the Philippines, fenpyroximate has the most potent toxic effects on the mites' eggs, but it shows lower toxicity towards the adults. Conversely, hexythiazox exhibits high toxicity to adults but, based on a previous study, does not surpass the toxicity of the biorational alternatives abamectin and emamectin benzoate. The results of this study contribute to greater evidence that some acaricides are ineffective against *T. kanzawai*. The study revealed that hexythiazox and fenpyroximate can alternatively be used in managing *T. kanzawai*. Considering cassava's importance as a vital root crop, educating farmers on the responsible use of

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these acaricides is vital for the effective management of *T. kanzawai* , thereby ensuring cassava crop yield preservation and food security. These efforts can contribute to the development of targeted and sustainable pest management strategies for *T. kanzawai* in cassava cultivation.

Keywords: Chemical control, IPM programs, Cassava, Agrochemical screening

INTRODUCTION

The kanzawa spider mite (KSM) *Tetranychus kanzawai* Kishida is one of the most prevalent mite pests threatening economically important crops in the Philippines. In East and South Asia, it infests cassava and papaya plants (Gavarra 1981), and many other plant species, including strawberries, peppers, tomatoes, potatoes, beans and corn (Takafuji et al 2005). The mites devour the chloroplasts on the underside of the leaf, leaving white or yellowish stippling on the upper surface. Stippling coalesces into brownish lesions as mite feeding continues (Cheng et al 2009). Heavy mite infestation eventually leads to withering and defoliation, which further lowers plant development owing to the plant's diminished photosynthetic activity.

Biological control agents, such as predatory mites, have gained popularity as a means to control spider mite populations due to their perceived environmental friendliness and increasing use in organic production (Zhang 2003). *Amblyseius longispinosus* Evans, for example, is among the promising predators known for effectively controlling *T. kanzawai* (Hamamura 1987, Mori and Saito 1979). However, achieving successful spider mite control may require a combination of tactics, as relying solely on a single approach may not be sufficient (Kim and Seo 2001, Rhodes and Liburd 2006). By integrating reduced-risk pesticides and strategically timed releases of predatory mites, a more effective and acceptable control of spider mite populations can potentially be achieved (Hoy and Cave 1985, Hoy and Ouyang 1986, Rhodes et al 2006).

In the Philippines, six acaricides, namely abamectin, emamectin benzoate, fenpyroximate, hexythiazox, spirotetramat and chlorfenapyr, are approved by the FPA (Food and Pesticide Authority) for general trade. Among these, abamectin and emamectin benzoate's toxicity to KSM adults has been investigated (Villacencio and Vasquez 2022). Additionally, fenpyroximate, hexythiazox, spirotetramat and chlorfenapyr's effects on specific mite species have been studied. However, research addressing *T. kanzawai* and efficient strategies for using these acaricides to control this mite in cassava is lacking both in the Philippines and globally.

This paper presents the results of laboratory-based experiments that examined how kanzawa red spider mites responded to six acaricides, namely abamectin, emamectin benzoate, fenpyroximate, hexythiazox, spirotetramat, and chlorfenapyr. Quantifying the toxicity of these acaricides for KSM is crucial to enable their proper utilization during emergencies. This is particularly important for tropical farmers who suffer substantial economic damage caused by pests like KSM that can severely affect both food security and the sustainability of livelihoods dependent on cassava farming.

MATERIALS AND METHODS

Mass Rearing of Mites

The KSM *T. kanzawai* colonies were obtained from susceptible varieties of cassava plants that had not been treated with pesticides. Cassava leaves infested with spider mites were transported to the Pest Management and Natural Products laboratory of PhilRootcrops, Visayas State University, Visca, Baybay City, Leyte in polyethylene bags and reared on one 2-month-old potted cassava (Rayong/NSIC Cv 30) in the laboratory. The mites produced were used for the ovicidal and adulticidal bioassay.

Acaricides

Six acaricides, namely: abamectin, emamectin benzoate, chlorfenapyr, spirotetramat, hexythiazox and fenpyroximate were evaluated against *T. kanzawai*. Although in this study, the adulticidal activity of abamectin (Agriguard®, Agway Chemicals Corporation) and emamectin benzoate (Proclaim Opti®, Syngenta) against *T. kanzawai* was not included since it has already been reported (Villacencio and Vasquez 2022). Hexythiazox (Nissorun®, Nippon Soda), and fenpyroximate (Ortus®, Nihon Nohyaku Co., Ltd.) are purely acaricides, while chlorfenapyr (Kotetsu®, BASF Crop Protection) and spirotetramat (Movento®, Covestro) have dual action and are primarily recognized as insecticides.

Ovicidal Test

Gravid adult females were introduced onto the untreated 23mm in diameter leaf disc laid on moist tissue paper in a Petri dish, and allowed to lay eggs for 24h. The adults were removed after egg deposition, and the number of eggs was counted before treatment. Twenty four hours after the removal of the parent mites, the leaf disc containing the deposited eggs was dipped for ten seconds (Wang et al 2015) in the prepared acaricide solutions at concentrations 0.0001, 0.001, 0.01, 0.1, 1, 10, 100, and 1000mg of active ingredient per liter of solution. . The treated discs were air-dried for one to two hours depending on the air humidity and placed back in a Petri dish lined with moist tissue paper. The treated eggs were incubated and allowed to hatch. The appearance of the eggs and the newly hatched spider mites were noted. The ovicidal activity was quantified as percentage hatchability, and the deformity of neonates was also recorded. The total counts of hatched eggs inside each Petri dish were determined by counting the hatched and unhatched eggs 24 and 48h after treatment. The ovicidal activity of the acaricides used in this study was more evident 48h after treatment because the eggs were already two days old before treatment and were expected to hatch on the fourth day (Vasquez 2016). Unsuccessful hatch was characterized by the denaturation of the egg albumin that was evident when the eggs became yellowish or with the death of a newly-hatched nymph.

$$\% \text{ Hatchability} = \frac{\text{Total number of hatched eggs}}{\text{Total number of eggs in a leaf}} x100$$

Adulticidal Test

The acaricides were evaluated for their toxicity against the female individuals of *T. kanzawai*. Female mites were used because they are the least sensitive (Vasquez 1994). Thus, immature mites will also succumb to the dosage that is toxic to female adults Female KSMs are carmine red in color with dark marks on the sides while the males are lighter, orange red (Corpuz-Raros 1986). Different concentrations of acaricides were prepared by diluting them by a factor of 10, resulting in solutions with 0.0001, 0.001, 0.01, 0.1, 1, 10, 100 and 1,000mg of active ingredient per liter of solution, while distilled water was used as a control. The experimental unit was a cassava leaf disc 23mm in diameter, immersed for 5s in the acaricide solution or water. Twenty female mites were placed on each cassava leaf disc laid on a Petri dish (160mmx10mm) lined with tissue paper saturated in distilled water. This experimental unit represented one replicate. Each treatment had three repetitions consisting of 20 individuals per repetition and a total of 60 mites for each acaricide concentration. The number of live and dead mites was quantified every 24h for three days. Mites were considered dead if no movement was seen for 5s after poking with a No. 000 brush (Helle and Sabelis 1985). The concentration range that produced 0 to 100% mortality was determined for each acaricide. Also, the percentage mortality data was corrected using Abbott's formula.

$$\% \text{ Mortality} = \frac{\text{Total number of dead mites}}{\text{Total number of introduced mites}} x100$$

Data Analysis

A Probit analysis (Finney 1971) was performed using the mortality data after it had been corrected in the control (Abbott 1925). An analysis of variance (ANOVA) along with Tukey's Honestly Significant Difference (HSD) test was employed to assess potential significant differences in the mean percentage mortality and percentage hatchability across various acaricides and concentrations. These analyses were performed at a 5% significance level using R software version 4.0.2.

RESULTS AND DISCUSSION

The hatchability of KSM eggs, 48h after exposure to the acaricide treatments, is shown in Table 1. As observed, a concentration of 100mg L^{-1} of abamectin, fenpyroximate, and hexythiazox resulted in 100% mortality of the eggs. The minimum effective concentration of abamectin, fenpyroximate, and hexythiazox was 10mg L^{-1}. In contrast, spirotetramat and emamectin benzoate did not significantly affect the hatchability of the eggs, as the percentage of eggs that hatched remained relatively constant across all concentrations. Based on the computed LC_{50} values shown in Table 2, fenpyroximate (0.001mg L^{-1}) is the most toxic to *T. kanzawai* eggs, followed by hexythiazox (0.02mg L^{-1}), abamectin (0.03mg L^{-1}), and chlorfenapyr (4.717mg L^{-1}).

Table 1. Mean percent hatchability (±SE) of *T. kanzawai* eggs against tested acaricides 2 days after treatment (DAT).

Concentrations (mg L^{-1})	Treatments					
	Chlorfenapyr	Spirotetramat	Hexythiazox	Fenpyroximate	Abamectin	Emamectin benzoate
1000	20.22±6d	30.82±10b	0±0d	0±0d	0±0a	39.39±6a
100	49.26±11c	46.93±24ab	0±0d	0±0d	0±0a	63.01±23a
10	51.48±3c	54.62±16ab	14.47±8d	11.41±7d	4.78±3a	69.08±3a
1	51.48±3c	58.47±6ab	30.18±2cd	31.22±13bcd	41.91±8b	67.06±3a
0.1	59.72±3bc	59.7±9ab	41.31±3bcd	22.25±7cd	47.69±16b	58.35±12a
0.01	63.16±2bc	67.37±14ab	62.1±15abc	33.28±9bcd	61.84±8bc	78.05±6a
0.001	80.86±3ab	68.29±6ab	78.46±11ab	48.54±5bc	76.25±2bc	75.31±7a
0.0001	81.97±3ab	75.86±3ab	69.31±15abc	60.59±11ab	76.92±7bc	68.44±8a
0 (Control)	89.57±3a	90.61±3a	90.61±3a	90.61±3a	90.61±3c	90.61±3a
P-value	<0.0001***	0.0992 ns	<0.0001***	<0.0001***	<0.0001***	0.1007 ns

Means on the same column in a particular acaricide with the same letter assignment are not significantly different at 5%. ns-Not significant; *-Significant at 5% level; **-Significant at 1% level; ***-Significant at 0.1% level based on the ANOVA and Tukey's HSD test

Table 2. Probit analysis to calculate LC_{50} values for KSM eggs after 2 days of exposure to various acaricides.

Chemical	LC50 (mg L^{-1})		95% Confidence interval		Chi-square (df = 6)
			Lower bound	Upper bound	
Abamectin	0.03	Concentration	-0.518	-0.404	42.337[a]
		Intercept	-0.769	-0.64	
Emamectin benzoate	5784.526	Concentration	-0.131	-0.052	22.715[a]
		Intercept	0.297	0.39	
Chlorfenapyr	4.717	Concentration	-0.231	-0.15	10.117[a]
		Intercept	0.081	0.175	
Spirotetramat	8.306	Concentration	-0.185	-0.105	4.739[a]
		Intercept	0.087	0.18	
Hexythiazox	0.02	Concentration	-0.479	-0.37	31.214[a]
		Intercept	-0.785	-0.659	
Fenpyroximate	0.001	Concentration	-0.383	-0.276	26.729[a]
		Intercept	-1.062	-0.931	

[a] - a heterogeneity factor is used in the calculation of confidence limits since the significance level is less than 0.150.

The mortality rates of female KSM at various concentrations of acaricides is displayed in Table 3. The toxicity of the three acaricides, chlorfenapyr, hexythiazox and fenpyroximate, was more noticeable at 2 DAT in comparison to 1 DAT. The LC_{50} values at 2 DAT suggest that chlorfenapyr (0.42mg L^{-1}) was the most toxic to adult mites followed by hexythiazox (1.12mg L^{-1}) and fenpyroximate (50.93mg L^{-1}). Conversely, spirotetramat did not demonstrate lethal toxicity up to three days after the treatment.

At 1 DAT, concentrations of 0.0001mg L^{-1}, 1000mg L^{-1}, and 100mg $L^{-1}$of chlorfenapyr (5±3), hexythiazox (70±15) and fenzpyroximate (33.33±12), respectively, significantly decreased the mite population compared to the water-sprayed control group (0±0). At 2 DAT, concentrations of 1000mg L^{-1} chlorfenapyr (100±0), 100mg L^{-1} hexythiazox (70±15) and fenpyroximate (44.98±10) also decreased the mite population compared to the water-sprayed control group (1.67±2). At 3 DAT, the lethal toxicity became more prominent, as evidenced by the extremely low LC_{50} values: chlorfenapyr 0.001mg L^{-1}, hexythiazox 0.07mg L^{-1} fenpyroximate 4.46mg L^{-1} (Table 4).

Table 3. Mean percent mortality (± SE) of *T. kanzawai* adult females after 1-, 2- and 3-days exposure to acaricides.

Treatments	AI Concentration (mg L^{-1})									P-value
	1000	100	10	1	0.1	0.01	0.001	0.0001	0 (Control)	
Chlorfenapyr										
1 DAT	100±0b	25±23b	11.67±12b	13.33±7b	1.67±2b	10±8b	6.67±3b	5±3b	0±0a	<0.0001***
2 DAT	100±0a	63.32±22ab	66.65±8ab	38.32±18ab	43.33±26ab	30±16ab	30±21ab	16.65±3b	1.67±2b	0.0127*
3 DAT	100±0a	88.32±7a	84.97±8a	68.3±15a	61.65±31a	59.98±30a	38.32±27a	53.3±21a	3.33±2a	0.0692 ns
Spirotetramat										
1 DAT	20±12a	13.33±13a	8.33±3a	8.33±6a	6.67±3a	5±3a	1.67±2a	0±0a	0±0a	0.4593 ns
2 DAT	40±20a	16.67±12a	26.65±17a	24.98±20a	11.65±4a	13.32±6a	23.33±12a	13.32±4a	1.67±2a	0.6434 ns
3 DAT	66.63±31a	33.32±24a	29.97±16a	34.97±23a	23.3±4a	29.97±8a	44.97±20a	29.97±15a	3.33±2a	0.5768 ns
Hexythiazox										
1 DAT	70±15a	53.33±25ab	35±28ab	18.33±13ab	10±0ab	6.67±2ab	3.33±2ab	1.67±2ab	0±0b	0.0188 *
2 DAT	90±10ab	93.32±2a	39.98±30abc	38.32±28abc	24.98±8abc	30±17abc	26.67±20abc	8.32±4bc	1.67±2c	0.0109*
3 DAT	98.32±2a	96.63±2a	64.98±24ab	44.97±25ab	39.97±16ab	46.63±20ab	39.97±28ab	16.63±7ab	3.33±2b	0.0132*
Fenpyroximate										
1 DAT	91.67±8a	33.33±12b	15±9bc	3.33±2c	1.67±2c	0±0c	0±0c	0±0c	0±0c	<0.0001***
2 DAT	96.65±3a	44.98±10b	16.67±9bc	13.33±7c	8.33±6c	5±5c	0±0c	0±0c	1.67±2c	<0.0001***
3 DAT	96.65±3a	54.97±16ab	36.65±23ab	41.65±28ab	39.98±20ab	21.65±13ab	8.32±8b	1.65±2b	3.33±2b	0.011*

Means on the same row in a particular time and acaricide with the same letter assignment are not significantly different at 5%.
ns-Not significant; *-Significant at 5% level; **-Significant at 1% level; ***-Significant at 0.1% level

Table 4. Probit analysis to calculate LC_{50} values for KSM adults after 1, 2, and 3 days of exposure to various acaricides.

Treatments	LC_{50} (mg L^{-1})		95% Confidence interval		Chi-square (df=6)
			Lower bound	Upper bound	
Chlorfenapyr					
1 DAT	169.339	concentration	0.329	0.445	147.015[a]
		intercept	-0.923	-0.803	
2 DAT	0.423	concentration	0.246	0.334	41.832[a]
		intercept	0.059	0.158	
3 DAT	0.001	concentration	0.209	0.301	26.795[a]
		intercept	0.67	0.782	
Spirotetramat					
1 DAT	26782610.84	concentration	0.129	0.261	3.659[b]
		intercept	-1.521	-1.378	
2 DAT	1181116762	concentration	0.042	0.128	21.162[a]
		intercept	-0.821	-0.72	
3 DAT	53164.213	concentration	0.027	0.105	43.222[a]
		intercept	-0.358	-0.266	
Hexythiazox					
1 DAT	75.994	concentration	0.346	0.464	3.035[b]
		intercept	-0.821	-0.702	
2 DAT	1.12	concentration	0.29	0.383	65.237[a]
		intercept	-0.067	0.033	
3 DAT	0.074	concentration	0.282	0.375	56.843[a]
		intercept	0.319	0.424	
Fenpyroximate					
1 DAT	113.137	concentration	0.806	1.112	28.624[a]
		intercept	-2.127	-1.811	
2 DAT	50.932	concentration	0.532	0.706	54.778[a]
		intercept	-1.137	-0.976	
3 DAT	4.465	concentration	0.315	0.416	51.324[a]
		intercept	-0.288	-0.187	

[a] - a heterogeneity factor is used in the calculation of confidence limits since the significance level is less than 0.150.
[b] - no heterogeneity factor is used in the calculation of confidence limits since the significance level is greater than 0.150

For chlorfenapyr, the percentage hatchability at concentrations of 0.0001 and 0.001mg L^{-1} did not differ significantly from the control group (Table 1). Ovicidal activity became evident at a concentration of 0.01mg L^{-1} (Table 1). Furthermore, there were no significant differences in percentage hatchability values between concentrations ranging from 0.01mg L^{-1} to 100mg L^{-1} (Table 1). As anticipated, the highest ovicidal activity was observed at the maximum tested concentration of chlorfenapyr, which was 1000mg L^{-1} (Table 1). In the ovicidal test, reduced hatchability was achieved at concentrations ≥0.01mg L^{-1}, with an LC_{50} value of 4.717mg L^{-1} (Table 2), considerably lower than the findings reported by Badawy et al (2022) and Ullah and Gotoh (2013). Badawy et al (2022) reported very low ovicidal activity of chlorfenapyr in *Tetranychus urticae* eggs, with an LC_{50} value of 1032.93mg L^{-1}. Additionally, Ullah and Gotoh (2013) found that eggs of other spider mite species, such as *Tetranychus macfarlanei* and *Tetranychus truncatus*, were susceptible to chlorfenapyr at an LC_{50} level of 492mg L^{-1}, which is ten times higher than the recommended rate (50mg L^{-1}). Chlorfenapyr exhibited high adulticidal

effects (100% mortality) only at a concentration of 1,000mg L^{-1} (Table 3). Furthermore, with regards to its toxicity to adults, Bozghani et al (2018) reported an LC_{50} value of 47.61mg L^{-1} for female adults of *T. urticae* at 1 DAT, which is significantly lower than the LC_{50} value of 169.34mg L^{-1} observed for *T. kanzawai* in this study (Table 4).

Spirotetramat had negligible effects on KSM, as only the highest concentration (1000mg L^{-1}) significantly reduced the number of hatched eggs compared to the control (Table 1). Regarding its adulticidal effect, percentage mortality was only significantly different from the control at a concentration of 1000mg L^{-1} (Table 3). Consequently, probit analysis revealed that it has a very high LC_{50} value (Table 4). Its toxic effects on spider mites have already been reported by Kramer and Nauen (2011) and Marcic (2011 and 2012). According to these studies, it does not instantly kill female spider mites but mainly affects their fecundity and egg hatching. Moreover, there are reports that female adults of *T. urticae* recover from intoxication when treated with spirodiclofen (Nauen 2005, Marcic 2007, van Pottelberge et al 2009) and spiromesifen (Nauen et al 2005, Wachendorff et al 2002), which both have a similar action to spirotetramat. In the results of Marcic et al (2011 and 2012), the mortality of the female adults of *T. urticae* between spirotetramat concentrations was not significant. However, the female fecundity and egg hatchability decreased as the concentration increased. The same study also revealed that the ovicidal effect of spirotetramat only occurs when eggs are laid by treated females but not from eggs of untreated females. The present study also showed the same result because the percentage hatchability of *T. kanzawai* eggs in all concentrations of spirotetramat was not significantly different from the control.

Hexythiazox was the most toxic to the adults of *T. kanzawai* with an LC_{50} value of 75.99mg L^{-1} (Table 4). Seventy percent of *T. kanzawai* were killed with the highest concentration (1,000mg L^{-1}) 24h after treatment (Table 3). This acaricide has been described as a mite growth regulator with various effects against spider mites, including ovicidal, nymphicidal, and adulticidal actions (Kumari et al 2017). Even so, its toxicity to adult KSM did not surpass that of its biorational counterparts, abamectin and emamectin benzoate. A 0.02mg L^{-1} and 0.2mg L^{-1} concentration of abamectin and ebamectin benzoate, respectively, can kill 50% of a *T. kanzawai* population (Villacencio and Vasquez 2022). Hexythiazox also exhibited high ovicidal activity (LC_{50}=0.02mg L^{-1}), next to fenpyroximate (LC_{50}=0.001mg L^{-1}) (Table 1 and 2), reducing egg hatchability of up to 14.47% to 100% at concentrations ≥10mg L^{-1} 48h after treatment. This agrees with the report of Alzoubi and Cobanoglu (2010 as they considered hexythiazox extremely toxic to the eggs of *T. urticae*. The LC_{50} for adult *T. urticae* in their study was 536.84mg L^{-1} at 1 DAT and 75.66mg L^{-1} at 3 DAT. These LC_{50} values are much higher compared to those reported in the present study, wherein the LC_{50} values for *T. kanzawai* at 1 and 3 DAT are 75.99mg L^{-1} and 0.07mg L^{-1} , respectively. Thus, the *T. kanzawai* population used in this study was more susceptible than *T. urticae* in the study of Alzoubi and Cobanuglo (2010). Furthermore, the US EPA (2007) stated that hexythiazox is an ovicide used for the control of mite growth through activity on eggs or early stages of development.

Fenpyroximate exhibited the lowest LC_{50} value for KSM eggs (0.0009mg L^{-1}), establishing it as the most potent ovicide among the tested acaricides (Table 2). As an adulticide, it is more toxic than spirotetramat but less toxic than chlorfenapyr and hexythiazox. Furthermore, its activity in KSM appears to be slower, as indicated by

its LC_{50} values per number of days since treatment: 113mg L^{-1} (1 DAT), 50.93mg L^{-1} (2 DAT), and 4.46mg L^{-1} (3 DAT) (Table 4). Additionally, lethal toxicity to adults was observed only at concentrations equal to or greater than 100mg L^{-1} (Table 3). An LC_{50} value of 113.14mg L^{-1} one day after treatment is higher compared to the results of Kim (1996), who reported that more than 50% of *T. kanzawai* was immobilized 24 hours after treatment at concentrations of 6.25-50mg L^{-1}. In the ovicidal test, fenpyroximate was able to suppress the hatching of 88.59 to 100% of the eggs at concentrations ≥10mg L^{-1}, and was relatively higher in toxicity compared to chlorfenapyr which was only able to suppress the hatching of all eggs at 1,000mg L^{-1} (Table 1). This fenpyroximate concentration is lower than that reported by Kim (1996), where all eggs failed to hatch at fenpyroximate concentrations of 25-50mg L^{-1}. The results suggest that fenpyroximate is more toxic to eggs than to the adults of *T. kanzawai*.

An application of 10mg L^{-1} of abamectin significantly reduced the egg hatchability down to 4.78% 48h after treatment (Table 1). Its LC_{50} value for KSM eggs, which is 0.0297mg L^{-1}, suggests that it is a more potent ovicide than chlorfenapyr, spirotetramat and emamectin benzoate (Table 2). It should be noted, however, that abamectin's ovicidal activity has been the subject of inconsistent findings. For instance, Kumar and Singh (2004) reported that *T. urticae* eggs were unaffected at various concentration of abamectin. In contrast, Salman (2007) claimed that abamectin was highly poisonous to eggs of all ages but had no effect on mite fertility. Ismail et al (2007) observed that Vapcomic 1.8% EC (Emulsifiable Concentrate) (abamectin) caused 87% mortality on the egg hatching of *T. urticae* at 2.5mg L^{-1}. Additionally, Hosny et al (2010) discovered that the LC_{50} of abamectin (1.8% EC) against *T. urticae* eggs was 1.05mg L^{-1}.

Emamectin benzoate is a semi-synthetic derivative of abamectin and also functions as a GABA agonist (IRAC 2019). It was found to be effective as an adulticide for *T. kanzawai* (Villacencio and Vasquez 2022). However, in this study, it did not significantly decrease the hatchability of the mites' eggs. Based on its LC_{50} value, which is 5784.3mg L^{-1}, it has the weakest ovicidal effect among the acaricides tested (Table 2). A similar result was reported by Yigezu et al (2022), wherein emamectin benzoate 1.92% EC exhibited the lowest ovicidal activity (37.5%) for *T. urticae* eggs at a 40µL dose compared with the other synthetic acaricides tested, such as amitraz and profenofols under laboratory conditions. The LC_{50} value of emamectin benzoate for the mite eggs remained high at 54.146mg L^{-1} even at 3 DAT (Yigezu et al 2022).

CONCLUSION

This study's findings reveal notable variations in the toxicity of the six FPA-registered acaricides available in the Philippines against *T. kanzawai*. Fenpyroximate demonstrates potent toxicity to mite eggs but is less toxic against adults, while hexythiazox exhibits significant toxicity to adults, but it did not surpass the toxicity of its biorational counterparts, such as abamectin and emamectin benzoate. These results underline the need for a comprehensive assessment of these acaricides, including their impact on mite fecundity, fertility and longevity. Moreover, it underscores the importance of educating farmers on the cautious use of these agrochemicals to manage *T. kanzawai* on cassava, a globally crucial crop, to ensure sustained product effectiveness and agricultural productivity.

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AUTHOR CONTRIBUTIONS

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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AVAILABILITY OF DATA AND MATERIALS

The required data are presented in the paper and supplementary materials. For any questions regarding the data, interested readers should contact the author directly.

ETHICAL CONSIDERATION

Ethics approval is not applicable, as no vertebrates or regulated invertebrates were utilized in the study. Mites were handled carefully, and their use was justified as necessary for the study's objectives. Secure containment, proper disposal methods, and minimal pesticide use were employed, along with established safety protocols.

COMPETING INTEREST

The author declared no potential competing interest concerning the research, authorship, and/or publication of this article.

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