Toxicity for Control of Frankliniella schultzei and Selenothrips rubrocinctus (Thysanoptera: Thripidae) of Several Common Synthetic Insecticides

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Toxicity for control of *Frankliniella schultzei* and *Selenothrips rubrocinctus* (Thysanoptera: Thripidae) of several common synthetic insecticides

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Abstract

Thrips are serious pests of several kinds of crop plants throughout the world. Their attack leads to loss in plant production. Common blossom thrips, *Frankliniella schultzei* (Trybom), and red-banded thrips, *Selenothrips rubrocinctus* (Giard) (both Thysanoptera: Thripidae), are serious insect pests attacking various plants, such as tomato (*Solanum esculentum* Miller [Solanaceae]), mango (*Mangifera indica* Linnaeus [Anacardiaceae]), avocado (*Persea americana* Miller [Lauraceae]), and lotus flower (*Nelumbo nucifera* Gaertn. [Nelumbonaceae]). Currently, basic thrips control relies on synthetic insecticides. However, the toxicity of each existing insecticide for control of some specific pest species still has not been well established. This study evaluated and reported the toxicity of 6 insecticides (chlorantraniliprole, cypermethrin, carbosulfan, fipronil, abamectin, and spinetoram) for control of the 2 thrips species mentioned above. The evaluation was done by exposing 10 thrips to a bean dipped in insecticide, and mortality was recorded after 24 h of exposure under laboratory conditions. Spinetoram was the most toxic to *F. schultzei* with an estimated LC_{50} of 0.05 ng per µL. For red-banded thrips, *S. rubrocinctus*, the most toxic insecticides were abamectin, spinetoram, and fipronil, with LC_{50} values of 1.67, 1.85, and 4.23 ng per µL, respectively. On the other hand, the least toxic insecticide to common blossom thrips and red-banded thrips was chlorantraniliprole, with LC_{50} values of 270.51 and 641.08 ng per µL, respectively. Overall, among the tested chemicals, spinetoram was the most effective in controlling these pests. The findings from this study will benefit developers of insecticide management strategies in thrips control programs.

Key Words: chemical control; spinetoram; abamectin; efficacy; thrips; pest

Resumen

Los trips son plagas importantes de varios tipos de plantas de cultivo en todo el mundo. Su ataque conduce a pérdidas en la producción vegetal. El trips común de las flores, *Frankliniella schultzei* (Trybom), y el trips de bandas rojas, *Selenothrips rubrocinctus* (Giard) (ambos Thysanoptera: Thripidae), son insectos plaga de graves que atacan a varias plantas, como el tomate (*Solanum esculentum* Miller [Solanaceae]), el mango (*Mangifera indica* Linnaeus [Anacardiaceae]), aguacate (*Persea americana* Miller [Lauraceae]) y laflor de loto (*Nelumbo nucifera* Gaertn. [Nelumbonaceae]). Actualmente, el control básico de los trips se basa en insecticidas sintéticos. Sin embargo, aún no se ha establecido bien la toxicidad de cada insecticida existente para el control de algunas especies de plagas específicas. Este estudio se evaluó y se informa sobre la toxicidad de 6 insecticidas (clorantraniliprol, cipermetrina, carbosulfán, fipronil, abamectina y spinetoram) para el control de las 2 especies de trips mencionadas anteriormente. Se realizó la evaluación exponiendo 10 trips a un frijol sumergido en insecticida y se registró la mortalidad a las 24 horas de exposición en condiciones de laboratorio. El espinetoram fue el más tóxico para *F. schultzei* con un valor CL_{50} estimada de 0,05 ng por µL. Para el trips de banda roja, *S. rubrocinctus*, los insecticidas más tóxicos fueron abamectina, spinetoram y fipronil, con un valor de CL_{50} de 1,67, 1,85 y 4,23 ng por µL, respectivamente. Por otro lado, el insecticida menos tóxico para el trips común de las flores y el trips de banda roja fue el clorantraniliprol, con un valor de CL_{50} de 270,51 y 641,08 ng por µL, respectivamente. En general, entre los productos químicos probados, el spinetoram fue el más efectivo para controlar estas plagas. Los hallazgos de este estudio beneficiarán a los desarrolladores de estrategias de manejo de insecticidas en los programas de control de trips.

Palabras clave: control químico; espinetoram; abamectina; eficacia; trips; plaga

Thrips are a serious pest causing a tremendous problem in agricultural production. It is a major pest for many kinds of crops, vegetables, and ornamental plants (Kakkar et al. 2012a). Thrips suck liquid nutrients from various plant tissues in the host plant, including tissues in the leaves, flower, and fruit (Palmer 1990) and, in the process, destroy them; the tissues become pale, dry, and shrunken, with dark spots in the infested areas (Milne & Walter 2000).

Common blossom thrips *Frankliniella schultzei* Trybom (Thysanoptera: Thripidae) is a highly polyphagous insect and 1 of the most serious pests of several vegetable crops, such as cucumber, squash, bean, tomato, and various ornamental plants (Milne et al. 2002; Seal et al. 2014), as well as fruit crops such as mango and avocado (Barbosa et al. 2005; Subhagan et al. 2020). This species always feeds on the floral part of a host plant (Kakkar et al. 2012b). *Frankliniella schultzei* has a very wide distribution and is mainly found in tropical and subtropical areas throughout the world. In the US, they are found in central and southern Florida, Colorado, and Hawaii (Vierbergen & Mantel 1991). In Florida, *F. schultzei* has been reported as a pest on tomato (Kakkar et al. 2012a, b). *Frankliniella schultzei* can cause significant indirect damage to host plants as a vector for transmission of viral pathogens (Seal et al. 2014). In Florida, *F. schultzei* is known as a vector of Tomato spotted wilt virus, Tomato chlorotic spot virus,

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and Groundnut ring spot virus in tomato (Mound 2004; Webster et al. 2010; Khan et al. 2020). In addition, the Florida pepper crop was reported to be damaged by Groundnut ring spot virus transmitted by *F. schultzei* (Seal et al. 2014). Furthermore, the study of abundance of *F. schultzei* on major vegetable crops of southern Florida has shown that the number of *F. schultzei* adults is high in the flowers of tomato, squash, and cucumber (Kakkar et al. 2012b). *Frankliniella schultzei* has been found to be associated with flowers of ornamental plants in Florida (Funderburk et al. 2007). In Thailand, *F. schultzei* is a severe pest of the lotus flower (Muangnimitr & Bumroongsook 2007; Bumroongsook 2018). In Florida, the lotus is used as an ornamental, and is produced as a nursery crop on a small scale (Worden & Sutton 2005; Tian 2008); this may provide a reservoir of pests outside of normal horticultural management oversight.

Selenothrips rubrocinctus Giard (Thysanoptera: Thripidae) is known as the red-banded thrips. *Selenothrips rubrocinctus* is a major pest of cocoa, *Theobroma cacao* L. (Malvaceae) (Retana-Salazar & Soto-Rodríguez 2001). It is a polyphagous species that feeds on a wide range of tropical and subtropical host plants, such as avocado (Dennill 1992), cashew (Igboekwe 1985), mango (Barbosa et al. 2005), papaya (Zanuncio-Junior et al. 2016), and lychee (Sánchez-Soto & Nakano 2004). It injures plants by feeding on leaves and fruit (Peng & Christian 2004; Demirozer et al. 2015). This species is found throughout Florida, including the temperate region of northern Florida (Demirozer et al. 2015) and has been reported to attack mango and avocado in Florida (Peña et al. 1998). The larvae and adults of *S. rubrocinctus* feed on leaves, causing damage that appears as discoloration and necrosis and subsequent leaf drop (Peña et al. 1998; Lima et al. 2016). Feeding on fruit by this species causes browning of the fruit surface resulting in reduction of fruit quality (Steyn et al. 1993; Peng & Christian 2004). Therefore, *S. rubrocinctus* can be a problem for mango and avocado production in Florida. Apart from the tree crops, ornamental plants can be damaged by this species (Walter et al. 2018). *Selenothrips rubrocinctus* can infest ornamental plants, especially lotus, where they aggregate on the underside, sucking the leaf tissue, and leading to lower lotus production efficiency (Milne et al. 2002; Bumroongsook 2018).

At present, an effective and convenient way to control thrips is to use chemical insecticides. However, after extensive use, thrips are likely to develop resistance to the insecticide (Lebedev et al. 2013; Gao et al. 2021). Selecting appropriate insecticides to control thrips effectively is essential for pest management, with an important criterion being toxicity to the target species. Therefore, this study evaluated the toxicity of 6 insecticides, chlorantraniliprole, cypermethrin, carbosulfan, fipronil, abamectin, and spinetoram, to control common blossom thrips, *F. schultzei*, and red-banded thrips, *S. rubrocinctus*, under laboratory conditions. The findings should provide essential information for effective chemical control of these pests.

Materials and Methods

SAMPLE COLLECTION

Frankliniella schultzei (Fig. 1) and *S. rubrocinctus* (Fig. 2) adults were collected from several lotus (*N. nucifera*) flowers harvested from a pesticide-free pond at the Faculty of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand from Jun to Sep 2020. *Frankliniella schultzei* was collected from the flower, and *S. rubrocinctus* was collected from the underside of the leaves. The collected samples were sent to the Entomology and Zoology Division, Plant Protection Research and Development office, Department of Agriculture, Ministry of Agriculture and Cooperatives, Bangkok, Thailand, and the species were positively identified by a professional entomologist using the key in Poonchaisri (2001).

Fig. 1. Adult *Frankliniella schultzei*. Photograph by Ittipon Bannakan, Insect Taxonomy Group, the Entomology and Zoology Division, Plant Protection Research and Development office, Department of Agriculture, Bangkok, Thailand.

INSECTICIDES

The insecticides were purchased from an agrochemical store in Bangkok, Thailand. They were chlorantraniliprole (Prevathon™ 5.17% SC, Dupont (Thailand) Co., Ltd., Bangkok, Thailand), cypermethrin (Danger 35® 35% EC, Original Marketing Co., Ltd., Bangkok, Thailand), carbosulfan (Posh 20% EC, Pitsulin Co., Ltd., Bangkok, Thailand), fipronil (Ascend® 5% SC, BASF (Thai) Ltd., Bangkok), abamectin (Jacket® 1.8% EC, Sotus International Co., Ltd., Nonthaburi, Thailand), and spinetoram (Exalt® 12% SC, Dow Agrosciences (Thailand) Ltd., Bangkok, Thailand).

Fig. 2. Adult *Selenothrips rubrocinctus*.

BIOASSAY

Each insecticide was prepared as solutions containing the active ingredient at concentrations of 0.1, 1, 10, 100, and 1,000 ng per µL in distilled water. Snap bean pods, *Phaseolus vulgaris* L. (Fabaceae), were purchased from a supermarket in Bangkok, Thailand, and rinsed with clean water several times. They were cut into 3 cm long pieces. A piece of bean was dipped into an insecticide solution at 1 concentration for 5 min and left to dry for 15 min. Dried bean pieces were covered with parafilm at each end then placed in a 90 mL plastic cup (7.5 cm diam) (Eastern Polypack Co., Ltd., Bangkok, Thailand) (Fig. 3). Ten thrips were put in the plastic cup with the treated bean piece. For each treatment of a different concentration of the insecticide solution, the assay was replicated 6 times. Thus, 1 treatment involved 60 insect samples. Distilled water was used as the control treatment. The uncovered cup was sealed with parafilm (Parafilm® M, Bemis Company, Inc., Neenah, Wisconsin, USA) and kept in the laboratory at 29 ± 2 °C and 65 ± 5% relative humidity (thermo-hygrometer, model 8865; Barigo, BARIGO Barometerfabrik GmbH, Baden-Württemberg, Germany). At 24 h post-treatment, the number of dead and living thrips were counted, and the mortality was calculated by Abbott's formula (Abbott 1925). Thrips were considered dead if they did not move when probed with a soft brush.

Five to 9 concentrations of each tested insecticide that provided mortality in the range of 10 to 90% were selected to be evaluated further in the final experiment. The final experiment was conducted using the same procedure with 6 replicates of each concentration. Mortality percentages were calculated by the same method. The median lethal concentration (LC_{50}) was determined by Probit analysis via SPSS software version 16.0 (SPSS Inc., Chicago, Illinois, USA).

Results

The LC_{50} of 6 insecticides was accurately determined. Spinetoram was the most toxic insecticide controlling *F. schultzei* with an LC_{50} of 0.05 ng per µL, followed by fipronil, carbosulfan, abamectin, and cypermethrin with LC_{50} values of 4.97, 17.68, 63.45, and 67.40 ng per µL, respectively (Table 1). The least toxic insecticide was chlorantraniliprole with an LC_{50} of 270.51 ng per µL (Table 1). The 95% confidence limits of the LC_{50} of every tested insecticide did not overlap, except those of abamectin and cypermethrin (Table 1). Control treatments for each insecticide resulted in zero mortality.

For *S. rubrocinctus*, the most effective insecticides were abamectin and spinetoram, followed by fipronil, carbosulfan, cypermethrin, and chlorantraniliprole, with LC_{50} values of 1.67, 1.85, 4.23, 8.80, 50.29, and 641.08 ng per µL, respectively (Table 2). The control treatment for each insecticide did not cause mortality of *S. rubrocinctus*. Chlorantraniliprole provided the lowest toxicity to both *F. schultzei* and *S. rubrocinctus*. The LC_{50} of abamectin was not significantly different from that of spinetoram; their 95% confidence limits overlapped.

Discussion

Frankliniella schultzei and *S. rubrocinctus* are serious pests causing damage to many crop and ornamental plants in tropical and subtropical environments. At the present time, insecticidal treatment is an effective approach for controlling thrips.

In this study, spinetoram was found to be the most toxic to *F. schultzei*. For *S. rubrocinctus*, the most effective tested insecticides were abamectin, spinetoram, and fipronil. For both species, the pattern of comparative toxicity of the tested insecticides was nearly the same. The highest toxicity provided by spinetoram in this study (LC_{50} = 0.05 ng per µL for *F. schultzei* and LC_{50} = 1.85 ng per µL for *S. rubrocinctus*) was similar to the reported toxicity controlling *S. rubrocinctus* (LC_{50} = 0.006 ng per µL) habituated in cocoa plants under similar environmental conditions in San José, Costa Rica (Walter et al. 2018). The same study also reported that spinosad was the most toxic among the tested agents to *Corynothrips stenopterus* Williams (Thysanoptera: Thripidae) (LC_{50} = 0.08 ng per µL) habituated in cassava plants. Similarly, the most toxic insecticide controlling *Frankliniella invasor* Sakimura (Thysanoptera: Thripidae) was spinosad (LC_{50} = 0.413 ng per µL) according to Infante et al. (2014) also in warm but slightly drier conditions at Chiapas, Mexico.

Spinetoram is a fermentation product of *Saccharopolyspora spinosa* Mertz & Yao (Pseudonocardiales: Pseudonocardiaceae) and is a derived analogue of the insecticide spinosad (EPA 2009). Spinetoram and spinosad are in the spinosyn group of insecticides, group 5 in the IRAC chemical classification (IRAC 2020), and are considered toxicologically equivalent by the EPA. Their mode of action involves interaction with nicotine acetylcholine receptors, causing paralysis and death of target insects (Shimokawatoko et al. 2012; IRAC 2020). Spinetoram exerts a broad range of actions to many kinds of insect pests at various stages of their life cycle (Rodriguez-Saona et al. 2016; Yee 2018). Of note is the low toxicity of spinetoram and spinosad to non-target in-

Fig. 3. The bioassays to evaluate the toxicity of selected insecticides on common blossom thrips, *Frankliniella schultzei*, and red-banded thrips, *Selenothrips rubrocinctus*, were conducted in 90 mL plastic cups. Each cup had 10 thrips and a 3 cm long piece of insecticide-treated bean.

Table 1. Toxicity of selected insecticides on *Frankliniella schultzei* after 24 h of exposure.

Insecticide name	N[a]	LC_{50} (ng per µL)[b]	95% Confidence limit Lower	Upper	Slope (± SE)	X^2 (df)
Chlorantraniliprole	480	270.51 e	221.98	337.77	0.005 (± 0.000)	78.43 (6)
Cypermethrin	420	67.40 d	60.75	75.32	0.024 (± 0.002)	26.55 (5)
Carbosulfan	420	17.68 c	15.81	20.00	0.100 (± 0.007)	30.32 (5)
Fipronil	420	4.97 b	4.47	5.50	0.270 (± 0.018)	18.12 (5)
Abamectin	480	63.45 d	57.70	69.06	0.020 (± 0.000)	19.30 (6)
Spinetoram	420	0.05 a	0.04	0.05	26.130 (± 1.939)	17.76 (5)

[a]Number of insects tested from 6 replicates.
[b]Median lethal concentrations (LC_{50}) followed by the same letter are not significantly different when their confidence limits at 95% overlap.

Table 2. Toxicity of selected insecticides on *Selenothrips rubrocinctus* after 24 h of exposure.

Insecticide name	N[a]	LC_{50} (ng per µL)[b]	95% Confidence limit Lower	Upper	Slope (± SE)	X^2 (df)
Chlorantraniliprole	300	641.08 e	514.95	859.51	0.003 (± 0.000)	30.78 (3)
Cypermethrin	540	50.29 d	37.65	64.86	0.018 (± 0.001)	134.20 (7)
Carbosulfan	360	8.80 c	7.23	10.61	0.129 (± 0.011)	23.36 (4)
Fipronil	420	4.23 b	3.55	5.11	0.212 (± 0.020)	55.86 (5)
Abamectin	300	1.67 a	1.18	2.39	0.633 (± 0.053)	82.09 (3)
Spinetoram	300	1.85 ab	−0.65	3.65	0.309 (± 0.028)	121.94 (3)

[a]Number of insects tested from 6 replicates.
[b]Median lethal concentrations (LC_{50}) followed by the same letter are not significantly different when their confidence limits at 95% overlap.

sects (Martinou et al. 2014; Amarasekare et al. 2016; Anjum & Wright 2016). Spinetoram also was reported to have low toxicity to mammals, as well as less harmful to the environment (Bacci et al. 2016). The current study has demonstrated that both thrips species, *F. schultzei* and *S. rubrocinctus*, were highly sensitive to spinosyn insecticides. This concurs with a finding from a field study on thrips and strawberry production in Florida, USA, by Renkema et al. (2020).

Abamectin was reported to be highly active against diamondback moth, *Plutella xylostella* Linnaeus (Lepidoptera: Plutellidae) (Anjum & Wright 2016), whereas lambda-cyhalothrin was reported to be highly toxic to peach-potato aphid, *Myzus persicae* Sulzer (Hemiptera: Aphididae), and 2 hymenopteran parasitoids, *Cotesia vestalis* Kurdjumov and *Aphidius colemani* Viereck (both Hymenoptera: Braconidae) under standard laboratory conditions in the United Kingdom (Anjum & Wright 2016). Spinosad was reported to be less toxic than abamectin and lambda-cyhalothrin to all of the above insects (Anjum & Wright 2016). The implication is that the toxicity of an insecticide varies with the insect species.

This study found that the LC_{50} values of spinetoram on *F. schultzei* (0.05 ng per µL) and *S. rubrocinctus* (1.85 ng per µL) were lower than the recommended application rate (60–90 ng per µL) on the label of the spinetoram product tested (Exalt® 12% SC, Dow Agrosciences) for agricultural use. Similarly, the LC_{50} value of abamectin on *S. rubrocinctus* (1.67 ng per µL) was lower than the recommended application rate on the product label (27 ng per µL) of the abamectin product tested (Jacket® 1.8% EC, Sotus International). On the other hand, the LC_{50} value of abamectin on *F. schultzei* (63.45 ng per µL) was higher than the recommended application rate. All of these results indicate that spinetoram was effective at controlling both thrips species, while abamectin was effective at controlling only *S. rubrocinctus*. Additionally, *F. schultzei* was not sensitive to abamectin. The toxicity findings of the selected insecticides from this study can be used as guiding data for selecting an active ingredient for a comprehensive thrips control program.

Nevertheless, there have been reports of resistance of *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) to spinosad, emamectin benzoate, and carbosulfan (Lebedev et al. 2013). Moreover, Gao et al. (2021) reported variation in the susceptibility of different thrips species to spinetoram in China, which should be taken into account in a comprehensive thrips management program.

Thrips are a significant threat to horticultural crops in Florida. Historically, the control of these insect pests has relied on chemical application; however, insecticide resistance to some active ingredients has developed in these pests. Therefore, to find insecticides with high efficacy to control thrips is needed greatly. This study found that spinetoram was the most effective insecticide among several tested insecticides for controlling both *F. schultzei* and *S. rubrocinctus*. This study provided useful toxicity data for selecting appropriate insecticides to control thrips. These data also can be used as a baseline for analyzing insect resistance to an active ingredient. Spinetoram was the most effective insecticidal agent for control of thrips among the tested insecticidal agents. This efficacy along with its safety profile with non-target organisms suggests that it should be included as a selected insecticidal agent in a thrips control program that may rotate multiple synthetic insecticidal agents in combination with biological control agents.

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