Toxicity of Different Insecticides Against Two Thrips (Thysanoptera: Thripidae) Pests of Concern in Central America

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Toxicity of different insecticides against two thrips (Thysanoptera: Thripidae) pests of concern in Central America

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Abstract

Cassava and cacao are 2 of the most important crops grown in Costa Rica, and also are major sources of income for rural farmers. These crops are frequently attacked by *Corynothrips stenopterus* Williams and redbanded thrips, *Selenothrips rubrocinctus* Giard (Thysanoptera: Thripidae). Most farmers who grow these crops apply synthetic insecticides on a calendar basis, but there are no well-established studies on the effectiveness or toxicity of different chemical insecticides on these species of thrips. The objective of this study was to determine the toxicity of 8 insecticides with different modes of action that are used in the control of other thrips species. Commercial formulations of chlorfenapyr, imidacloprid, chlorpyrifos, spinosad, malathion, thiamethoxam, spinetoram, and α-cypermethrin were evaluated on adults of both thrips species under laboratory conditions. Probit analyses showed that spinetoram, spinosad, and chlorfenapyr were the most effective against both thrips species, with median lethal dosages of 50% below 1 µg per mL for both species: 0.12, 0.08, and 0.21 µg per mL for *C. stenopterus,* and 6×10^{-3}, 0.06, and 0.53 µg per mL for *S. rubrocinctus*. For the other 5 insecticides tested, *C. stenopterus* had a higher susceptibility than *S. rubrocinctus*. Among all the insecticides tested, malathion was the least efficacious against both thrips species. The mortality rate in the control treatments never exceeded 10%. The results of this study suggest that spinetoram, spinosad, and chlorfenapyr are the most efficacious insecticides for the control of both thrips species. These results should be complemented with field trials for confirmation.

Key Words: cassava; cacao; *Corynothrips*; *Selenothrips*; spinosyn

Resumen

La yuca y el cacao son dos de los cultivos más importantes que se siembran en Costa Rica y también son una importante fuente de ingresos para la mayoría de los agricultores rurales. Estos cultivos son atacados frecuentemente atacados por *Corynothrips stenopterus* Williams (yuca) y trips de banda roja *Selenothrips rubrocinctus* Giard (ambos Thysanoptera: Thripidae) (cacao). La mayoría de los agricultores que se dedican a la producción de estos cultivos aplican insecticidas sintéticos con regularidad contra estos trips, pero no existen estudios bien establecidos sobre la efectividad o toxicidad de los diferentes insecticidas químicos en estas especies de trips. Por lo tanto, se realizó el presente estudio con el objetivo de determinar la toxicidad de 8 insecticidas con diferentes modos de acción que se utilizan en el control de otras especies de trips. Las formulaciones comerciales de chlorfenapyr, imidacloprid, chlorpyrifos, spinosad, malathion, thiamethoxam, spinetoram y α-cipermetrina se evaluaron en adultos de ambas especies de trips en condiciones de laboratorio. Se usaron las siguientes 6 concentraciones de cada uno de los 8 insecticidas; 0, 1, 1.0, 10, 100, 1,000 y 10,000 ppm. Se utilizó un diseño completamente aleatorizado y cada tratamiento tuvo 5 repeticiones. Los análisis Probit mostraron que spinetoram, spinosad, y chlorfenapyr fueron los más efectivos contra ambas especies de trips con LD_{50} por debajo de 1 µg por ml para ambas especies (0.12, 0.08 y 0.21 µg por mL) respectivamente para *Corynothrips stenopterus* y (6.10-3, 0.06 y 0.53 µg por mL) respectivamente para *Selenothrips rubrocinctus*. Los otros 5 insecticidas evaluados indicaron que *C. stenopterus* tenía una susceptibilidad más alta que *S. rubrocinctus*. Entre todos los insecticidas probados, malathion fue el menos eficaz contra ambas especies de trips. La tasa de mortalidad en los tratamientos de control (con agua destilada) nunca excedió el 10%. Este estudio sugiere que spinetoram, spinosad, y chlorfenapyr son los más eficientes para el control de ambas especies de trips. Sin embargo, estos resultados deberían completarse conensayos de campo para su confirmación.

Palabras Clave: yuca; caco; *Corynothrips*; *Selenothrips*; spinosyns

Cocoa (*Theobroma cacao* L.) (Malvaceae) is a major source of income for rural farmers in many tropical countries, including Costa Rica. It is attacked by the redbanded thrips, *Selenothrips rubrocinctus* Giard (Thysanoptera: Thripidae), a tropical-subtropical species presumed to have originated in northern South America (Mound & Marullo 1996). It was discovered in Guadeloupe and the West Indies, and it is now found in all cacao-producing regions of Africa, Asia, Australia, and South America (Denmark & Wolfenbarger 1999). The species occurs throughout Florida, including the temperate region of northern Florida (Demirozer et al. 2015). Besides cacao, a range of other tropical and subtropical tree crops are damaged, such as guava, cashew, mango, avocado, mangosteen, rambutan, and different types of ornamental

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trees (Igboekwe 1985; Dennill 1992; Peng & Christian 2004). The adult thrips are uniformly dark-bodied with internal red pigment, chiefly in the first 3 abdominal segments. The larvae and pupae are light yellow to orange with the first, second, third, and tenth abdominal segments bright red, which is the basis for the common name of 'redbanded thrips' (Denmark & Wolfenbarger 1999). The adults and larvae feed on the leaves, causing leaf distortion, silvering, necrosis, and subsequent leaf drop. On cacao, the feeding activity of the adults and larvae of *S. rubrocinctus* on the leaves causes the development of chlorotic spots and premature leaf drop, while feeding on the pods causes brown patches that coalesce during heavy infestations, forming a dark brown and corky layer of dead cells. The presence of dead cells on the pods makes the estimation of pod ripeness very difficult. In ornamentals, *S. rubrocinctus* injury is primarily cosmetic (Fig. 1).

Cassava (*Manihot esculenta* Crantz) (Euphorbiaceae) is another major crop grown in Central and South America, and it is seriously attacked by various thrips species, particularly *Corynothrips stenopterus* Williams (Thysanoptera: Thripidae). Both the adults and larvae of the pest injure the growing terminals and leaves by sucking the contents of leaf cells, which causes spotting, discoloration, and yellowing of leaves resulting in loss of vigor and reduced yields (Fig. 2). Severe attack may lead to leaf drop. Attacks occur more frequently during periods of drought, and the infestations generally begin on the plants located on the edges of the plantation.

Although *S. rubrocinctus* and *C. stenopterus* are important pests of cacao and cassava, respectively, they also are occasional pests of ornamentals (Fig. 1). Despite this, there are no well-established studies on the toxicity of different chemical insecticides on these species of thrips. Therefore, the objective of this study was to determine the toxicity of 8 insecticides with different modes of action (Table 1) that are used in the control of other thrips species. We determined and compared the median lethal dosages at 50 and 95% of these insecticides against the adult stages of *S. rubrocinctus* and *C. stenopterus* under laboratory conditions.

Materials and Methods

A bean-dip bioassay method previously developed by Eger et al. (1998) for thrips was used to determine the susceptibility of *C. stenopterus* and *S. rubrocinctus* to the insecticides with different modes of action (IRAC 2018). The insecticides were purchased from local agrochemical stores in Costa Rica. The following insecticides were used in the bioassays: chlorfenapyr (Sunfire® 24 SC, Agrotico); imidacloprid (Muralla Delta® 19 OD, Agrotico); chlorpyrifos (Sassex® 48 EC, Agrotico); spinosad (Spintor® 12 CS, Centro Agrícola Guácimo); malathion (Agromart malathion® 60 EC, Colono Agropecuario); thiamethoxam (Actara® 25 WG, Cafesa); spinetoram (Winner® 6 SC, Colono Agropecuario); and α-cypermethrin (Arrivo® 25 EC, Colono Agropecuario).

Fresh snap bean pods (*Phaseolus vulgaris* L.) (Fabaceae) were washed with 1% bleach, rinsed thoroughly with tap water, and allowed to air dry on paper towels. The pods were cut into 20 mm long sections, and the ends were sealed with a thin layer of paraffin (Fisherfinest™ Histoplast Paraffin Wax, Fisher Scientific, Waltham, Massachusetts, USA). After the bean pods were sealed, they were immersed in the different insecticide concentrations for 5 min and subsequently air-dried on paper towels for 15 min. For the control, the bean pods were immersed in distilled water. Mortality for both thrips species was

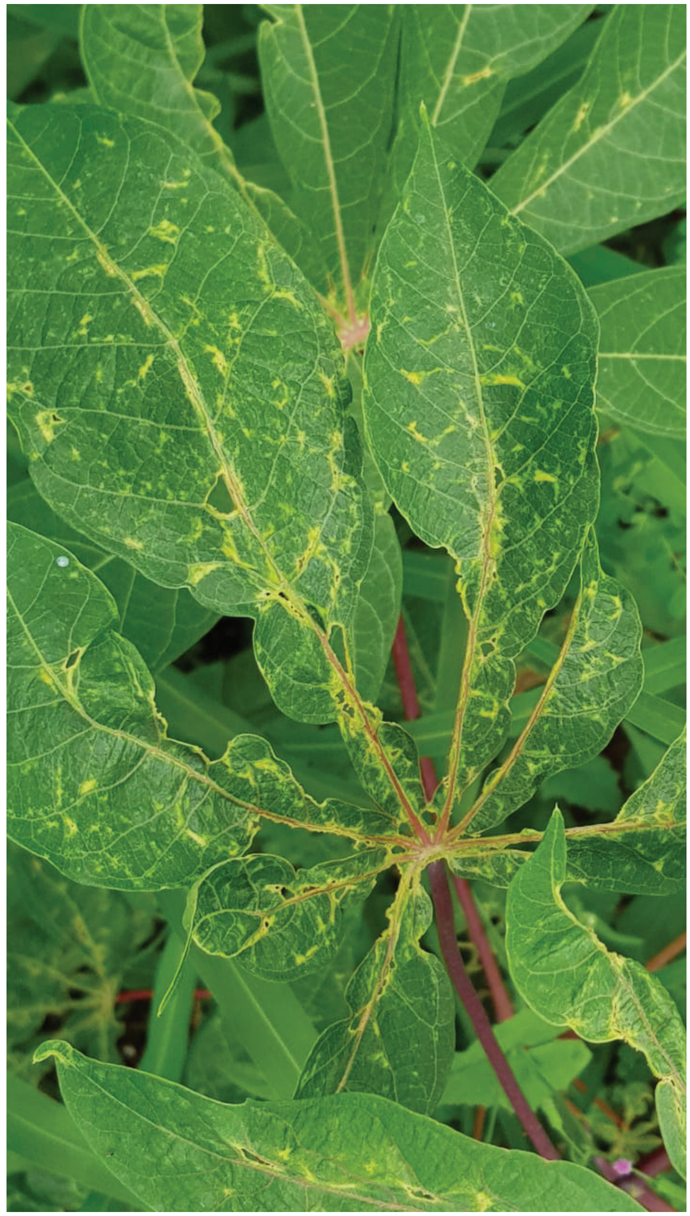

Fig. 2. Injuries to the leaves of cassava by *Corynothrips stenopterus*, Earth University Academic farm, Limon, Costa Rica.

Fig. 1. Injury to the leaves of *Rosa* species by *Selenothrips rubrocinctus*, Leon County, Florida, USA (photo by Gary Knox, University of Florida).

Table 1. The insecticide classifications and the biochemical targets of the insecticides evaluated (IRAC 2018).

Insecticide	IRAC group	Class	Biochemical target	Action
Chlorpyrifos	1B	Organophoshate	Acetylcholine esterase	Inhibitor
Malathion	1B	Organophoshate	Acetylcholine esterase	Inhibitor
α-Cypermethrin	3A	Pyrethroid	Voltage-gated sodium ion channel	modulator
Imidacloprid	4A	Neonicotinoid	Nicotinic acetylcholine receptor	Agonist
Thiamethoxam	4A	Neonicotinoid	Nicotinic acetylcholine receptor	Agonist
Spinetoram	5	Spinosyn	Nicotinic acetylcholine receptor	Allosteric modulator
Spinosad	5	Spinosyn	Nicotinic acetylcholine receptor	Allosteric modulator
Chlorfenapyr	13	Pyrrole	Coupling between the electron transport and phosphorylation reactions	Disruptant

determined after 24 h using a stereoscope, and the adult thrips were considered dead if they were unable to move after being pricked.

After drying, individual beans were placed into individual 35 mL diet cups (Fill-Rite Corporation, Newark, New Jersey, USA). Ten adult thrips from field-collected samples were aspirated into each cup. Five diet cups were used for each concentration for a total of 50 thrips per concentration for each species. Diet cups were sealed with a lid and placed into a sealed 5.7 L plastic rearing container that was lined with a paper towel to reduce condensation. These containers were held in controlled-environment chambers maintained between 26 to 30 °C, 60 to 80% RH, and a photoperiod of 16: 8 h (L:D).

For the *S. rubrocinctus* assay, adult thrips were collected from cocoa leaves at a cocoa farm (10.1842°N, 83.6116°W, 37 m asl). For the *C. stenopterus* assay, adult thrips were collected from the cassava leaves at a cassava farm (10.2188°N, 83.5930°W, 37 m asl).

For both species, we ran 2 successive toxicology assays. We started with 6 concentrations and a control (0, 0.1, 1, 10, 100, 1,000, and 10,000 ppm) of each insecticide prepared using distilled water. Each treatment had 5 replicates. The first assay allowed us to restrict each insecticide to a more appropriate concentration range for the second toxicology assay. These new concentration ranges were chosen to have at least 5 data points between 20 to 80% mortality in order to create a reliable dose response curve (Yu 2015). For *S. rubrocinctus* the concentration ranges of the second assay varied between 0.0001 and 1 µg per mL for spinosad, and between 4.10 to 1,000 µg per mL for malathion and α-cypermethrin. The other insecticides were tested with concentrations that fell between these 2 concentration ranges. For *C. stenopterus*, concentration ranges of the second assay varied between 0.410 to 33.333 µg per mL for malathion, and 0.041 to 3.333 µg per mL for all the other insecticides. Only the LD_{50} and LD_{95} values were calculated with the data obtained in the second toxicology assay.

The keys in Mound and Marullo (1996) were used to identify the adult thrips. Voucher specimens are located in the Florida State Collection of Arthropods, Division of Plant Industry, Florida Department of Agriculture and Consumer Services in Gainesville, Florida, USA, and in the collection at the North Florida Research and Education Center in Quincy, Florida, USA.

STATISTICAL ANALYSIS

The LD_{50} and LD_{95} estimates and their 95% confidence intervals were determined using the probit model. The dose-'death, life' outcomes of *S. rubrocinctus* and *C. stenopterus* in the bioassays were modeled using the LOGISTIC option in PROC PROBIT (SAS Institute 2011). The ratio of the number dead to total number per dose, and the logarithm (log10) of the dosage levels were included in the PROBIT procedure to model the data and to compare the predicted probabilities from various dosage levels and the control. This generated the intercept and slope of the log10 of the dosage level along with the probability levels. The *P* values for the goodness-of-fit tests (Pearson chi-square) were used to indicate an adequate fit describing the relationship between dosage levels and observed and fitted values. Control mortality was corrected for by SAS. Logistic mortality curves of *S. rubrocinctus* and *C. stenopterus* for each insecticide were generated with SigmaPlot version 14 (SYSTAT, San Jose, California, USA). The overlap test, where significance is determined based on the overlap of the LD_{50} values and their 95% confidence intervals, was used to compare values between the 2 species.

Results

The probit models provided a good fit for the different insecticides tested (Figs. 3, 4), as demonstrated by the overwhelming majority of chi-tests that were not significant at $\alpha = 0.05$ (Tables 2, 3). For *S. rubrocinctus*, spinetoram was the most effective insecticide tested. It had the lowest LD_{50} value, and it did not overlap with the LD_{50} values of any of the other insecticides. For *C. stenopterus*, the most efficacious insecticides were α-cypermethrin, imidacloprid, spinetoram, and chlorfenapyr. Of the insecticides tested, the spinosyns (spinetoram, spinosad) and the pyrrole chlorfenapyr were the most effective against both thrips species with LD_{50} values below 1 µg per mL for both species. The 95% confidence intervals of the 2 thrips species did not overlap for chlorpyrifos, malathion, α-cypermethrin, imidacloprid, or thiamethoxam, demonstrating a significantly higher susceptibility of *C. stenopterus* to these insecticides than *S. rubrocinctus*. Among all the insecticides tested, malathion was the least efficacious against both thrips species with 23.85 and 7.25 µg per mL for *S. rubrocinctus* and *C. stenopterus*, respectively.

Discussion

From the experiments conducted, it appears that pyrrole, neonicotinoids, and spinosyns were the most effective compounds tested to control both *C. stenopterus* and *S. rubrocinctus*. The spinosyn IRAC (2018) group 5 insecticides spinetoram and spinosad interact with the insect nicotinic acetylcholine receptor at a distinct site from that of the neonicotinoid group 4A insecticides imidacloprid and thiamethoxam (Orr et al. 2009; Watson et al. 2010). Thrips are less likely to build up resistance to spinosyns than other insecticides, and the spinosyns are less toxic for beneficial insects than other insecticide classes (Sparks et al. 2012). However, sublethal effects are possible for the spinosyns which need to be better evaluated (Biondi et al. 2012). For instance, the spinosyns have shown low toxicity to *Orius insidiosus* Say (Hemiptera: Anthocoridae) (Studebaker & Kring 2009); this key predator feeds on many different *Frankliniella* sp. (Thysanoptera: Thripidae) flower thrips larvae and adults in a wide variety of cultivated and non-cultivated plants (Funderburk et al. 2000; Srivastava et al. 2014).

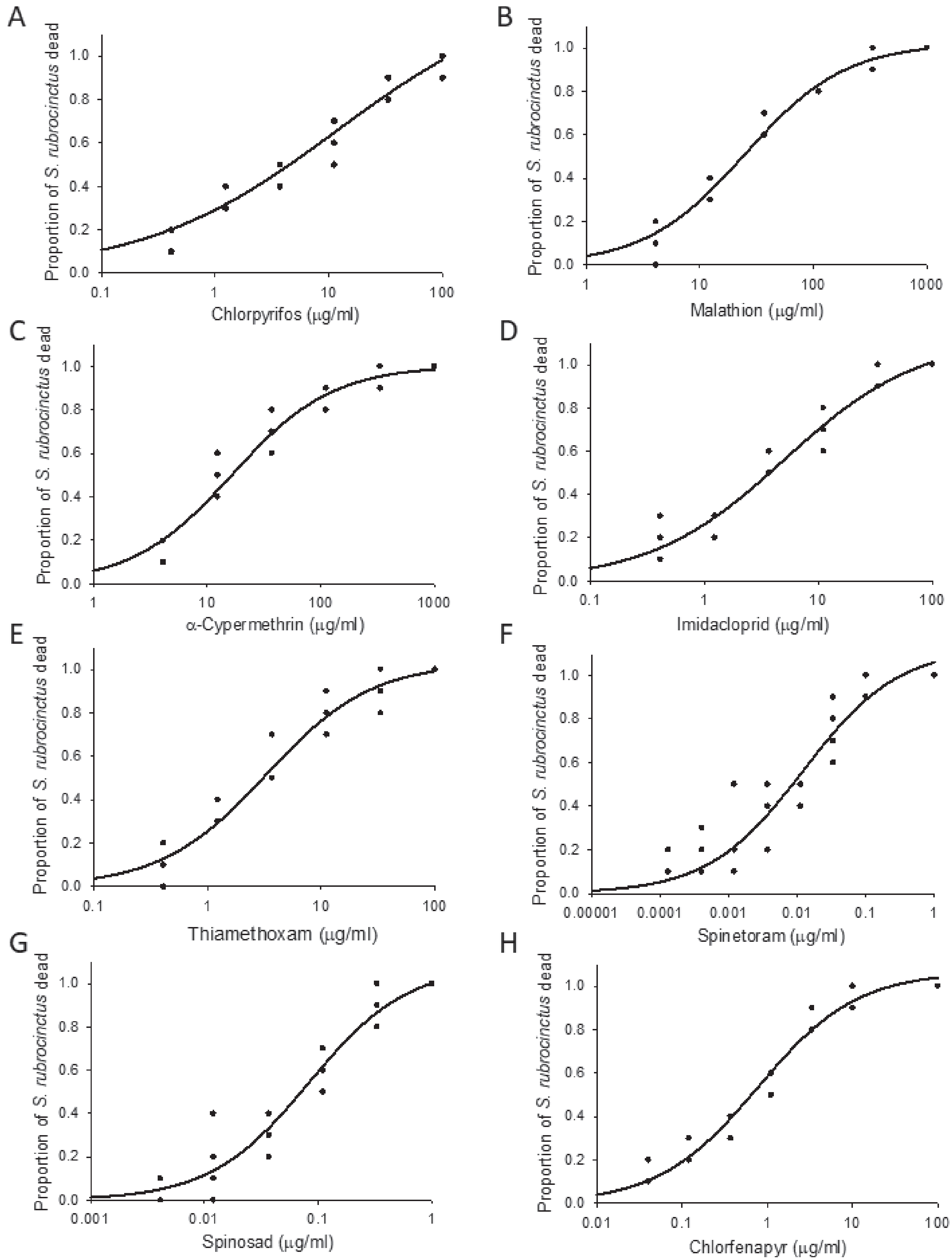

Fig. 3. Logistic mortality curves for the thrips *Selenothrips rubrocinctus* for 8 selected insecticides with the dip method.

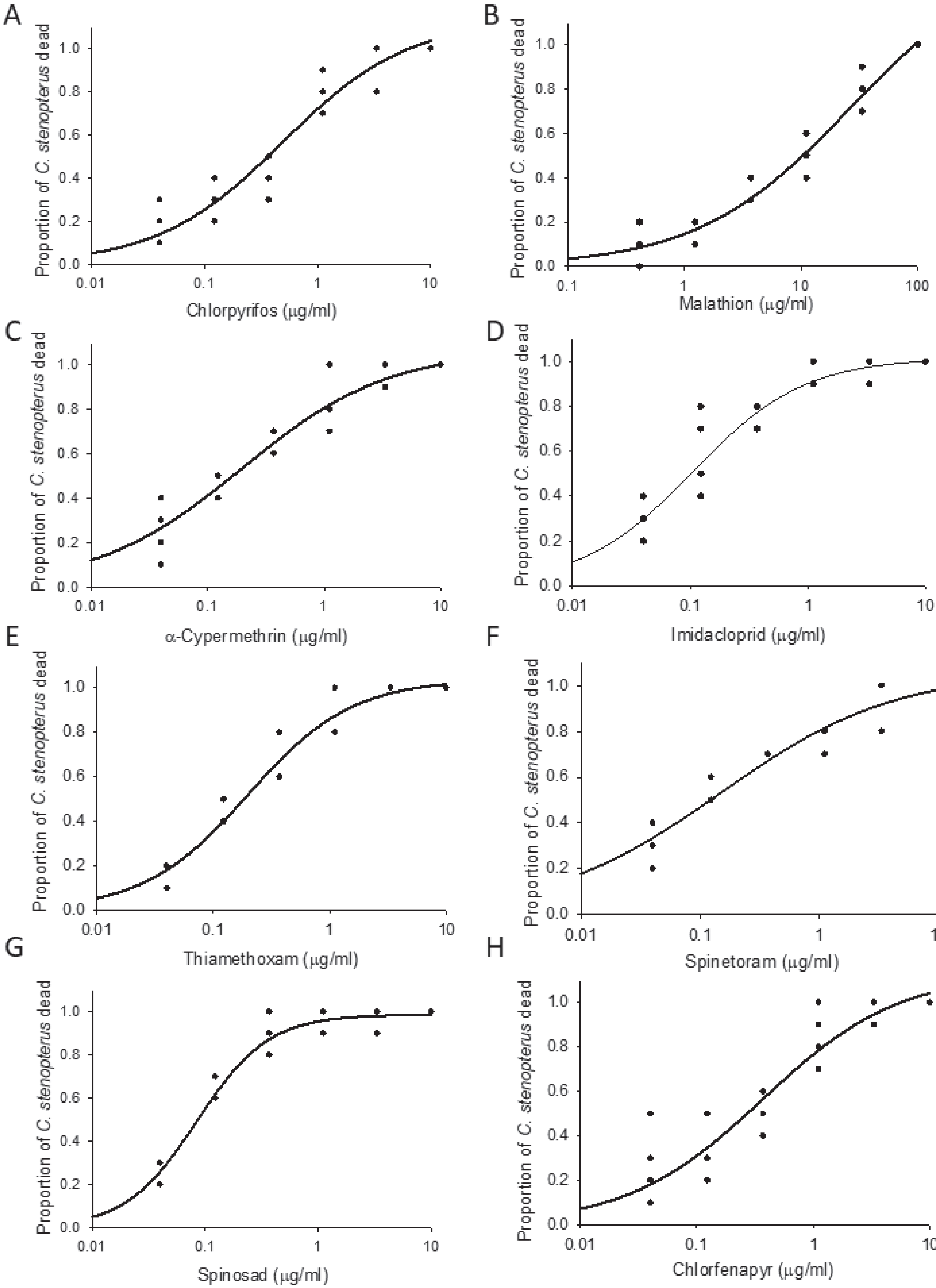

Fig. 4. Logistic mortality curves for the thrips *Corynothrips stenopterus* for 8 selected insecticides with the dip method.

Table 2. The LD_{50} and LD_{95} estimates for 8 selected insecticides after 24 h exposure to control *Selenothrips rubrocinctus* collected on cacao. CI: confidence interval.

Insecticide	n	χ^2 (df)	Slope ± SE	LD_{50} µg per mL (95% CI)	LD_{95} µg per mL (95% CI)
Chlorpyrifos	350	3.50 (4)	1.06 ± 0.11	3.61 (2.47 – 5.14)	130.02 (66.96 – 345.52)
Malathion	350	1.56 (4)	1.49 ± 0.15	23.85 (17.59 – 31.61)	304.60 (192.64 – 580.85)
α-Cypermethrin	350	2.21 (4)	1.39 ± 0.15	17.26 (12.24 – 23.33)	260.80 (161.47 – 519.28)
Imidacloprid	350	5.29 (4)	1.29 ± 0.13	3.16 (2.28 – 4.29)	59.36 (35.02 – 125.33)
Thiamethoxam	350	1.92 (4)	1.44 ± 0.122	2.99 (2.21 – 3.98)	41.48 (25.88 – 80.26)
Spinetoram	350	20.70 (5)*	0.89 ± 0.43	6×10^{-3} (2×10^{-3} – 21×10^{-3})	0.42 (0.07 – 45.55)
Spinosad	350	5.18 (4)	1.54 ± 0.14	0.06 (0.04 – 0.07)	0.71 (0.45 – 1.34)
Chlorfenapyr	350	6.51 (4)	1.16 ± 0.12	0.53 (0.38 – 0.74)	13.90 (7.51 – 33.57)

*Asterisk indicates significant difference at α = 0.05.

Table 3. The LD_{50} and LD_{95} estimates for 8 selected insecticides after 24 h exposure to control *Corynothrips stenopterus* collected on cassava. CI: confidence interval.

Insecticide	n	χ^2 (df)	Slope ± SE	LD_{50} µg per mL (95% CI)	LD_{95} µg per mL (95% CI)
Chlorpyrifos	350	9.36 (4)	1.38 ± 0.20	0.29 (0.14 – 0.54)	0.41 (1.79 – 30.20)
Malathion	350	11.91 (4)*	1.31 ± 0.19	7.25 (3.67 – 14.96)	131.34 (46.98 – 1202)
α-cypermethrin	350	2.16 (4)	1.18 ± 0.13	0.16 (0.10 – 0.22)	3.89 (2.23 – 8.81)
Imidacloprid	350	1.00 (4)	1.36 ± 0.16	0.10 (0.07 – 0.14)	1.67 (1.03 – 3.48)
Thiamethoxam	350	3.60 (4)	1.60 ± 0.17	0.18 (0.13 – 0.23)	1.89 (1.22 – 3.54)
Spinetoram	350	4.86 (4)	1.01 ± 0.12	0.12 (0.07 – 0.19)	5.24 (2.75 – 14.00)
Spinosad	350	2.52 (4)	1.53 ± 0.19	0.08 (0.06 – 0.12)	1.03 (0.66 – 2.01)
Chlorfenapyr	350	11.76 (4)*	1.38 ± 0.25	0.21 (0.08 – 0.44)	3.22 (1.18 – 42.36)

*Asterisks indicate significant difference at α = 0.05.

Because thrips used in these experiments were from field populations, it is not clear if the lower susceptibility of *S. rubrocinctus* to organophosphates, pyrethroids, and neonicotinoids compared to *C. stenopterus* is due to an acquired resistance of the population tested, or if *S. rubrocinctus* is naturally less susceptible to these insecticidal classes than *C. stenopterus*. Indeed, resistance of the western flower thrips, *Frankliniella occidentalis* Pergande (Thysanoptera: Thripidae), to pyrethroid and organophosphate insecticides has been abundantly described in the literature (Immaraju et al. 1992).

In the context of IPM, it is important to rotate insecticides with different modes of action and resistance mechanisms to decrease the risk of resistance development in the populations (Bielza 2008). In this case, pyrroles, neonicotinoids, and spinosyns may be used in rotation to control both *C. stenopterus* and *S. rubrocinctus* in cassava and cacao. In addition to rotating modes of action, resistance development also can be reduced by applying insecticides only when required, and by using accurate and precise methods for insecticide applications to avoid drift onto non-target plants (Bielza 2008). Therefore, additional research to determine economic thresholds for *C. stenopterus* and *S. rubrocinctus* in cocoa and cassava is needed to avoid the unnecessary use of insecticides.

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