UNIVERSIDADE FEDERAL DE SANTA MARIA
CENTRO DE CIÊNCIAS RURAIS
PROGRAMA DE PÓS-GRADUAÇÃO EM AGRONOMIA

Luiz Francisco Warpechowski

VARIABILIDADE GEOGRÁFICA E INTERESPECÍFICA NA SUSCETIBILIDADE DE TRIPES (THYSANOPTERA: THRIPIDAE) A INSETICIDAS NA CULTURA DA SOJA

Santa Maria/RS
2023

Luiz Francisco Warpechowski

VARIABILIDADE GEOGRÁFICA E INTERESPECÍFICA NA SUSCETIBILIDADE DE TRIPES (THYSANOPTERA: THRIPIDAE) A INSETICIDAS NA CULTURA DA SOJA

Dissertação apresentada ao Programa de Pós-Graduação em Agronomia da Universidade Federal de Santa Maria (UFSM, RS), como requisito parcial para a obtenção do título de Mestre em Agronomia.

Orientador: Prof. Dr. Oderlei Bernardi

Santa Maria/RS
2023

Warpechowski, Luiz Francisco
VARIABILIDADE GEOGRÁFICA E INTERESPECÍFICA NA SUSCETIBILIDADE DE TRIPES (THYSANOPTERA: THRIPIDAE) A INSETICIDAS NA CULTURA DA SOJA / Luiz Francisco Warpechowski.- 2023.
48 p.; 30 cm

Orientador: Oderlei Bernardi
Dissertação (mestrado) - Universidade Federal de Santa Maria, Centro de Ciências Rurais, Programa de Pós Graduação em Agronomia, RS, 2023

1. Frankliniella schultzei 2. Caliothrips phaseoli 3. Controle químico 4. Tolerância 5. Manejo integrado de pragas I. Bernardi, Oderlei II. Título.

Sistema de geração automática de ficha catalográfica da UFSM. Dados fornecidos pelo autor(a). Sob supervisão da Direção da Divisão de Processos Técnicos da Biblioteca Central. Bibliotecária responsável Paula Schoenfeldt Patta CRB 10/1728.

Declaro, LUIZ FRANCISCO WARPECHOWSKI, para os devidos fins e sob as penas da lei, que a pesquisa constante neste trabalho de conclusão de curso (Dissertação) foi por mim elaborada e que as informações necessárias objeto de consulta em literatura e outras fontes estão devidamente referenciadas. Declaro, ainda, que este trabalho ou parte dele não foi apresentado anteriormente para obtenção de qualquer outro grau acadêmico, estando ciente de que a inveracidade da presente declaração poderá resultar na anulação da titulação pela Universidade, entre outras consequências legais.

Luiz Francisco Warpechowski

VARIABILIDADE GEOGRÁFICA E INTERESPECÍFICA NA SUSCETIBILIDADE DE TRIPES (THYSANOPTERA: THRIPIDAE) A INSETICIDAS NA CULTURA DA SOJA

Dissertação apresentada ao Curso de Mestrado do Programa de Pós-Graduação em Agronomia da Universidade Federal de Santa Maria (UFSM, RS), como requisito parcial para a obtenção do título de **Mestre em Agronomia.**

Aprovado em 08 de dezembro de 2023.

____

Oderlei Bernardi, Dr. (UFSM)
(Presidente/Orientador)

____

Cristiane Müller, Dra. (Corteva Agriscience)
(Videoconferência)

____

Samuel Roggia, Dr. (Embrapa Soja)
(Videoconferência)

Santa Maria/RS
2023

AGRADECIMENTOS

Aos meus pais, Luiz Antônio Warpechowski e Elizandra de Fatima Costa, e a minha noiva, Caroline Cristina Brouwers, pelo amor, carinho, apoio, incentivo e suporte.

Ao professor Oderlei Bernardi, pela amizade e companheirismo durante o tempo de mestrado, pela orientação e os ensinamentos transmitidos, além da confiança em mim depositada.

Aos meus amigos e colegas de equipe que formam o nosso grupo de pesquisa, Alexandre Castro Reis, Daniela Neves Godoy, Venicius Ernesto Pretto, Arthur Dallanora, Eduardo Argenta Steinhaus, Luiz Henrique Maia Diniz, Rafaella Pretto Moreira, Ramon Braida Palharini, Helena Baggiotto Rubin, Gabriela Soares Massoli e Amanda de Freitas Wendt que sempre ajudaram quando necessário, além da amizade e companheirismo dentro e fora do laboratório.

Aos colegas de trabalho, Juliano Ricardo Farias, Jorge França e Luiz Eduardo Braga, pela convivência, amizade e ensinamentos transmitidos.

A todos os agricultores que permitiram as coletas nas suas áreas de produção.

À Universidade Federal de Santa Maria e ao Programa de Pós-Graduação em Agronomia pela oportunidade de realizar o curso de mestrado.

A todos aqueles que direta ou indiretamente contribuíram para realização do mestrado.

Muito obrigado!

RESUMO

VARIABILIDADE GEOGRÁFICA E INTERESPECÍFICA NA SUSCETIBILIDADE DE TRIPES (THYSANOPTERA: THRIPIDAE) A INSETICIDAS NA CULTURA DA SOJA

AUTOR: Luiz Francisco Warpechowski
ORIENTADOR: Oderlei Bernardi

Os tripes (Thysanoptera: Thripidae) tem sido, historicamente, considerados pragas secundárias em soja no Brasil e outros países da América do Sul. Entretando, desde 2010, esses insetos ganharam importância na cultura da soja no centro e norte do Brasil. A partir de 2017, também foram detectadas altas infestações de tripes em soja no sul do Brasil. Diante disso, o objetivo do trabalho foi coletar e identificar as espécies de tripes que ocorrem em soja no sul do Brasil durante a safra 2022/2023 e avaliar a suscetibilidade dessas espécies a inseticidas. Após a coleta, os tripes foram expostos a doses de bula de inseticidas em bioensaios de imersão de discos de folhas de soja. Os resultados indicaram que *Frankliniella schultzei* (Trybom, 1910) e *Caliothrips phaseoli* (Hood, 1912) são as principais espécies de tripes que infestam a soja no sul do Brasil. Ambas as espécies apresentaram alta mortalidade e baixa variação geográfica e interespecífica na suscetibilidade a espinetoram, metomil, espinetoram + metoxifenozida e profenofos + cipermetrina. De modo geral, a maioria das populações de *C. phaseoli* foram mais suscetíveis a acefato, clorfenapir e a abamectina do que as populações de *F. schultzei*. Em contraste, bifentrina + carbosulfano apresentou maior letalidade para a maioria das populações de *F. schultzei*, no entanto, ambas as espécies apresentaram grande variação geográfica na suscetibilidade aos inseticidas acefato, clorfenapir, abamectina e bifentrina + carbosulfano. Por outro lado, populações de ambas as espécies apresentaram baixa mortalidade quando expostas a imidacloprido, lambda-cialotrina e lambda-cialotrina + sulfoxaflor. Em resumo, este estudo demonstra a existência de variação significativa na suscetibilidade de *F. schultzei* e *C. phaseoli* a inseticidas, tanto entre espécie como entre áreas de produção de soja geograficamente distintas. Estes resultados destacam a importância da identificação da espécie para um controle efetivo de tripes em soja no Brasil e em outros países da América do Sul.

Palavras-chave: *Frankliniella schultzei*, *Caliothrips phaseoli*, controle químico, tolerância, manejo integrado de pragas.

ABSTRACT

GEOGRAPHICAL AND INTERESPECIFIC VARIATION IN SUSCEPTIBILITY OF THRIPS (THYSANOPTERA: THRIPIDAE) TO INSECTICIDES IN SOYBEAN

AUTOR: Luiz Francisco Warpechowski
ORIENTADOR: Oderlei Bernardi

Thrips (Thysanoptera: Thripidae) have historically been considered secondary soybean pests in Brazil and other south America countries. However, since the 2010s they have gained importance in soybean in central e northern Brazil. From 2017 onwards, high infestations of thrips have also been detected in soybean in southern Brazil. Here, we collect and identify thrips species from soybean fields in southern Brazil throughout the 2022/2023 season and conducted laboratory bioassays to assess their susceptibility to selected insecticides. Thrips were exposed to field label doses of insecticides in leaf-dip bioassays using soybean leaves. Our results indicated that *Frankliniella schultzei* (Trybom, 1910) and *Caliothrips phaseoli* (Hood, 1912) are the major thrips species found in soybean in southern Brazil. These species exhibited high mortality and relatively low geographic and interspecific variation in susceptibility to field doses of spinetoram, methomyl, spinetoram + methoxyfenozide and profenofos + cypermethrin. In general, most populations of *C. phaseoli* were more susceptible to acephate, chlorfenapyr and abamectin than *F. schultzei*, whereas bifenthrin + carbosulfan showed high lethality against most populations of *F. schultzei*, however, both species had wide geographic variation in susceptibility to these chemistries. In contrast, populations of both species have low mortality when exposed to field doses imidacloprid, lambda-cyhalothrin and lambda-cyhalothrin + sulfoxaflor. In summary, our study documents the existence of high variation in susceptibility of *F. schultzei* and *C. phaseoli* to field doses of selected insecticides, both among species and among geographical areas in southern Brazil. These results highlight the importance of species identification for the effective control of thrips in soybean fields in Brazil and other South American countries.

Keywords: *Frankliniella schultzei*, *Caliothrips phaseoli*, chemical control, tolerance, integrated pest management.

LISTA DE FIGURAS

ARTIGO 1

FIGURE 1 – Sampling sites of thrips species collected from soybean in southern Brazil. 18

FIGURE 2 – Collection and leaf-dip bioassay method used to assess the susceptibility of thrips species to insecticides in southern Brazil 21

FIGURE 3 – Mortality of populations of *F. schultzei* and *C. phaseoli* from southern Brazil exposed to single-mode-of-action insecticides. Bars (± SE) with the same letters within each thrips species are not significantly different 25

FIGURE 4 – Joint mortality of populations of *F. schultzei* and *C. phaseoli* exposed to single-mode-of-action insecticides. Bars (± SE) with the same lowercase letters within each mixture and those with the same uppercase letters within each species are not significantly different 26

FIGURE 5 – Mortality of populations of *F. schultzei* and *C. phaseoli* from southern Brazil exposed to pre-formulated mixtures of insecticides. Bars (± SE) with the same letters within each thrips species are not significantly different 28

FIGURE 6 – Joint mortality of populations of *F. schultzei* and *C. phaseoli* exposed to pre-formulated mixtures. Bars (± SE) with the same lowercase letters within each mixture and those with the same uppercase letters within each species are not significantly different 29

LISTA DE TABELAS

ARTIGO 1

TABLE 1 – Location and date of collection of thrips species in southern Brazil 19

TABLE 2 – Commercial insecticides used to assess the susceptibility of thrips species that attack soybean in southern Brazil 20

SUMÁRIO

1 INTRODUÇÃO **10**
2 REVISÃO DE LITERATURA **11**
2.1 ASPECTOS BIOECOLÓGICOS DE TRIPES 11
2.2 MANEJO DE TRIPES EM SOJA 13
3 ARTIGO 1 .... **15**
1 INTRODUCTION **16**
2 MATERIAL AND METHODS **17**
2.1 COLLECTION AND IDENTIFICATION OF THRIPS SPECIES 18
2.2 INSECTICIDES 19
2.3 BIOASSAYS 20
2.4 STATISTICAL ANALYSIS 22
3 RESULTS **22**
3.1 THRIPS SPECIES COLLECTED FROM SOYBEAN IN SOUTHERN BRAZIL 22
3.2 GEOGRAPHIC AND INTERSPECIFIC SUSCEPTIBILITY OF THRIPS TO SINGLE-MODE-OF-ACTION INSECTICIDES 23
3.3 GEOGRAPHIC AND INTERSPECIFIC SUSCEPTIBILITY OF THRIPS TO PRE-FORMULATED MIXTURE OF INSECTICIDES 26
4 DISCUSSION **29**
REFERENCES **32**
4 CONSIDERAÇÕES FINAIS **38**
5 CONCLUSÕES **39**
REFERÊNCIAS **39**

1 INTRODUÇÃO

Tripes (Thysanoptera: Thripidae) são insetos polífagos que causam danos a diversas plantas cultivadas, como soja (*Glycine max* L.), milho (*Zea mays* L.), algodão (*Gossypium hirsutum* L.), cebola (*Allium cepa* L.), tomate (*Solanum lycopersicum* L.), dentre outras (CHITTURI et al., 2018; DING et al., 2018; GREENBERG; LIU; ADAMCZYK, 2009; HOULE; KENNEDY, 2017; MUNAIZ; GROVES; HAVEY, 2020). Diversas espécies de tripes tem sido reportadas atacando soja em diferentes partes do mundo, como *Frankliniella tritici* (Fitch, 1855) e *Neohydatothrips variabilis* (Bench, 1896) na América do Norte, *Thrips tabaci* (Lindeman, 1889) e *Frankliniella occidentalis* (Pergande, 1895) na África e *Thrips flavus* (Schrank, 1776) na China (CHITTURI et al., 2018; EL-WAHAB, 2021; GAO et al., 2022). No Brasil e países vizinhos, as principais espécies que atacam soja são *Caliothrips phaseoli* (Hood, 1912) e *Frankliniella schultzei* (Trybom, 1910) (DOS SANTOS et al., 2021; DOS SANTOS et al., 2022; GAMUNDI et al., 2005; PERINI et al., 2020).

A principal injúria causada por tripes em soja se deve a raspagem da epiderme das folhas para alimentação, deixando um aspecto prateado devido ao extravasamento do líquido celular e morte das células da epiderme, que reduz a capacidade fotossintética da planta (CHILDERS, 1997; REITZ; GAO; LEI, 2011; TOGOLA et al., 2019). Os danos de tripes, principalmente em períodos de clima seco e quente, podem reduzir a produtividade da soja em até 17% (GAMUNDI et al., 2005; GERARDO et al., 2021). Além dos danos diretos, os tripes causam danos indiretos devido a transmissão de vírus às plantas, como o *soybean vein necrosis virus* em soja, o qual afeta negativamente a qualidade dos grãos (teor de óleo) ou sementes, afetando a germinação e o vigor (ANDERSON et al., 2017; RILEY et al., 2011; SIKORA; CONNER; JACOBSON, 2018). No Brasil, também foi reportada a transmissão de *tobacco streak virus* e *groundnut rigspot orthotospovirus* por *F. schultzei* em soja (ALMEIDA, 2008; DE MARCHI et al., 2019; FONTES et al., 2019).

Para o controle de tripes, a pulverização de inseticidas químicos sintéticos tem sido a principal estratégia de manejo quando constatada infestação superior a cinco tripes por folíolo em soja (NEVES et al., 2022). De acordo com o Sistema de Agrotóxicos Fitossanitários (2023), os inseticidas registrados para tripes pertencem ao grupo dos inibidores de acetilcolinesterase (organofosforados - grupo 1B), moduladores alostéricos de receptores nicotínicos da acetilcolina (espinosinas - grupo 5), desacopladores da fosforilação oxidativa via disrupção do gradiente de próton (clorfenapir - grupo 13), moduladores competitivos de receptores nicotínicos da acetilcolina (neonicotinoides - grupo 4A), moduladores alostéricos de canais de cloro mediados pelo GABA (isoxazolines - grupo 30) e moduladores de canais de sódio (piretroides grupo - 3A).

O sucesso no controle de tripes em soja depende diretamente da identificação da espécie, que exige atenção devido ao tamanho reduzido dos insetos e a similaridade morfológica (CAVALLERI; MOUND, 2012; LIMA; O'DONNELL; MIYASATO, 2020). A necessidade da identificação correta da espécie se deve a existência de diferenças ou variações significativas na suscetibilidade de tripes aos inseticidas comumente aplicados para seu controle (GAO et al., 2021; KILASO, 2022; SHEN et al., 2023). Ainda, o uso frequente de inseticidas com mesmo modo de ação pode favorecer a seleção de insetos resistentes ou da espécie mais tolerante, afetando diretamente a performance dos inseticidas em campo.

A resistência a inseticidas é um processo em que determinada linhagem de um inseto-praga é capaz de tolerar doses de um produto que é letal para os demais indivíduos da população, sendo essa característica transmitida para a sua progênie (LI; SCHULER; BERENBAUM, 2007). Para os tripes, o ciclo relativamente curto (~18 dias) aumenta a probabilidade de seleção de resistentes, uma vez que, vários ciclos são realizados durante uma mesma safra de cultivo (SOSA; ZAMAR; TORREJON, 2017). No Brasil não há relatos de resistência de tripes a inseticidas, porém, nos Estados Unidos, Paquistão, China, Israel e Irã, foram reportados casos de resistência de *F. occidentalis* e *T. tabaci* a espinosinas, avermectinas, carbamatos, piretroides, organofosforados, neonicotinoides, sulfoxaminas e clorfenapir (BILBO; KENNEDY; WALGENBACH, 2023; LEBEDEV et al., 2013; NAZEMI; KHAJEHALI; LEEUWEN, 2016; SHEN et al., 2023; WAKIL et al., 2023). Diante disso, existe a necessidade de considerar práticas de Manejo Integrado de Pragas (MIP) e Manejo de Resistência de Insetos (MRI) quando do controle de tripes que atacam plantas cultivadas no Brasil. Sendo assim, o objetivo deste estudo foi:

1) Identificar espécies de tripes que ocorrem em soja no sul do Brasil e realizar bioensaios para avaliar a variação intra e interspecífica na suscetibilidade aos inseticidas comumente usados para controle.

2 REVISÃO DE LITERATURA

2.1 BIOECOLOGIA DE TRIPES

No Brasil, as espécies de tripes de maior relevância agronômica pertencem a família Thripidae (MOUND et al., 2022). As espécies *F. schultzei* e *C. phaseoli* são as mais abundantes em soja (DE SOUZA, 2021; DOS SANTOS et al., 2021; DOS SANTOS et al., 2022). O ciclo médio de ovo-adulto de espécies de tripes é de aproximadamente 18 dias, passando pelos estágios de larva I, larva II, pré-pupa, pupa e adulto (SOSA; ZAMAR; TORREJON, 2017), com o estágio de pupa sendo realizado no solo (PINENT; CARVALHO, 1998). As fêmeas vivem em média 38 dias e podem ovipositar até 50 ovos (REITZ, 2008), os quais são depositados sob a epiderme das folhas, flores ou frutos (REITZ, 2009). A eclosão das larvas ocorre cerca de 7 dias após a oviposição (SOSA; ZAMAR; TORREJON, 2017). Os tripes são haplodiploides e realizam reprodução sexuada e assexuada, sendo que durante a reprodução assexuada (partenogênese), apenas machos são gerados dos ovos não fertilizados, enquanto na reprodução sexuada, os ovos fertilizados originam fêmeas (REITZ, 2009).

Tripes são insetos polífagos que atacam desde plantas daninhas a plantas cultivadas como soja, milho, algodão, hortaliças, tomate, flores, entre outras (ATAKAN; PEHLIVAN, 2021; MOUND et al., 2022; REITZ; GAO; LEI, 2011). A dispersão destes insetos ocorre principalmente pelo vento ou devido a estímulos de sobrevivência como migração de plantas velhas para plantas novas e presença de inimigos naturais (FERNANDES; FERNANDES, 2015).

Na cultura da soja, os danos diretos de tripes ocorrem principalmente nas folhas, nas quais ninfas e adultos durante o processo de alimentação, causam injúrias na epiderme, que resulta em extravasamento do conteúdo intracelular, deixando as folhas com aspecto prateado (CHISHOLM; LEWIS, 1984). As injúrias causadas às folhas reduzem a capacidade fotossintética, podendo resultar em até 17% de redução na produtividade (GAMUNDI et al., 2005; GERARDO et al, 2021). Algumas espécies, como as do gênero *Frankliniella*, também se alimentam nas flores, as quais podem ser abortadas pela planta (TOGOLA et al., 2019). Em algodão, os tripes são responsáveis por danos logo após a emergência das plântulas, cujo ataque causa má formação das folhas, podendo levar à morte do meristema apical (COOK et al., 2011). Na cultura do tomateiro, os tripes causam deformações nos frutos, devido a alimentação e oviposição sob a epiderme do fruto, que resulta em perda do valor comercial (GHIDIU; HITCHNER; FUNDERBURK, 2006; SALGUERO NAVAS et al., 1991).

Os tripes também podem causar danos indiretos em diversas plantas cultivas devido a transmissão de viroses, como o *tomato chlorotic spot vírus*, *groundnut ringspot vírus*, *soybean vein necrosis virus, tobbaaco streack virus* e *tomato spotted wilt vírus* em soja*, tobbaaco streack* *virus* para o algodoeiro e *tomato spotted wilt vírus* para o tomateiro (ALMEIDA, 2008; BATUMAN et al., 2020; DE JENSEN et al., 2019; FONTES et al., 2019; JAGTAP; JADHAV; UTPAL, 2012; RILEY et al., 2011; SIKORA; CONNER; JACOBSON, 2018).

A incidência de tripes em plantas cultivadas está relacionada a diversos fatores, tais como: (i) fatores climáticos e ambientais; (ii) estádio fenológico da cultura; (iii) o manejo em nível local e regional. Por exemplo, períodos de estiagem e clima quente tendem a beneficiar o desenvolvimento dos tripes, por acelerarem seu ciclo biológico, enquanto períodos chuvosos acabam por reduzir a população, devido ao impacto das gotas sobre os insetos, que faz com que os tripes caiam no solo, e devido a umidade que dificulta os insetos de voarem e migrarem para outras áreas (AHMED et al., 2017; DOS SANTOS et al., 2022; GONÇALVES et al., 2019; ULLAH et al., 2010; ZAINAB et al., 2016). As espécies *F. schultzei* e *F. occidentalis* têm sido mais abundantes em feijão (*Phaseolus vulgaris*), tomate (*Solanum lycopersicum*) e abobrinha (*Cucurbita* sp.) durante o florescimento das plantas, devido a disponibilidade de pólen para sua alimentação, que favorece o desenvolvimento e reprodução (HEALEY et al., 2017; KIRK, 1985). Na Argentina, *F. schultzei* e *C. phaseoli* ocorrem em momentos distintos do ciclo do amendoim (*Arachis hypogaea* L.), com *F. schultzei* infestando as lavouras em dezembro e tendo pico populacional em meados de janeiro, período que coincide com a floração da cultura, enquanto *C. phaseoli* se torna a espécie dominante na fase final de desenvolvimento da cultura, entre final de fevereiro até meados de março (DE BREUIL et al., 2021).

O controle químico empregado em nível local ou regional também impacta diretamente a dinâmica populacional de espécies de tripes. A coexistência de diversas espécies em uma mesma área de produção é marcada por um manejo complexo devido a variação interespecífica na suscetibilidade (SHEN et al., 2023). Nesse contexto, as práticas de manejo químico adotadas ao longo do ciclo da cultura hospedeira pode determinar a espécie dominante, uma vez que, ao ser realizado o manejo, a população remanescente será predominantemente composta pela espécie menos suscetível (GAO et al., 2021).

2.2 MANEJO DE TRIPES EM SOJA

O manejo de tripes em soja tem sido basicamente realizado pela aplicação de inseticidas. Dentre os grupos químicos registrados para controle de tripes em soja no Brasil estão os organofosforados, espinosinas, clorfenapir, neonicotinoides, isoxazoline e piretroides

(SISTEMAS DE AGROTÓXICOS FITOSSANITÁRIOS, 2023). Entretanto, mais de 60% dos inseticidas registrados para manejo de tripes pertencem ao grupo dos organofosforados.

De acordo com NEVES et al., (2022), o nível de dano econômico na cultura da soja é de 5 tripes por folíolo. No entanto, para o manejo eficaz de tripes é importante a correta identificação da(s) espécie(s), visto que espécies distintas tem variação significativa na suscetibilidade a inseticidas (GAO et al., 2021; SHEN et al., 2023). Ainda, o uso antecipado de inseticidas de amplo espectro, especialmente do grupo dos piretroides, pode afetar a dinâmica populacional destes insetos, aumentando as infestações nos estádios mais avançados do desenvolvimento da cultura, devido à redução na abundância dos inimigos naturais nas áreas de cultivo (REGAN et al., 2017).

No Brasil, ainda não foram reportados casos de resistência de tripes a inseticidas, entretanto, uma redução na suscetibilidade de *C. phaseoli* a lambda-cialotrina foi detectada em soja em Minas Gerais e Goiás (DE SOUZA, 2021). Por outro lado, casos de resistência de tripes, incluindo espécies dos gêneros *Frankliniella* e *Thrips*, foram reportados para mais de 40 ingredientes ativos pertencentes aos grupos das avermectinas, organofosforados, neonicotinoides, piretroides, carbamatos, diamidas, ciclodienos, fenilpirazois, piriproxifem e espinosinas na China, Estados Unidos, Quênia, Suíça, Dinamarca, Espanha, Austrália, Turquia e Coréia do Sul (MOTA-SANCHEZ; WISE, 2023).

Nesse cenário, é essencial avaliar a suscetibilidade das espécies de tripes presentes em soja no Brasil para subsidiar o MIP e fornecer informações para uma rotação efetiva de modos de ação de inseticidas em programas de MRI.

3 ARTIGO

Why does identification matter? Thrips species (Thysanoptera: Thripidae) found in soybean in southern Brazil show high levels of geographical and interspecific variation in susceptibility to insecticides

Luiz F. Warpechowski[a], Eduardo A. Steinhaus[a], Rafaella P. Moreira[a], Daniela N. Godoy[a], Venicius E. Preto[a], Luiz E. Braga[a], Amanda de F. Wendt[a], Alexandre C. Reis[a], Élison F. B. Lima[b], Juliano R. Farias[c] and Oderlei Bernardi[a]

[a]*Department of Plant Protection, Federal University of Santa Maria (UFSM), Roraima Avenue, 1000, 97105-900, Santa Maria/RS.*

[b]*UFPI Natural History Collection, Federal University of Piauí (UFPI), Campus Amílcar Ferreira Sobral, BR 343, Km 3.5, 64808-605, Floriano/PI.*

[c]*Algaagro Soluções Agrícolas Ltda., Rst-287, Km 207, 97200-000, Restinga Sêca/RS.*

Abstract

Thrips have historically been considered secondary soybean pests in Brazil and neighboring countries. However, since the 2010s they have gained importance in soybean in central and northern Brazil. From 2017 onwards, high infestations of thrips have also been detected in soybean in southern Brazil. Here, we collected and identified thrips species from soybean fields in southern Brazil throughout the 2022/2023 season and conducted laboratory bioassays to assess their susceptibility to selected insecticides. Thrips were exposed to the field concentrations of insecticides in leaf-dip bioassays using soybean leaves. Our results indicated that *Frankliniella schultzei* (Trybom, 1910) and *Caliothrips phaseoli* (Hood, 1912) are the major thrips species found in soybean in southern Brazil. These species exhibited high mortality and relatively low geographic and interspecific variation in susceptibility to the field concentration of spinetoram, methomyl, spinetoram + methoxyfenozide and profenofos + cypermethrin. In general, most populations of *C. phaseoli* were more susceptible to acephate, chlorfenapyr and abamectin than *F. schultzei*, whereas bifenthrin + carbosulfan showed high lethality against most populations of *F. schultzei*, however, both species had wide geographic variation in susceptibility to these chemistries. In contrast, populations of both species have low mortality when exposed to the field concentrations of imidacloprid, lambda-cyhalothrin and lambda-cyhalothrin + sulfoxaflor. In summary, our study documents the existence of high variation in the susceptibility of *F. schultzei* and *C. phaseoli* to the field concentrations of selected insecticides, both among species and among geographical areas in southern Brazil. These results highlight the importance of species identification for the effective control of thrips in soybean fields in Brazil and other South American countries.

Keywords: Frankliniella schultzei; *Caliothrips phaseoli*; chemical control; tolerance; integrated pest management.

1. Introduction

Thrips (Thysanoptera) are polyphagous pests that attack a wide range of agricultural, horticultural and ornamental plants worldwide (Mound et al., 2022). The major pest species belong to the family Thripidae (Mound et al., 2022), being *Frankliniella schultzei* (Trybom, 1910) and *Caliothrips phaseoli* (Hood, 1912) considered the most frequent species found in soybean, cotton, peanut and tomato in South America (de Araújo et al., 2020; de Breuil et al., 2021; dos Santos et al., 2022; Gamundi and Perotti, 2009; Silva et al., 2022).

Thrips cause both direct and indirect damage due to their feeding on leaves, flowers and petioles. These insects suck the sap, causing leaf yellowing, silver spots, leaf deformation and flower abortion (Childers, 1997; Reitz et al., 2011; Togola et al., 2019). The direct damage by thrips species on soybean reduces photosynthesis rate and causes yield loss up to 17% (Gamundi et al., 2005; Santos et al., 2023), whereas indirect damage is due to virus transmission (such as *soybean vein necrosis virus* and *groundnut ringspot orthotospovirus*) that affects seed quality, germination and vigor (Almeida, 2008; Anderson et al., 2017; de Marchi et al., 2019; Sikora et al., 2018).

In Brazil, thrips have been recorded in soybean since the 1980s, but were historically considered secondary pests (Almeida et al., 1994; Moscardi and Almeida, 1980; Monteiro et al., 1999). This scenario began to change in the 2010s, when thrips became more abundant in soybeans; from 2017 onwards, high infestations of thrips were detected in soybean in north, central-west and south Brazil, requiring insecticide applications for their control (de Souza, 2021; dos Santos et al., 2022; Lima et al., 2013). Previous studies reported that thrips species have natural variation in susceptibility to various insecticides, thus limiting their control effectiveness and favoring the survival and outbreaks of the more tolerant species, particularly when insecticides with the same mode of action are repeatedly applied (Gao et al., 2021; Kilaso, 2022; Shen et al., 2023).

In this scenario, understanding the geographic and interspecific variation in susceptibility to insecticides in thrips species is necessary to improve control effectiveness. For that reason, we collected and identified thrips species that infest soybean in southern Brazil and conducted a series of laboratory bioassays to assess their susceptibility to selected insecticides.

2. Material and methods

2.1. Collection and identification of thrips species

Field populations of thrips were collected from soybean fields in Rio Grande do Sul state, Brazil, throughout the 2022/2023 soybean season (Table 1; Fig. 1). For the collection, we used a beat sheet (1 m length) below soybean plants, and the thrips were collected using an aspirator attached to a clear plastic pot with screw-on cap (3.5 cm diameter × 5.5 cm height) (Cralplast, CRAL Artigos para Laboratório Ltda, Cotia, SP, Brazil). During this process, thrips were separated into morphospecies based on body color to assign an initial species identification. The collected thrips were transported to the laboratory, where they were fed fresh soybean leaves placed in the same plastic pots used during the collections. Pots were maintained in a climate-controlled room for 24 h at 25 ± 2 °C, 60% ± 10% relative humidity and 14-h photoperiod. Afterwards, 20 adult thrips from each location and expected species were transferred to 1.5 ml-Eppendorf tubes containing 70% alcohol to be used for identification, and the remainder were used in the bioassays. For species confirmation, thrips were mounted on permanent microscope slides as described by Mound and Marullo (1996) and identified based on Cavalleri and Mound (2012) and Lima et al. (2020). Voucher specimens were deposited in the Natural History Collection of the Federal University of Piaui, Floriano, PI, Brazil.

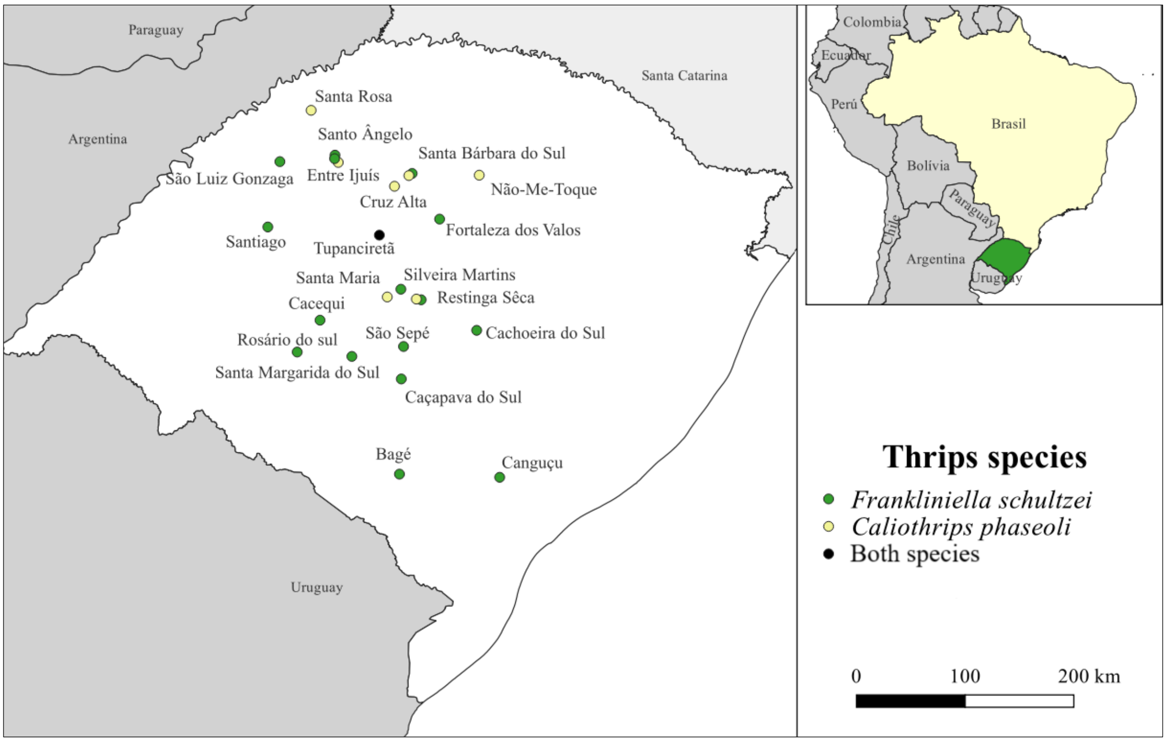

Figure 1. Sampling sites of thrips species collected from soybean in southern Brazil.

Table 1. Location and date of collection of thrips species in southern Brazil.

Location of collection sites	Latitude (S); longitude (W)	Date of collection	Soybean stage
Frankliniella schultzei			
Fortaleza dos Valos, RS	28°56′17″; 53°12′47″	December 2022	V2
Santo Ângelo, RS	28°16′32″; 54°16′23″	December 2022	V3
Tupanciretã, RS	29°12′07″; 53°55′11″	January 2023	V8
Restinga Sêca, RS	29°43′07″; 53°26′46″	January 2023	V3
Silveira Martins, RS	29°38′11″; 53°35′36″	January 2023	R3
Entre Ijuís, RS	28°22′16″; 54°13′35″	January 2023	V5
São Luiz Gonzaga, RS	28°21′44″; 54°48′19″	January 2023	R2
Santiago, RS	29°01′06″; 54°55′18″	January 2023	R2
Cachoeira do Sul, RS	30°02′47″; 52°50′32″	January 2023	R2
Santa Margarida do Sul, RS	30°18′00″; 54°04′54″	January 2023	V4
Rosário do Sul, RS	30°14′23″; 54°38′02″	January 2023	R2
Cacequi, RS	29°56′45″; 54°24′03″	January 2023	R3
Santa Bárbara do Sul, RS	28°29′14″; 53°29′01″	February 2023	R4
São Sepé, RS	30°12′14″; 53°33′43″	February 2023	R2
Caçapava do Sul, RS	30°31′38″; 53°35′33″	February 2023	R3
Canguçu, RS	31°30′03″; 52°36′53″	February 2023	R3
Bagé, RS	31°28′42″; 53°37′05″	February 2023	R4
Caliothrips phaseoli			
Tupanciretã, RS	29°12′07″; 53°55′11″	January 2023	V8
Cruz Alta, RS	28°36′31″; 53°39′59″	January 2023	R2
Entre Ijuís 2, RS	28°20′18″; 54°15′28″	February 2023	R5
Santa Rosa, RS	27°51′21″; 54°29′57″	February 2023	R4

Santa Maria, RS	29°43′00″; 53°43′59″	March 2023	R2
Santa Bárbara do Sul 2, RS	28°30′32″; 53°30′51″	March 2023	R4
Não-Me-Toque, RS	28°29′34″; 52°48′49″	March 2023	R3
Restinga Sêca 2, RS	29°44′02″; 53°26′48″	March 2023	R4

[a] *RS, Rio Grande do Sul*

2.2. Insecticides

The selected insecticides used to assess the susceptibility of thrips species of soybean in southern Brazil are presented in Table 2. These insecticides and concentrations were selected based on label registration for thrips species on soybean or other crops or by use against thrips on soybean in southern Brazil.

Table 2. Selected insecticides used to assess the susceptibility of thrips species that infest soybean in southern Brazil.

Insecticide class (IRAC MoA)	Active ingredient (AI)	Trade name	Company/manufacturer	Concentration tested (g a.i./ha)
Spinosyns (5)	Spinetoram	Exalt®	CTVA Proteção de Cultivos Ltda.	12
Organophosphates (1B)	Acephate	Orthene Gold	UPL do Brasil Indústria e Comércio de Insumos Agropecuários S.A.	750
Pyrroles (13)	Chlorfenapyr	Pirate®	BASF S.A.	180
Avermectins (6)	Abamectin	Vertimec® 18 EC	Syngenta Proteção de Cultivos Ltda.	7.2
Neonicotinoids (4A)	Imidacloprid	Imidagold 700 WG	UPL do Brasil Indústria e Comércio de Insumos Agropecuários S.A.	120
Organophosphates (1B) + Pyrethroids (3A)	Profenofos + Cypermethrin	Polytrin®	Syngenta Proteção de Cultivos Ltda.	320 + 32
Pyrethroids (3A) + Carbamates (1A)	Bifenthrin + Carbosulfan	Talisman®	FMC Química do Brasil Ltda.	30 + 90
Pyrethroids (3A)	Lambda-cyhalothrin	Karate Zeon® 250 CS	Syngenta Proteção de Cultivos Ltda.	30
Diacylhydrazines (18) + Spinosyns (5)	Methoxyfenozide + Spinetoram	Intrepid® Edge	CTVA Proteção de Cultivos Ltda.	60 + 12
Pyrethroids (3A) + Sulfoximines (4C)	Lambda-cyhalothrin + Sulfoxaflor	Expedition®	CTVA Proteção de Cultivos Ltda.	45 + 30

2.3. Bioassays

Adult thrips were exposed to selected insecticides (Table 2) in leaf-dip bioassays using soybean leaves as shown in Figure 2. Initially, completely expanded leaves were excised from the upper-third part of the plants (variety NA 5909 RG; Nidera Sementes Ltda, São Paulo, SP, Brazil) at $V_{4–6}$ growth stages. In the laboratory, leaf discs measuring 2.5 cm in diameter were cut using a metallic cutter. The insecticides were diluted in distilled water to the concentration commonly applied for managing thrips in soybean, simulating a spray volume of 150 L/ha (Table 2), and the solutions were homogenized for 10 min using a magnetic stirrer. After insecticide dilution, leaf discs were dipped into the solution for 30 s. For controls, leaf discs were dipped only into distilled water. After treatment, leaf discs were placed onto paper towels and allow to dry. Test arenas were prepared using plastic pots (3.5 cm diameter × 5.5 cm height — as used during the collection process), containing a gelled mixture of 2% agar–water covered with a filter paper disc (Fig. 2). Subsequently, 10 adult thrips per species per collection site per insecticide were transferred to each pot using an aspirator (Fig. 2), and a single treated or control leaf disc was carefully placed into each pot. Pots were closed and placed in a climate-controlled room at 25 ± 2°C, 60% ± 10% relative humidity and 14-h photoperiod. The experimental design was randomized with 5 replicates (arenas) of 10 thrips per species, collection site and insecticide. The control treatment was also composed of 5 replicates. Mortality was assessed 24 h after exposure to insecticides. Thrips without movement after a light touch with a fine brush were considered dead.

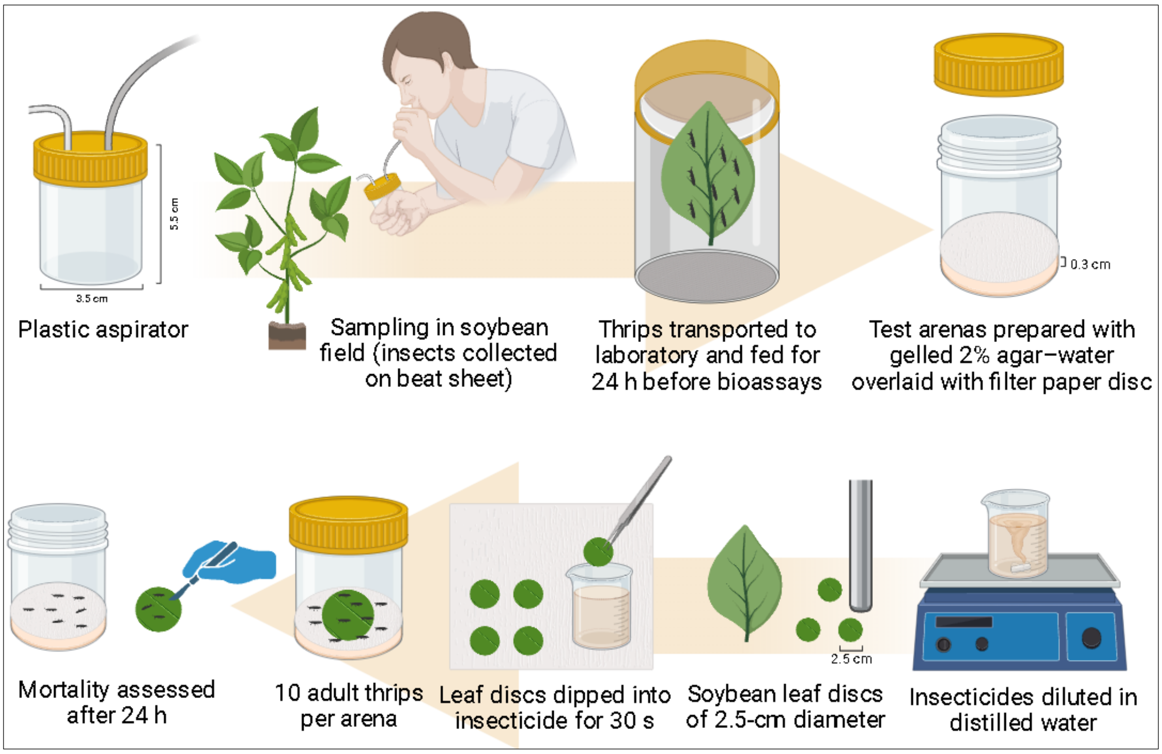

Figure 2. Collection and leaf-dip bioassay method used to assess the susceptibility of thrips species to insecticides in southern Brazil. Created with BioRender.com.

2.4. Statistical analysis

To assess the susceptibility of thrips to insecticides, initially mortality data were subjected to studentized residual analysis to confirm assumptions of normality with the Shapiro–Wilk test (Shapiro and Wilk, 1965), and homogeneity of variances was tested with the Bartlett test (Bartlett, 1937) in R 4.1.1 (R Development Core Team, 2021). As the data did not meet the assumption of parametric distribution, they were subjected to nonparametric analysis: the numbers of thrips tested and dead from each population or species were submitted to binominal distribution analysis to estimate the probability of mortality and the respective 95% confidence intervals (CIs). The percent mortality of thrips treated with each insecticide was corrected based on untreated controls using Abbott's formula (Abbott, 1925). Then, mortality data were compared pairwise to assess the geographic variation in susceptibility to insecticides. Mortality data were also grouped by species and insecticide to estimate interspecific variation in susceptibility to insecticides. Mortality rates were considered significantly different when the 95% CIs for the probability of mortality did not overlap (Dorai-Raj, 2009). All analyses were performed in R software version 4.1.1 (R Development Core Team, 2021).

3. Results

3.1. Thrips species collected from soybean in southern Brazil

From December 2022 to March 2023, a total of 25 thrips populations were collected from 24 soybean fields in Rio Grande do Sul state, Brazil (Fig. 1). Two thrips species were identified infesting soybean in this region: *F. schultzei* and *C. phaseoli*. *Frankliniella schultzei* was found in 16 fields and *C. phaseoli* in 7 fields, representing 66.6% and 29.2% of the soybean fields sampled, respectively. The co-occurrence of both species was detected in only one sampling field (4.2%).

3.2. Geographic and interspecific susceptibility of thrips to single-mode-of-action insecticides

In general, populations of *F. schultzei* and *C. phaseoli* found in soybean in southern Brazil presented high susceptibility to the field concentration of spinetoram, with mortality ranging from 83% to 100% (Fig. 3A). Our findings also indicate that both species had little geographic variation in susceptibility to this mode of action, as indicated by the overlapping of 95% CIs for the probability of mortality (Fig. 3A). Similarly, the majority of populations of both thrips species were also susceptible to the field concentration of methomyl, presenting mortality >81%, but some populations of *F. schultzei* (Entre Ijuís, Santiago and Caçapava do Sul) and *C. phaseoli* (Restinga Sêca and Santa Bárbara do Sul) presented significantly lower mortality (67–77%), as indicated by the non-overlapping of 95% CIs (Fig. 3B).

A higher level of geographic variation in susceptibility to the field concentration of acephate and chlorfenapyr was detected in populations of *F. schultzei* than in *C. phaseoli* (Fig. 3C, D). These insecticides showed intermediate or low lethality against half of the populations of *F. schultzei* (mortality ranging from 23% to 76%), whereas another half-exhibited mortality >80% (Fig. 3C, D). Even though significant differences in susceptibility of *C. phaseoli* to acephate and chlorfenapyr were detected (non-overlapping of 95% CIs), all populations of this species showed mortality >80% (Fig. 3C, D).

The exposure of *F. schultzei* and *C. phaseoli* to the field concentration of abamectin and imidacloprid revealed intermediate or low susceptibility of both species to these chemistries (Fig. 3E, F). A large geographic variation in susceptibility to abamectin was verified in populations of *F. schultzei*, as indicated by the non-overlapping of 95% CIs, with mortality ranging from 0% to 54% (Fig. 3E). Except for the populations from Cruz Alta, Não-Me-Toque and Restinga Sêca (10–46% mortality), abamectin caused mortality >60% against *C. phaseoli* (Fig. 3E). Both species also presented wide geographic variation in susceptibility to imidacloprid and lambda-cyhalothrin, with both insecticides also having low lethality; mortality ranged from 2% to 61% (Fig. 3F, G).

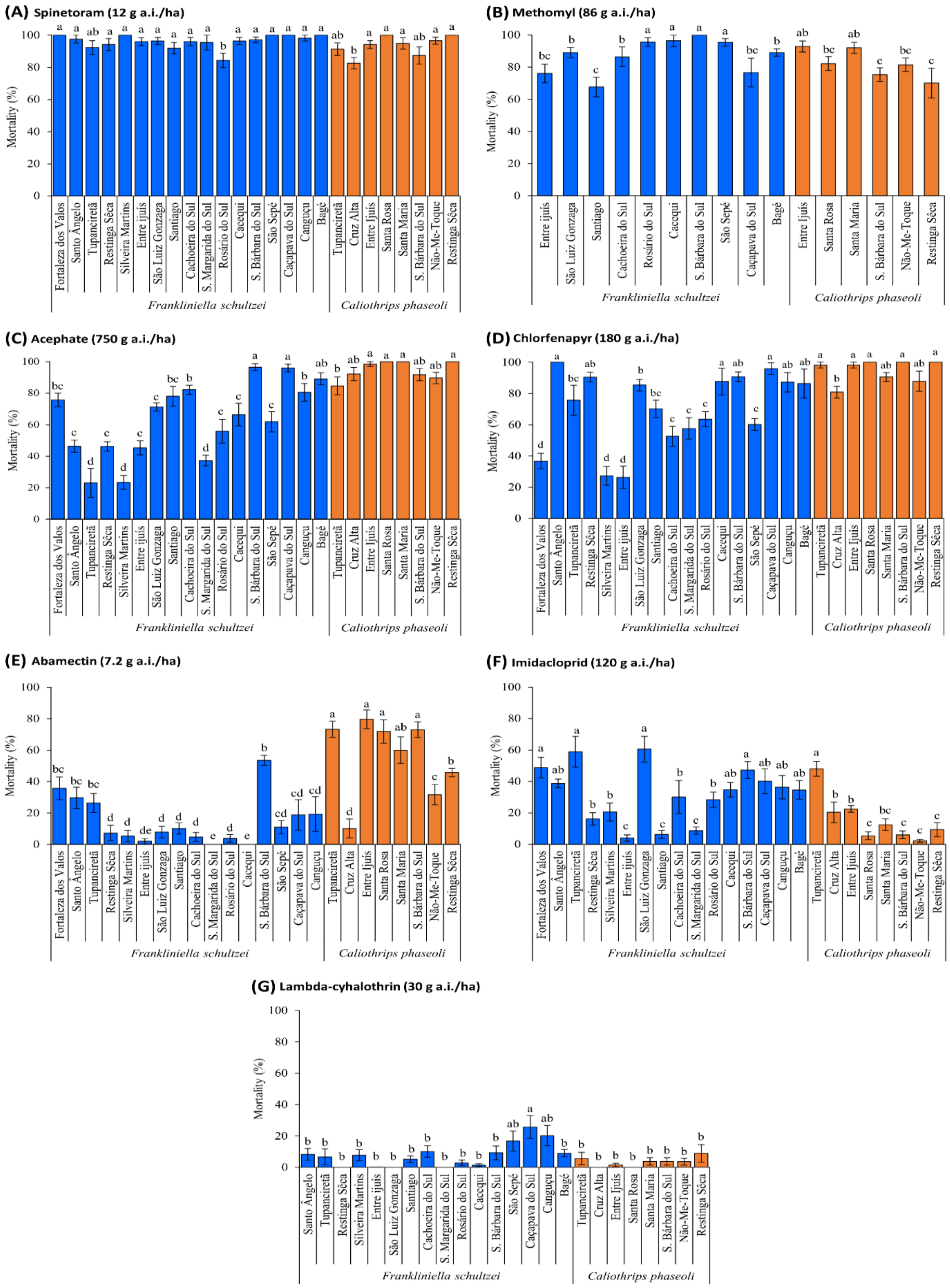

Figure 3. Mortality of populations of *F. schultzei* and *C. phaseoli* from southern Brazil exposed to the field concentration of single-mode-of-action insecticides. Bars (± SE) with the same letters within each thrips species are not significantly different.

When mortality data from all populations of each species was considered in a joint analysis, spinetoram and methomyl were the most lethal insecticides for concurrent control of *F. schultzei* and *C. phaseoli* (Fig. 4). In contrast, chlorfenapyr and acephate caused higher mortality (~94%) against *C. phaseoli* than *F. schultzei* (<74%) (Fig. 4). Although thrips species differed significantly in susceptibility to abamectin, imidacloprid and lambda-cyhalothrin, these chemistries were less effective against both species (Fig. 4).

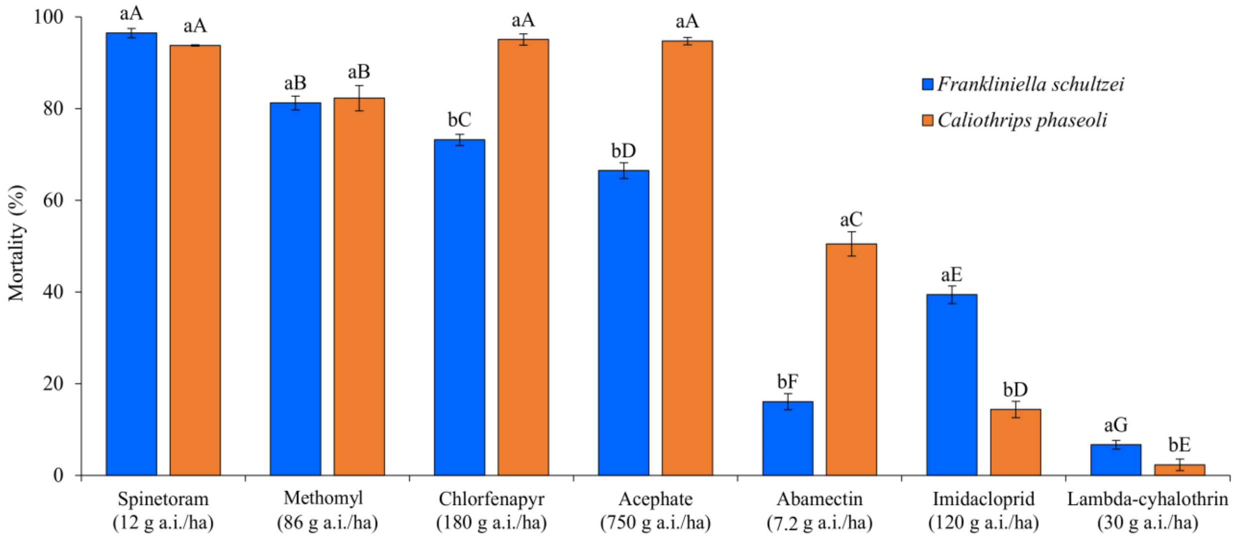

Figure 4. Joint mortality of populations of *F. schultzei* and *C. phaseoli* exposed to the field concentration of single-mode-of-action insecticides. Bars (± SE) with the same lowercase letters within each mixture and those with the same uppercase letters within each species are not significantly different.

3.3. Geographic and interspecific susceptibility of thrips to pre-formulated mixtures of insecticides

There was little geographic variation in susceptibility of *F. schultzei* and *C. phaseoli* to the field concentration of pre-formulated mixture of spinetoram + methoxyfenozide, with mortality ranging from 79% to 99% (Fig. 5A). The mortality caused by this insecticide mixture was significantly lower (based on non-overlapping of 95% CIs) for populations of *F. schultzei* from Silveira Martins and Santa Margarida do Sul (mortality <84%) than for the other populations tested (mortality >88%). Except for the populations of *C. phaseoli* from Cruz Alta and Santa Bárbara do Sul (mortality <87%), this species presented >90% mortality when exposed to the field concentration of spinetoram + methoxyfenozide (Fig. 5A).

The exposure of thrips species to the field concentration of profenofos + cypermethrin also revealed significant geographic variation in their susceptibility (Fig. 5B). Populations of *F. schultzei* from Santo Ângelo, Tupanciretã, Rosário do Sul and Silveira Martins presented relatively low mortality (<77%), whereas all other populations showed >85% mortality when exposed to profenofos + cypermethrin (Fig. 5B). Like previous results with *F. schultzei*, significant variation in susceptibility of *C. phaseoli* to profenofos + cypermethrin was also detected, with mortality ranging from 80% to 100% (Fig. 5B).

A wide variation in susceptibility to bifenthrin + carbosulfan was also identified in thrips species that attacks soybean in southern Brazil, with mortality ranging from 2% to 95% (Fig. 5C). Populations of *F. schultzei* from Santiago, Santa Margarida do Sul, Rosário do Sul and Santa Bárbara do Sul presented significantly lower mortality (30–46%) than other populations (mortality >53%) (Fig. 5C). In contrast, most populations of *C. phaseoli* showed low susceptibility when exposed to the field concentration of bifenthrin + carbosulfan, with mortality <67% (Fig. 5C). Our results also revealed that the mixture of lambda-cyhalothrin + sulfoxaflor cause diminished mortality against populations of both thrips species (<28%) (Fig. 5D).

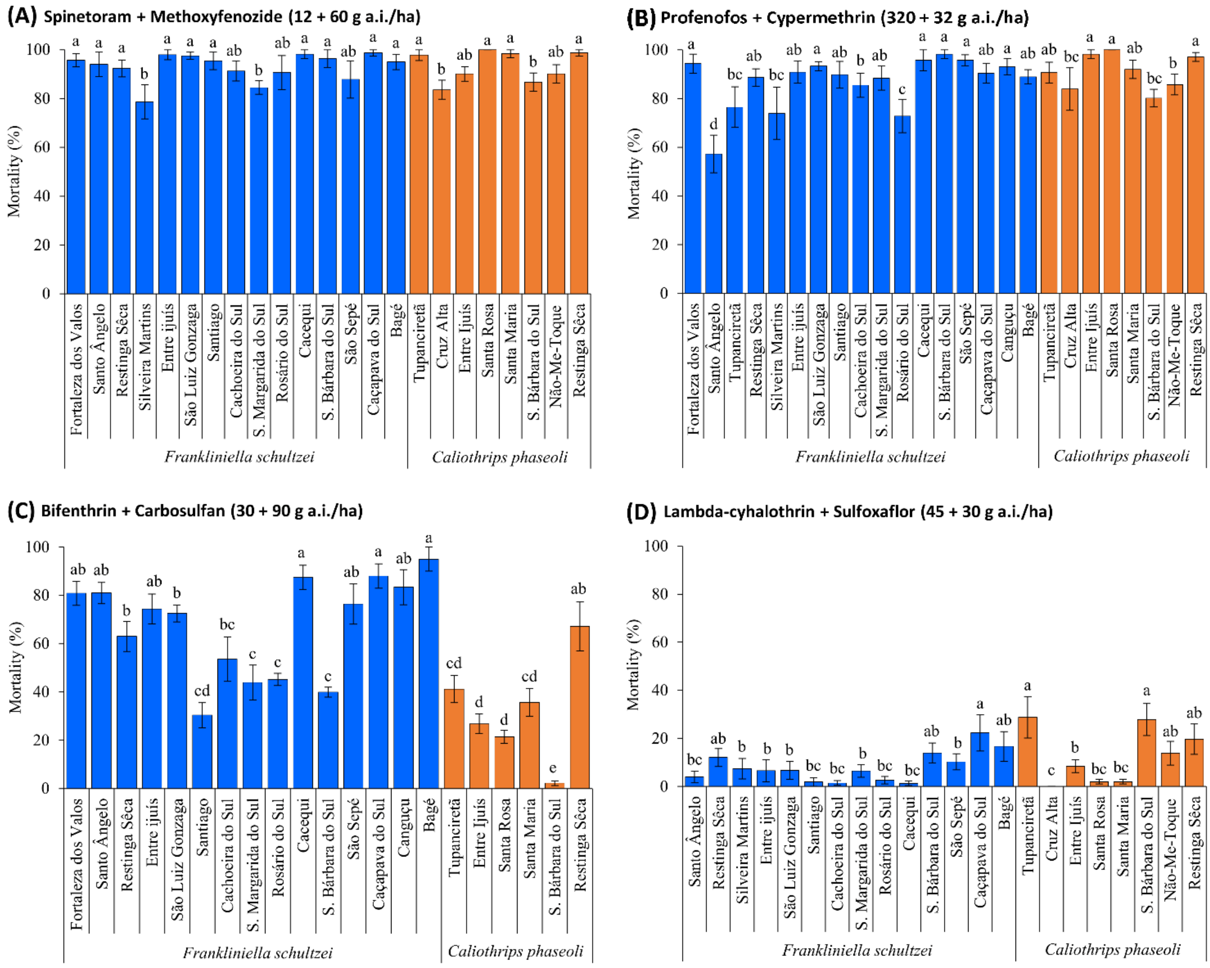

Figure 5. Mortality of populations of *F. schultzei* and *C. phaseoli* from southern Brazil exposed to the field concentration of pre-formulated mixtures of insecticides. Bars (± SE) with the same letters within each thrips species are not significantly different.

When mortality data from all populations of each species were grouped, it was observed that *F. schultzei* and *C. phaseoli* had similar susceptibility (overlapping of 95% CIs) to pre-formulated mixtures of methoxyfenozide + spinetoram and profenofos + cypermethrin; in each case, mortality was >88%, differing significantly from the other mixtures evaluated (Fig. 6). On the other hand, the concentration of bifenthrin + carbosulfan showed higher lethality against *F. schultzei* (68% mortality) than against *C. phaseoli* (25% mortality), whereas lambda-cyhalothrin + sulfoxaflor had low and similar lethality against both species, causing <11% mortality (Fig. 6).

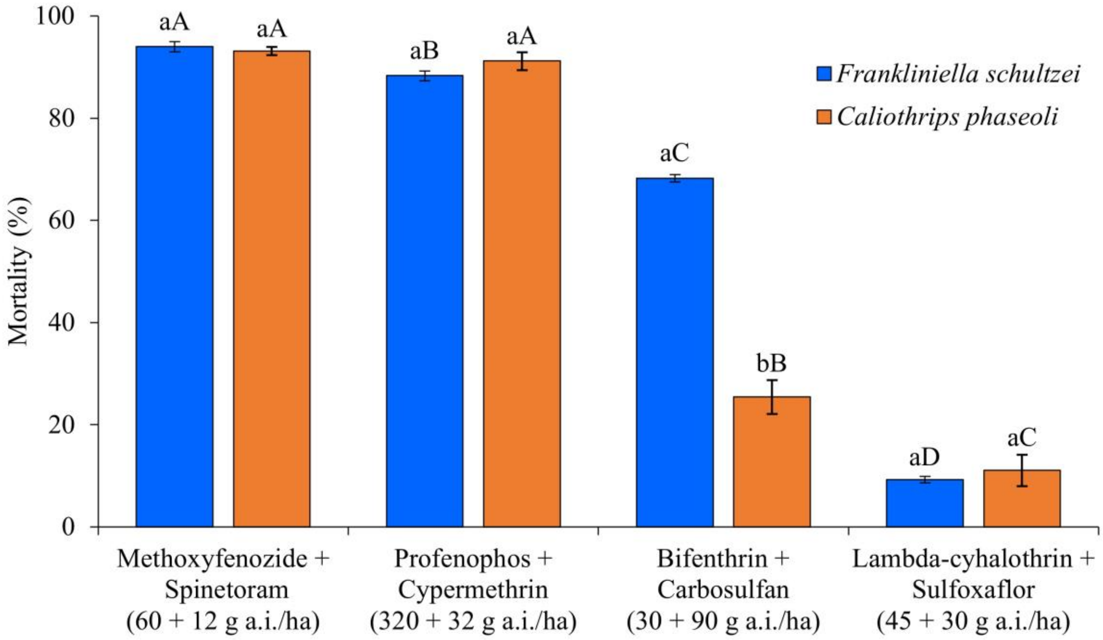

Figure 6. Joint mortality of populations of *F. schultzei* and *C. phaseoli* exposed to the field concentration of pre-formulated insecticide mixtures. Bars (± SE) with the same lowercase letters within each mixture and those with the same uppercase letters within each species are not significantly different.

4. Discussion

The major thrips species found in soybean fields in southern Brazil were identified as *F. schultzei* and *C. phaseoli*. Previous studies also reported that these species were the most abundant thrips in soybean in southeast, central-west and northern Brazil (Almeida et al., 1994; Dos Santos et al., 2021; Dos Santos et al., 2022; Lima et al., 2013; Monteiro et al., 1999). These same species have also been reported infesting soybean in Argentina, Uruguay and Paraguay (Gamundi et al., 2005; Kakkar et al., 2017; Perini et al., 2020). In contrast, the thrips fauna associated with soybean in North America is composed mainly of *Frankliniella tritici* (Fitch, 1855) and *Neohydatothrips variabilis* (Beach, 1896), whereas *Thrips tabaci* (Lindeman, 1889) and *Frankliniella occidentalis* (Pergande, 1895) were the most abundant in soybean in Africa and *Thrips flavus* (Schrank, 1776) was the most abundant in soybean in China (Chitturi et al., 2018; El-Wahab, 2021; Gao et al., 2022).

The main control method used for managing thrips in soybean in Brazil and neighboring countries has been chemical control. According to our results, populations of *F. schultzei* and *C. phaseoli* were most susceptible and presented lower geographic variation in susceptibility to the field concentration of spinetoram, methomyl and pre-formulated mixtures of spinetoram + methoxyfenozide and profenofos + cypermethrin than to the other insecticides evaluated. In addition, *C. phaseoli* was more susceptible to the field concentration of acephate, chlorfenapyr and abamectin than *F. schultzei*. Previous studies also revealed that populations of *C. phaseoli* sampled in soybean in Minas Gerais and Goiás, Brazil were susceptible to spinetoram and acephate (de Souza, 2021). Species of the genus *Frankliniella* from horticultural and ornamental plants in China and Turkey also exhibited high susceptibility to spinetoram and methomyl (Dağlı and Tunç, 2007; Fan et al., 2023; Gao et al., 2021; Shen et al., 2023; Wang et al., 2016; Zhang et al., 2022). Similarly, *T. tabaci* and *Thrips palmi* (Karny, 1925) in the United States, Pakistan and China were also susceptible to spinetoram and methomyl (Adesanya et al., 2020; Gao et al., 2021; Wakil et al., 2023).

Unlike to previous insecticides, populations of *F. schultzei* and *C. phaseoli* had low susceptibility when exposed to the field concentration of abamectin, imidacloprid, lambda-cyhalothrin, lambda-cyhalothrin + sulfoxaflor and bifenthrin + carbosulfan. Imidacloprid and lambda-cyhalothrin also showed low lethality against *C. phaseoli* from soybean fields of Central Brazil (de Souza, 2021). Similarly, species of the genus *Frankliniella* sampled in cotton, soybean, horticultural and ornamental plants presented low susceptibility to abamectin and imidacloprid in China, Pakistan and the United States (Huseth et al., 2016; Wakil et al., 2023; Wang et al., 2016; Zhang et al., 2022). Other thrips species, such as *T. tabaci* and *T.*

palmi, also showed low susceptibility to lambda-cyhalothrin and sulfoxaflor in the United States, China and Pakistan (Shelton et al., 2003, 2006; Shen et al., 2023; Wakil et al., 2023).

The present study documents that major thrips pest species of soybean in southern Brazil have both geographic and interspecific variation in susceptibility to the concentrations of most of the insecticides tested. We hypothesize that these differences in susceptibility to insecticides can be explained by the combination of biological characteristics of insects, agronomic practices and environmental conditions, such as (i) naturally low susceptibility of thrips species to a particular insecticide; (ii) local or regional management using insecticides with the same mode of action, thus increasing insecticide resistance due to frequent exposure to the same chemistries, which might also be used against other soybean pests (i.e. stink bugs and mites); and (iii) environmental conditions (high temperatures and dry periods during the spring/summer) from 2017 to early 2023 in southern Brazil that favored the occurrence of frequent outbreaks of thrips in soybean and other crops and, consequently, increased their exposure to insecticides. Similarly, genetic characteristics of thrips species, environmental conditions and agronomic practices also affected the susceptibility of *F. occidentalis, T. palmi* and *T. flavus* to several insecticides in China and Spain (Bielza et al., 2008; Gao et al., 2022; Shen et al., 2023).

From a pest control perspective, for the management of thrips in soybean in southern Brazil and neighboring countries, several agronomic practices must be considered: (i) correct identification of the species; (ii) use of accurate information on the susceptibility of the species to insecticides to support decision-making about insecticide choice; (iii) avoidance of broad-spectrum insecticides (i.e. pyrethroids) in early stages of soybean, since they reduce populations of natural enemies and thus contribute to more frequent outbreaks of thrips and other pests (i.e. mites); (iv) implementation of a rotation of insecticides with distinct modes of action to reduce the probability of evolution of resistance at the local (farm) or regional level;

and (v) use of non-chemical control methods to promote sustainable management. In summary, our results will help growers, pesticide applicators and other stakeholders to make decisions for more effective control of major thrips species found in soybean in Brazil and other countries.

Acknowledgments

We are grateful to the National Council for Technological and Scientific Development (CNPq) for the research fellowship to O.B. (Process 305464/2020-5).

References

Abbott, W.S., 1925. A method of computing the effectiveness of an insecticide. J. Econ. Entomol. 18, 265–267.

Adesanya, A.W., Waters, T.D., Lavine, M.D., Walsh, D.B., Lavine, L.C., Zhu, F., 2020. Multiple insecticide resistance in onion thrips populations from Western USA. Pestic. Biochem. Physiol. 165, 104553.

Almeida, A.M.R., Nakahara, S., Sosa-Gomez, D.R., 1994. Thrips species identified in soybean fields in Brazil. An. Soc. Entomol. Bras. 23, 363–365.

Almeida, A.M.R., 2008. Viroses da soja no Brasil: Sintomas, etiologia e controle. Londrina: Embrapa Soja. n. 306.

Anderson, N.R., Irizarry, M.D., Bloomingdale, C.A., Smith, D.L., Bradley, C.A., Delaney, D.P., Kleczewskin N.M., Sikora, E.J., Mueller, D.S., Wise, K. A., 2017. Effect of *soybean vein necrosis* on yield and seed quality of soybean. Can. J. Plant Pathol. 39, 334–341.

Bartlett, M.S., 1937. Properties of sufficiency and statistical tests. Proc. R. Soc. Lond. A. Math. Phys. Sci. 160, 268–282.

Bielza, P., Quinto, V., Grávalos, C., Fernández, E., Abellán, J., 2008. Impact of production system on development of insecticide resistance in *Frankliniella occidentalis* (Thysanoptera: Thripidae). J. Econ. Entomol. 101, 1685–1690.

Cavalleri, A., Mound, L.A., 2012. Toward the identification of *Frankliniella* species in Brazil (Thysanoptera, Thripidae). Zootaxa 3270, 1–30.

Childers, C.C., 1997. Feeding and oviposition injuries to plants. In: Lewis T, ed., Thrips as Crop Pests. CAB International, New York. pp. 505–537.

Chitturi, A., Conner, K., Sikora, E.J., Jacobson, A.L., 2018. Monitoring seasonal distribution of thrips vectors of *soybean vein necrosis virus* in Alabama soybeans. J. Econ. Entomol. 111, 2562–2569.

Dağlı, F., Tunç, İ., 2007. Insecticide resistance in *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) collected from horticulture and cotton in Turkey. Aust. J. Entomol. 46, 320–324.

de Araújo, T.A., Pezzini, D.T., Ramos, R.S., Picanço, M.C., Bastos, C.S., Hunt, T.E., Hutchison, W.D., 2020. Development and validation of sampling plans for *Frankliniella schultzei* on tomato. Crop Prot. 134, 105163.

de Breuil, S., Giudici, A., La Rossa, F.R., Baldessari, J., Bejerman, N., Giolitti, F., Lenardon, S., 2021. Exploring species composition and population dynamics of thrips (Thysanoptera: Thripidae) in peanut crops in Argentina. Phytoparasitica 49, 785–792.

de Marchi, B.R., Bello, V.H., Watanabe, L.F.M., da Silva, F.B., Müller, C., Pavan, M.A., Krause-Sakate, R., 2019. Characterization and complete genome sequence of *groundnut ringspot orthotospovirus* in soybean in Brazil. J. Plant Pathol.101, 401.

de Souza, S. A., 2021. Suscetibilidade de populações de tripes a inseticidas e efeito da utilização de espinosina, piretroide e sulfoxamina em *Caliothrips phaseoli* (Hood) (Thysanoptera: Thripidae) na cultura da soja. Master's dissertation, Universidade Estadual Paulista - UNESP.

Dorai-Raj, S., 2009. binom: Binomial confidence intervals for several parameterizations. R package version 1.0–5. https://cran.r-project.org/web/packages/binom/binom.pdf

dos Santos, J.L., Sarmento, R.A., Pereira, P.S., Noleto, L.R., Reis, K.H., Pires, W.S., Peluzio, J.M., Medeiros, J.G., Santos, A.A., Picanço, M.C., 2022. Assessing the temporal dynamics of *Frankliniella schultzei* (Thysanoptera: Thripidae) in commercial soybean crops in North Brazil. Agric. For. Entomol. 24, 97–103.

dos Santos, R.C., Lopes, M.C., de Almeida Sarmento, R., Pereira, P.S., Picanço, M.M., dos Santos Pires, W., Noleto, L.R., de Araújo, T.A., Picanço, M.C., 2021. Conventional sampling plan for thrips in tropical soybean fields. Crop Prot. 148, 105740.

El-Wahab, A.S.A., 2021. Molecular characterization and incidence of new tospovirus: *Soybean Vein Necrosis Virus* (SVNV) in Egypt. Braz. J. Biol. 84.

Fan, R., Fan, Z., Sun, Z., Chen, Y., Gui, F., 2023. Insecticide susceptibility and detoxification enzyme activity of *Frankliniella occidentalis* under three habitat conditions. Insects 14, 643.

Gamundi, J.C., Perotti, E., Molinari, A., Manlla, A., Quijano, D., 2005. Evaluación del daño de trips *Caliothrips phaseoli* (Hood) en soja. INTA EEA Oliveros 30, 71–76.

Gamundi, J.C., Perotti, E., 2009. Evaluación de daño de *Frankliniella schultzei* (Trybom) y *Caliothrips phaseoli* (Hood) en diferentes estados fenológicos del cultivo de soja. INTA EEA Oliveros 1, 107–111.

Gao, Y.F., Gong, Y.J., Cao, L.J., Chen, J.C., Gao, Y.L., Mirab-balou, M., Chen, M., Hoffmann, A.A., Wei, S.J., 2021. Geographical and interspecific variation in susceptibility of three common thrips species to the insecticide, spinetoram. J. Pest Sci. 94, 93–99.

Gao, Y., Ding, N., Wang, D., Zhao, Y.J., Cui, J., Li, W.B., Pei, T., Shi, S.S., 2022. Effect of temperature on the development and reproduction of *Thrips flavus* (Thysanoptera: Thripidae). Agric. For. Entomol. 24, 279–288.

Huseth, A.S., Chappell, T.M., Langdon, K., Morsello, S.C., Martin, S., Greene, J.K., Herbert, A., Jacobson, A.L., Reay-Jones, F.P.F., Reed, T., Reisig, D.D., Roberts, P.M., Smith, R., Kennedy, G.G., 2016. *Frankliniella fusca* resistance to neonicotinoid insecticides: an emerging challenge for cotton pest management in the eastern United States. Pest Manag. Sci. 72, 1934–1945.

Kakkar, G., Seal, D.R., Jha, V.K., Bagnall, F., 2017. Common blossom thrips, *Frankliniella schultzei* Trybom (Insecta: Thysanoptera: Thripidae). EENY 477(IN860): Series of the Entomology and Nematology Department, University of Florida/Institute of Food and Agricultural Sciences Extension: 1–5.

Kilaso, M., 2022. Toxicity for control of *Frankliniella schultzei* and *Selenothrips rubrocinctus* (Thysanoptera: Thripidae) of several common synthetic insecticides. Fla. Entomol. 105, 155–159.

Lima, É.F.B., Monteiro, R.C., Zucchi, R.A., 2013. Thrips species (Insecta: Thysanoptera) associated to Fabaceae of agricultural importance in Cerrado and Amazon-Caatinga ecotone from Brazilian Mid-North. Biota Neotropica 13, 283–289.

Lima, É.F.B., O'Donnell, C., Miyasato, E.A., 2020. The Panchaetothripinae (Thysanoptera, Thripidae) of Brazil, with one new *Caliothrips* species. Zootaxa 4820, 201–230.

Monteiro, R.C., Mound, L.A., Zucchi, R.A., 1999. Thrips (Thysanoptera) as pests of plant production in Brazil. Rev. Bras. Entomol. 43, 163–171.

Moscardi, F., Almeida, A.M.R., 1980. Ocorrência de espécies de tripes em soja e outras plantas hospedeiras, comumente associadas a esta cultura, no estado do Paraná. In: Resultados de pesquisa de soja 1979/1980. Londrina: Embrapa Soja. p. 169–171.

Mound, L.A., Marullo, R., 1996. The thrips of Central and South America: an introduction (Insecta: Thysanoptera). Mem. Entomol. Int. 6, 1–488.

Mound, L.A., Wang, Z., Lima, É.F., Marullo, R., 2022. Problems with the concept of “pest” among the diversity of pestiferous thrips. Insects 13, 61.

Perini, C.R., Abbate, S., Sosa, V. Risso, A.A., Froehlich, R., Selli, V.S., Ceolin, M., Puntel, L., Daltrozo, W.B., Guedes, J.C., 2020. Ocorrência e manejo de pragas em soja Bt e não Bt no sul da América do Sul. Ver. Plantio Direto, 175, 21–31

R Development Core Team. 2021. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Reitz, S.R., Gao, Y.L., LEI, Z.R., 2011. Thrips: pests of concern to China and the United States. Agric. Sci. China 10, 867–892.

Santos, J.L., Pereira, P.S., Reis, K.H.B., Freitas, D.R., Picanço Filho, M.C., Peluzio, J.M., Sarmento, R.A., Guedes, R.N.C., Picanço, M.C., 2023. Decision-making for thrips control in soybean fields using precision agriculture principles. J. Applied Entomol., https://doi.org/10.1111/jen.13215

Shapiro, S.S., Wilk, M.B., 1965. An analysis of variance test for normality (complete samples). Biometrika. 52, 591–611.

Shelton, A.M., Nault, B.A., Plate, J., Zhao, J.Z., 2003. Regional and temporal variation in susceptibility to λ-cyhalothrin in onion thrips, *Thrips tabaci* (Thysanoptera: Thripidae), in onion fields in New York. J. Econ. Entomol. 96, 1843–1848.

Shelton, A.M., Zhao, J.Z., Nault, B.A., Plate, J., Musser, F.R., Larentzaki, E., 2006. Patterns of insecticide resistance in onion thrips (Thysanoptera: Thripidae) in onion fields in New York. J. Econ. Entomol. 99, 1798–1804.

Shen, X.J., Chen, J.C., Cao, L.J., Ma, Z.Z., Sun, L.N., Gao, Y.F., Ma, L.J., Wang, J.X., Ren, Y.J., Cao, H.Q., Gong, Y.J., Hoffmann, A.A., Wei, S.J., 2023. Interspecific and intraspecific variation in susceptibility of two co-occurring pest thrips, *Frankliniella occidentalis* and *Thrips palmi,* to nine insecticides. Pest Manag. Sci. 79, 3218–3226

Sikora, E.J., Conner, K.N., Jacobson, A.L., 2018. Incidence of s*oybean vein necrosis virus* in Alabama soybean fields. Plant Health Prog. 19, 76–81.

Silva, C.A.D., Cavalleri, A., Morais, M.M.D., Andrade, W.L., Albuquerque Junior, P.S., Serrão, J.E., Zanuncio, J.C., 2022. *Retithrips syriacus* (Mayet) (Thysanoptera: Thripidae): first record damaging cotton plants in Brazil. Braz. J. Biol. 82, e264466.

Togola, A., Boukar, O., Chamarthi, S., Belko, N., Tamò, M., Oigiangbe, N., Ojo, J., Ibikunle, M., Fatokun, C., 2019. Evaluation of cowpea mini core accessions for resistance to flower bud thrips *Megalurothrips sjostedti* Trybom (Thysanoptera: Thripidae). J. Appl. Entomol. 143 683–692.

Wakil, W., Gulzar, S., Wu, S., Rasool, K.G., Husain, M., Aldawood, A.S., Toews, M.D., 2023. Development of insecticide resistance in field populations of onion thrips, *Thrips tabaci* (Thysanoptera: Thripidae). Insects 14, 376.

Wang, Z.H., Gong, Y.J., Jin, G.H., Li, B.Y., Chen, J.C., Kang, Z.J., Zhu, L., Gao Y., Reitz, R. Wei, S. J., 2016. Field-evolved resistance to insecticides in the invasive western flower thrips *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) in China. Pest Manag. Sci. 72, 1440–1444.

Zhang, K., Yuan, J., Wang, J., Hua, D., Zheng, X., Tao, M., Zhang, Z., Wan, Y., Wang, S., Zhang, Y., Liang, P., Wu, Q., 2022. Susceptibility levels of field populations of *Frankliniella occidentalis* (Thysanoptera: Thripidae) to seven insecticides in China. Crop Prot. 153, 105886.

4 CONSIDERAÇÕES FINAIS

As principais espécies de tripes encontradas em soja no sul do Brasil durante a safra 2022/2023 foram *F. schultzei* e *C. phaseoli*. Em geral, as populações de *F. schultzei* e *C. phaseoli* foram suscetíveis e apresentaram baixa variação na suscetibilidade a espinetoram, metomil, espinetoram + metoxifenozida e profenofos + cipermetrina. Constatou-se também que *C. phaseoli* foi mais suscetível a acefato, clorfenapir e abamectina do que *F. schultzei*. Em contraste, populações de ambas as espécies apresentaram reduzida suscetibilidade a abamectina, imidacloprido, lambda-cialotrina, lambda-cialotrina + sulfoxaflor e bifentrina + carbosulfano.

Estudos prévios também indicaram que espécies do gênero *Frankliniella*, provenientes de hortaliças e plantas ornamentais na China e Turquia, também foram suscetíveis a espinetoram e metomil (DAĞLI; TUNÇ, 2007; FAN et al., 2023; GAO et al., 2021; SHEN et al., 2023; WANG et al., 2016; ZHANG et al., 2022). Outras espécies de tripes, como *T. tabaci* e *T. palmi*, nos Estados Unidos, Paquistão e China, também foram suscetíveis a espinetoram e metomil (ADESANYA et al., 2020; GAO et al., 2021; WAKIL et al., 2023). Corroborando com nossos resultados, espécies do gênero *Frankliniella* coletadas em algodão, soja, hortaliças e plantas ornamentais na China, Paquistão e Estados Unidos também exibiram reduzida suscetibilidade a abamectina e imidacloprido (HUSETH et al., 2016; WAKIL et al., 2023; WANG et al., 2016; ZANG et al., 2022). Similarmente, espécies do gênero *Thrips* provenientes de hortaliças nos Estados Unidos, China e Paquistão também apresentaram baixa suscetibilidade a lambda-cialotrina e sulfoxaflor (SHELTON et al., 2003; 2006; SHEN et al., 2023; WAKIL et al., 2023).

Diante dos resultados deste estudo e de trabalhos prévios, fica evidente que para o sucesso no manejo de tripes em diferentes plantas cultivadas, se faz necessário a adoção de algumas práticas agrícolas, tais como: (i) correta identificação da espécie; (ii) conhecer a suscetibilidade da(s) espécie(s) aos inseticidas, para auxiliar na escolha do produto a ser aplicado; (iii) evitar a utilização de inseticidas de amplo espectro em estádios iniciais da soja, pois eles reduzem a população de inimigos naturais, contribuindo para surtos populacionais mais frequentes de tripes e outras espécies-praga; (iv) rotacionar modos de ação de inseticidas para evitar ou retardar a resistência; e (v) uso ou preservação de outros agentes de controle, como fungos entomopatogênicos e predadores. Em resumo, espera-se que os resultados deste estudo auxiliem os agricultores, consultores, agrônomos e técnicos na escolha mais assertiva do inseticida a ser usado para controle de tripes que infestam a soja e outras plantas cultivadas.

5 CONCLUSÕES

As espécies de tripes encontradas em soja no sul do Brasil durante a safra 2022/2023 foram *F. schultzei* e *C. phaseoli*, as quais apresentam variação geográfica e interespecífica na suscetibilidade a inseticidas.

Ambas as espécies foram suscetíveis a espinetoram, metomil, espinetoram + metoxifenozida e profenofos + cipermetrina.

Caliothrips phaseoli tem maior suscetibilidade a acefato, clorfenapir e abamectina do que *F. schultzei*, enquanto bifentrina + carbosulfano tem maior letalidade para *F. schultzei*.

Imidacloprido, lambda-cialotrina e lambda-cialotrina + sulfoxaflor tem baixa letalidade para *F. schultzei* e *C. phaseoli*.

REFERÊNCIAS

ADESANYA, Adekunle Wasiu. *et al*. Multiple insecticide resistance in onion thrips populations from Western USA. **Pesticide Biochemistry and Physiology**, San Diego, v. 165, p. 104553, may 2020. DOI: https://doi.org/10.1016/j.pestbp.2020.104553, Disponível em: https://www.sciencedirect.com/science/article/pii/S0048357520300481. Acesso em: 8 novembro 2023.

AHMED, Muhammad Hannan *et al*. Population dynamics of *Thrips tabaci* (Lindeman) in relation to abiotic climate factors on Bt and non-Bt cotton cultivars. **Pakistan Journal of Zoology**, Lahore, v. 49, n. 6, oct 2017. DOI: http://dx.doi.org/10.17582/journal.pjz/2017.49.6.1937.1943. Disponível em: http://researcherslinks.com/current-issues/Population-Dynamics-of-Thrips-tabaci/20/1/790/html. Acesso em: 8 novembro 2023.

ALMEIDA, Alvaro Manuel Rodrigues. Viroses da soja no Brasil: sintomas, etiologia e controle. EMBRAPA SOJA, Londrina, n. 306, 2008. Disponível em: https://www.infoteca.cnptia.embrapa.br/bitstream/doc/470937/1/Documentos306.pdf. Acesso em: 27 dezembro 2023.

ANDERSON, Nolan R. *et al*. Effect of soybean vein necrosis on yield and seed quality of soybean. **Canadian Journal of Plant Pathology**, Ontario, v. 39, n. 3, p. 334-341, aug 2017. DOI: https://doi.org/10.1080/07060661.2017.1354333. Disponível em: https://www.tandfonline.com/doi/full/10.1080/07060661.2017.1354333. Acesso em: 17 novembro 2023.

ATAKAN, Ekrem; PEHLIVAN, Serkan. Seasonal abundance of thrips species (Thysanoptera) and predatory bug, *Orius niger* (Wolff, 1811) (Hemiptera: Anthocoridae) on weeds in an okitsu mandarin grove. **Alinteri Journal of Agriculture Science**, Yakutiye, v. 36, n. 1, p. 90-98, feb 2021. DOI: 10.47059/alinteri/V36I1/AJAS21015. Disponível em: https://www.researchgate.net/profile/Serkan-Pehlivan-2/publication/349427163_Seasonal_Abundance_of_Thrips_Species_Thysanoptera_and_Predatory_Bug_Orius_niger_Wolff_1811_Hemiptera_Anthocoridae_on_Weeds_in_an_Okitsu_Mandarin_Grove/links/602f755492851c4ed5806619/Seasonal-Abundance-of-Thrips-Species-Thysanoptera-and-Predatory-Bug-Orius-niger-Wolff-1811-Hemiptera-Anthocoridae-on-Weeds-in-an-Okitsu-Mandarin-Grove.pdf. Acesso em: 8 novembro 2023.

BATUMAN, Ozgur *et al*. Development of an IPM strategy for thrips and *Tomato spotted wilt virus* in processing tomatoes in the central valley of California. **Pathogens**, Basel, v. 9, n. 8, p. 636, aug 2020. DOI: https://doi.org/10.3390/pathogens9080636. Disponível em: https://www.mdpi.com/2076-0817/9/8/636. Acesso em: 08 novembro 2023.

BILBO, Tom R.; KENNEDY, George G.; WALGENBACH, James F. Western flower thrips (*Frankliniella occidentalis*) field resistance to spinetoram in North Carolina. **Crop Protection**, Guildford, v. 165, p. 106168, mar 2023. DOI: https://doi.org/10.1016/j.cropro.2022.106168. Disponível em: https://www.sciencedirect.com/science/article/pii/S0261219422002642. Acesso em: 8 novembro 2023.

CAVALLERI, Adriano; MOUND, Laurence Alfred. Toward the identification of *Frankliniella* species in Brazil (Thysanoptera, Thripidae). **Zootaxa**, Auckland, v. 3270, n. 1, p. 1–30, apr 2012. DOI: https://doi.org/10.11646/zootaxa.3270.1.1. Disponível em: https://www.biotaxa.org/Zootaxa/article/view/zootaxa.3270.1.1. Acesso em: 08 novembro 2023.

CHILDERS, Carl C. *et al*. Feeding and oviposition injuries to plants. **Thrips as crop pests**., CAB International, Wallingford, p. 505-537, 1997. Disponível em: https://www.cabdirect.org/cabdirect/abstract/19981100130. Acesso em 08 novembro 2023.

CHISHOLM, Ian F.; LEWIS, Trevor A New look at thrips (Thysanoptera) mouthparts, their action and effects of feeding on plant tissue. **Bulletin of Entomological Research**, London, v. 74, n. 4, p. 549- 724, dec 1984. DOI: https://doi.org/10.1017/S0007485300014048. Disponível em: https://www.cambridge.org/core/journals/bulletin-of-entomological-research/article/abs/new-look-at-thrips-thysanoptera-mouthparts-their-action-and-effects-of-feeding-on-plant-tissue/6CE48C54F9A79DDBD2BB4F63A6780601. Acesso em: 08 novembro 2023.

CHITTURI, Anitha *et al*. Monitoring seasonal distribution of thrips vectors of *soybean vein necrosis virus* in Alabama soybeans. **Journal of Economic Entomology**, Annapolis, v. 111, n. 6, p. 2562- 2569, dec 2018. DOI: https://doi.org/10.1093/jee/toy237. Disponível em: https://academic.oup.com/jee/article/111/6/2562/5075551. Acesso em: 08 novembro 2023.

COOK, Don *et al*. Biology, crop injury, and management of thrips (Thysanoptera: Thripidae) infesting cotton seedlings in the United States. **Journal of Integrated Pest Management**, Annapolis, v. 2, n. 2, p. B1-B9, oct 2011. DOI: https://doi.org/10.1603/IPM10024. Disponível em: https://academic.oup.com/jipm/article/2/2/B1/860751?login=true. Acesso em: 08 novembro 2023.

DAĞLI, Fatih; TUNÇ, İrfan. Insecticide resistance in *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) collected from horticulture and cotton in Turkey. **Australian journal of entomology**, Brisbane, v. 46, n. 4, p. 320-324, oct 2007. DOI: https://doi.org/10.1111/j.1440-6055.2007.00593.x. Disponível em: https://onlinelibrary.wiley.com/doi/full/10.1111/j.1440-6055.2007.00593.x. Acesso em: 08 novembro 2023.

DE BREUIL, Soledad *et al*. Exploring species composition and population dynamics of thrips (Thysanoptera: Thripidae) in peanut crops in Argentina. **Phytoparasitica**, Bet Dagan, v. 49, n. 5, p. 785-792, apr 2021. DOI: https://doi.org/10.1007/s12600-021-00913-z. Disponível em: https://link.springer.com/article/10.1007/s12600-021-00913-z#citeas. Acesso em: 08 novembro 2023.

DE JENSEN, Consuelo Estévez *et al*. First report of *tomato chlorotic spot virus* in soybean (*Glycine max*). **Plant Disease**, St. Paul v. 103, n. 10, p. 2701, aug 2019. DOI: https://doi.org/10.1094/PDIS-05-19-0979-PDN. Disponível em: https://apsjournals.apsnet.org/doi/full/10.1094/PDIS-05-19-0979-PDN. Acesso em: 08 novembro 2023.

DE MARCHI, Bruno Rossitto *et al*. Characterization and complete genome sequence of *groundnut ringspot orthotospovirus* in soybean in Brazil. **Journal of Plant Pathology**, Piacenza, v. 101, p. 401, may 2019. DOI: https://doi.org/10.1007/s42161-018-0172-1. Disponível em: https://link.springer.com/article/10.1007/s42161-018-0172-1. Acesso em: 27 dezembro 2023.

DE SOUZA, Suyanne Araújo. **Suscetibilidade de populações de tripes a inseticidas e efeito da utilização de espinosina, piretroide e sulfoxamina em *Caliothrips phaseoli* (Hood)(Thysanoptera: Thripidae) na cultura da soja**. 2021. Dissertação (Mestrado em Agronomia) – Universidade Estadual Paulista, Botucatu, SP, 2021. Disponível em: https://bdtd.ibict.br/vufind/Record/UNSP_cadcc7b10fff39dafad8f3740c60dd18. Acesso em: 17 novembro 2023.

DING, Jinfeng *et al*. Thiamethoxam, clothianidin, and imidacloprid seed treatments effectively control thrips on corn under field conditions. **Journal of Insect Science**, Annapolis, v. 18, n. 6, p. 19, dec 2018. DOI: https://doi.org/10.1093/jisesa/iey128. Disponível em: https://academic.oup.com/jinsectscience/article/18/6/19/5253388?login=true. Acesso em: 08 novembro 2023.

DOS SANTOS, Juliana L. *et al*. Assessing the temporal dynamics of *Frankliniella schultzei* (Thysanoptera: Thripidae) in commercial soybean crops in North Brazil. **Agricultural and Forest Entomology**, St Albans, v. 24, n. 1, p. 97-103, feb 2022. DOI: https://doi.org/10.1111/afe.12471. Disponível em: https://resjournals.onlinelibrary.wiley.com/doi/full/10.1111/afe.12471. Acesso em: 08 novembro 2023.

DOS SANTOS, Renata Cordeiro *et al*. Conventional sampling plan for thrips in tropical soybean fields. **Crop Protection**, Guildford. 148, p. 105740, oct 2021. DOI:

https://doi.org/10.1016/j.cropro.2021.105740. Disponível em: https://www.sciencedirect.com/science/article/pii/S0261219421002106. Acesso em: 09 novembro 2023.

EL-WAHAB, Abeer Salah El-deen Abd. Molecular characterization and incidence of new tospovirus: *Soybean Vein Necrosis Virus* (SVNV) in Egypt. **Brazilian Journal of Biology**, São Carlos, v. 84, dec 2021. DOI: https://doi.org/10.1590/1519-6984.246460. Disponível em: https://www.scielo.br/j/bjb/a/zg3K9y3JCHRpyTy4r3CdH8H/?lang=en. Acesso em: 08 novembro 2023.

FAN, Rui *et al*. Insecticide susceptibility and detoxification enzyme activity of *Frankliniella occidentalis* under three habitat conditions. **Insects**, Basel, v. 14, n. 7, p. 643, jul 2023. DOI: https://doi.org/10.3390/insects14070643. Disponível em: https://www.mdpi.com/2075-4450/14/7/643. Acesso em: 08 novembro 2023.

FERNANDES, Flávio Lemes; FERNANDES, Maria Elisa de Sena. Flight movement and spatial distribution of immunomarked thrips in onion, potato, and tomato. **Pesquisa Agropecuária Brasileira**, Brasília v. 50, p. 399-406, may 2015. DOI: https://doi.org/10.1590/S0100-204X2015000500007. Disponível em: https://www.scielo.br/j/pab/a/cSSM44zGNxwYByW7v4Nqp6M/?lang=en. Acesso em: 08 novembro 2023.

FONTES, Maria Geane *et al*. First report of *groundnut ringspot orthotospovirus* infecting soybeans in Brazil. **Plant Disease**, St, Paul, v. 103, n. 4, p. 777, feb 2019. DOI: https://doi.org/10.1094/PDIS-07-18-1246-PDN. Disponível em: https://apsjournals.apsnet.org/doi/10.1094/PDIS-07-18-1246-PDN. Acesso em: 08 novembro 2023.

GAMUNDI, Juan Carlos *et al*. Evaluación del daño de trips *Caliothrips phaseoli* (Hood) en soja. **INTA EEA Oliveros**, Santa Fe, V. 30, p 71-76, set 2005. Disponível em: https://aws.agroconsultasonline.com.ar/ticket.html/Evaluaciondedanodetrips.pdf?op=d&ticket_id=9779&evento_id=20221. Acesso em: 08 novembro 2023.

GAO, Yong-Fu *et al*. Geographical and interspecific variation in susceptibility of three common thrips species to the insecticide, spinetoram. **Journal of Pest Science**, Heidelberg, v. 94, p. 93-99, jan 2021. DOI: https://doi.org/10.1007/s10340-019-01128-2. Disponível em: https://link.springer.com/article/10.1007/s10340-019-01128-2. Acesso em: 08 novembro 2023.

GAO, Yu *et al*. Effect of temperature on the development and reproduction of *Thrips flavus* (Thysanoptera: Thripidae). **Agricultural and Forest Entomology**, St. Albans, v. 24, n. 3, p. 279-288, aug 2022. DOI: https://doi.org/10.1111/afe.12491. Disponível em: https://resjournals.onlinelibrary.wiley.com/doi/full/10.1111/afe.12491. Acesso em: 08 novembro 2023.

GERARDO, Ulises Abel *et al*. Eficacia de control de insecticidas sobre *Caliothrips phaseoli* en soja para la región centro-sur de Córdoba. **Ab Intus**, Córdoba, v. 7, p. 10-18, ago 2021. Disponível em: https://ri.conicet.gov.ar/handle/11336/151687. Acesso em: 08 novembro 2023.

GHIDIU, Gerard M.; HITCHNER, Erin Marie; FUNDERBURK, Joseph. E. Goldfleck damage to tomato fruit caused by feeding of *Frankliniella occidentalis* (Thysanoptera: Thripidae). **Florida Entomologist**, Gainesville, v. 89, n. 2, p. 279-281, jun 2006. DOI: https://doi.org/10.1653/0015-4040(2006)89[279:GDTTFC]2.0.CO;2. Disponível em: https://bioone.org/journals/florida-entomologist/volume-89/issue-2/0015-4040(2006)89[279:GDTTFC]2.0.CO;2/GOLDFLECK-DAMAGE-TO-TOMATO-FRUIT-CAUSED-BY-FEEDING-OF-FRANKLINIELLA/10.1653/0015-4040(2006)89[279:GDTTFC]2.0.CO;2.full. Acesso em: 08 novembro 2023.

GONÇALVES, Paulo Antonio de souza *et al*. Modelo para a previsão da incidência de tripes em cebola pelo clima. **Revista da Universidade Vale do Rio Verde**, Betim, v. 17, n. 2, dez 2019. DOI: http://dx.doi.org/10.5892/ruvrd.v17i2.4574. Disponível em: http://periodicos.unincor.br/index.php/revistaunincor/article/view/4574. Acesso em: 08 novembro 2023.

GREENBERG, Shoil Moishe; LIU, Tong-Xian; ADAMCZYK, John Joseph. Thrips (Thysanoptera: Thripidae) on cotton in the lower Rio Grande Valley of Texas: species composition, seasonal abundance, damage, and control. **Southwestern Entomologist**, Dallas, v. 34, n. 4, p. 417-430, dec 2009. DOI: https://doi.org/10.3958/059.034.0406. Disponível em: https://bioone.org/journals/southwestern-entomologist/volume-34/issue-4/059.034.0406/Thrips-Thysanoptera--Thripidae-on-Cotton-in-the-Lower-Rio/10.3958/059.034.0406.full. Acesso em: 08 novembro 2023.

HEALEY, Madaline A. *et al*. Relative abundance and temporal distribution of adult *Frankliniella occidentalis* (Pergande) and *Frankliniella schultzei* (Trybom) on French bean, lettuce, tomato and zucchini crops in relation to crop age. **Journal of Asia-Pacific Entomology**, Seongbuk-gu, v. 20, n. 3, p. 859-865, sep 2017. DOI: https://doi.org/10.1016/j.aspen.2017.05.008. Disponível em: https://www.sciencedirect.com/science/article/pii/S1226861516303880. Acesso em: 08 novembro 2023.

HOULE, Jessica Lee; KENNEDY, George G. *Tomato spotted wilt virus* can infect resistant tomato when western flower thrips inoculate blossoms. **Plant Disease**, St. Paul, v. 101, n. 9, p. 1666-1670, sep 2017. DOI: https://doi.org/10.1094/PDIS-12-16-1716-RE. Disponível em: https://apsjournals.apsnet.org/doi/full/10.1094/PDIS-12-16-1716-RE. Acesso em: 08 novembro 2023.

HUSETH, Anders Schmidt. *et al*. *Frankliniella fusca* resistance to neonicotinoid insecticides: an emerging challenge for cotton pest management in the eastern United States. **Pest Management Science**, Sussex, v. 72, n. 10, p. 1934-1945, oct 2016. DOI: https://doi.org/10.1002/ps.4232. Disponível em: https://onlinelibrary.wiley.com/doi/full/10.1002/ps.4232. Acesso em: 08 novembro 2023.

JAGTAP, Gajendra Pandurang.; JADHAV, Tanmay; UTPAL, Dey. Host range and transmission of *Tobacco streak virus* (TSV) causing cotton mosaic. **Scientific Journal of Veterinary Advances**, Tehran, v. 1, n. 1, p. 22-27, jul 2012. Disponível em: https://www.researchgate.net/profile/Gp-Jagtap/publication/268060853_Host_range_and_transmission_of_Tobacco_streak_virus_TSV_causing_cotton_mosaic_disease/links/5541ebc70cf2b790436bec1b/Host-range-and-transmission-of-Tobacco-streak-virus-TSV-causing-cotton-mosaic-disease.pdf. Acesso em: 08 novembro 2023.

KILASO, Manlika. Toxicity for control of *Frankliniella schultzei* and *Selenothrips rubrocinctus* (Thysanoptera: Thripidae) of several common synthetic insecticides. **Florida Entomologist**, Gainesville, v. 105, n. 2, p. 155-159, jun 2022. DOI: https://doi.org/10.1653/024.105.0208. Disponível em: https://bioone.org/journals/florida-entomologist/volume-105/issue-2/024.105.0208/Toxicity-for-Control-of-Frankliniella-schultzei-and-Selenothrips-rubrocinctus-Thysanoptera/10.1653/024.105.0208.full. Acesso em: 08 novembro 2023.

KIRK, William D. J. Pollen-feeding and the host specificity and fecundity of flower thrips (Thysanoptera). **Ecological Entomology**, London, v. 10, n. 3, p. 281-289, aug 1985. DOI: https://doi.org/10.1111/j.1365-2311.1985.tb00725.x. Disponível em: https://resjournals.onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2311.1985.tb00725.x. Acesso em: 08 novembro 2023.

LEBEDEV, Galina *et al*. High-level of resistance to spinosad, emamectin benzoate and carbosulfan in populations of *Thrips tabaci* collected in Israel. **Pest Management Science**, Sussex, v. 69, n. 2, p. 274- 277, feb 2013. DOI: https://doi.org/10.1002/ps.3385. Disponível em: https://onlinelibrary.wiley.com/doi/full/10.1002/ps.3385. Acesso em: 08 novembro 2023.

LI, Xianchun; SCHULER, Mary A.; BERENBAUM, May Roberta. Molecular mechanisms of metabolic resistance to synthetic and natural xenobiotics. **Annual Review of Entomology**, Stanford, v. 52, p. 231-253, jan 2007. DOI: https://doi.org/10.1146/annurev.ento.51.110104.151104. Disponível em: https://www.annualreviews.org/doi/abs/10.1146/annurev.ento.51.110104.151104. Acesso em: 08 novembro 2023.

LIMA, Élison Fabrício Bezerra; O'DONNELL, Cheryle Ann; MIYASATO, Elisa Aiko. The Panchaetothripinae (Thysanoptera, Thripidae) of Brazil, with one new *Caliothrips* species. **Zootaxa**, Auckland, v. 4820, n. 2, p. 1, jul 2020. DOI: https://doi.org/10.11646/zootaxa.4820.2.1. Disponível em: https://europepmc.org/article/med/33056065. Acesso em: 08 novembro 2023.

MOTA-SANCHEZ, David; WISE, John C. The Arthropod Pesticide Resistance Database; **Michigan State University**: East Lansing, nov 2023; Diponível em: https://www.pesticideresistance.org/search.php. Acesso em: 14 novembro 2023.

MOUND, Laurence Alfred. *et al*. Problems with the concept of “pest” among the diversity of pestiferous thrips. **Insects**, Basel, v. 13, n. 1, p. 61, jan 2022. DOI: https://doi.org/10.3390/insects13010061. Disponível em: https://www.mdpi.com/2075-4450/13/1/61. Acesso em: 09 novembro 2023.

MUNAIZ, Eduardo D.; GROVES, Russell Leon; HAVEY, Michael J. Amounts and types of epicuticular leaf waxes among onion accessions selected for reduced damage by onion thrips. **Journal of the American Society for Horticultural Science**, Alexandria, v. 145, n. 1, p. 30-35, jan 2020. DOI: https://doi.org/10.21273/JASHS04773-19. Disponível em: https://journals.ashs.org/jashs/view/journals/jashs/145/1/article-p30.xml. Acesso em 09 novembro 2023.

NAZEMI, Abolfazl.; KHAJEHALI, Jahangir.; LEEUWEN, Thomas Van. Incidence and characterization of resistance to pyrethroid and organophosphorus insecticides in *Thrips tabaci* (Thysanoptera: Thripidae) in onion fields in Isfahan, Iran. **Pesticide Biochemistry and Physiology**, San Diego, v. 129, n. 1, p. 28-35, may 2016. DOI: https://doi.org/10.1016/j.pestbp.2015.10.013. Disponível em: https://www.sciencedirect.com/science/article/pii/S0048357515300523. Acesso em: 09 novembro 2023.

NEVES, Daniel Victor Chaves *et al*. Economic injury levels for control decision-making of thrips in soybean crops (*Glycine max* (L.) Merrill). **Research, Society and Development**, São Paulo, v. 11, n. 9, p. e52411932114-e52411932114, jul 2022. DOI: https://doi.org/10.33448/rsd-v11i9.32114. Disponível em: https://rsdjournal.org/index.php/rsd/article/view/32114. Acesso em: 09 novembro 2023.

PERINI, Clerison Regis *et al*. Ocorrência e manejo de pragas em soja Bt e não Bt no sul da América do Sul. **Revista Plantio Direto**, Passo Fundo, v. 175, p. 21-31, jun 2020. Disponível em: https://www.plantiodireto.com.br/artigos/59. Acesso em: 09 novembro 2023.

PINENT, Silvia Marisa Jesien; CARVALHO, Gervásio Silva. Biologia de *Frankliniella schultzei* (Trybom)(Thysanoptera: Thripidae) em tomateiro. **Anais da Sociedade Entomológica do Brasil**, Londrina, v. 27, p. 519-524, dez 1998. DOI: https://doi.org/10.1590/S0301-80591998000400003. Disponível em: https://www.scielo.br/j/aseb/a/fCVBGY7YwW6Q3P4WLkkBYCG/?lang=pt. Acesso em: 09 novembro 2023.

REGAN, Karly *et al*. Effects of a pyrethroid and two neonicotinoid insecticides on population dynamics of key pests of soybean and abundance of their natural enemies. **Crop Protection**, Guildford, v. 98, p. 24-32, aug 2017. DOI: https://doi.org/10.1016/j.cropro.2017.03.004. Disponível em: https://www.sciencedirect.com/science/article/pii/S0261219417300601. Acesso em: 09 novembro 2023.

REITZ, Stuart Roy. Biology and ecology of the western flower thrips (Thysanoptera: Thripidae): the making of a pest. **Florida Entomologist**, Gainesville, v. 92, n. 1, p. 7-13, mar 2009. DOI: https://doi.org/10.1653/024.092.0102. Disponível em: https://bioone.org/journals/florida-entomologist/volume-92/issue-1/024.092.0102/Biology-and-Ecology-of-the-Western-Flower-Thrips-Thysanoptera/10.1653/024.092.0102.full. Acesso em: 09 novembro 2023.

REITZ, Stuart Roy. Comparative bionomics of *Frankliniella occidentalis* and *Frankliniella tritici*. **Florida Entomologist**, Gainesville, v. 91, n. 3, p. 474-476, sep 2008. DOI: https://doi.org/10.1653/0015-4040(2008)91[474:CBOFOA]2.0.CO;2. Disponível em: https://bioone.org/journals/florida-entomologist/volume-91/issue-3/0015-4040_2008_91_474_CBOFOA_2.0.CO_2/Comparative-Bionomics-of-Frankliniella-occidentalis-and-Frankliniella-tritici/10.1653/0015-4040(2008)91[474:CBOFOA]2.0.CO;2.full. Acesso em: 09 novembro 2023.

REITZ, Stuart Roy; GAO, Yu-lin; LEI, Zhong-ren. Thrips: pests of concern to China and the United States. **Agricultural Sciences in China**, Beijing, v. 10, n. 6, p. 867-892, jun 2011. DOI: https://doi.org/10.1016/S1671-2927(11)60073-4. Disponível em:

https://www.sciencedirect.com/science/article/pii/S1671292711600734. Acesso em: 09 novembro 2023.

RILEY, David G. *et al*. Thrips vectors of tospoviruses. **Journal of Integrated Pest Management**, Minneapolis, v. 2, n. 1, p. 1-10, apr 2011. DOI: https://doi.org/10.1603/IPM10020. Disponível em: https://academic.oup.com/jipm/article/2/1/I1/2194119?login=false. Acesso em: 27 dezembro 2023.

SALGUERO NAVAS, Victor Eberto *et al*. Damage to tomato fruit by the western flower thrips (Thysanoptera: Thripidae). **Journal of Entomological Science**, Tifton, v. 26, n. 4, p. 436-442, oct 1991. DOI: https://doi.org/10.18474/0749-8004-26.4.436. Disponível em: https://meridian.allenpress.com/jes/article/26/4/436/75046/Damage-to-Tomato-Fruit-by-The-Western-Flower. Acesso em: 09 novembro 2023.

SHELTON, Anthony M. *et al*. Patterns of insecticide resistance in onion thrips (Thysanoptera: Thripidae) in onion fields in New York. **Journal of Economic Entomology**, Annapolis, v. 99, n. 5, p. 1798-1804, oct 2006. DOI: https://doi.org/10.1093/jee/99.5.1798. Disponível em: https://academic.oup.com/jee/article-abstract/99/5/1798/2218653?login=true. Acesso em: 09 novembro 2023.

SHELTON, Anthony M. *et al*. Regional and temporal variation in susceptibility to λ-cyhalothrin in onion thrips, *Thrips tabaci* (Thysanoptera: Thripidae), in onion fields in New York. **Journal of Economic Entomology**, Annapolis, v. 96, n. 6, p. 1843-1848, dec 2003. DOI: https://doi.org/10.1093/jee/96.6.1843. Disponível em: https://academic.oup.com/jee/article-abstract/96/6/1843/2217908?login=true. Acesso em: 09 novembro 2023.

SHEN, Xiu-Jing *et al*. Interspecific and intraspecific variation in susceptibility of two co-occurring pest thrips, *Frankliniella occidentalis* and *Thrips palmi*, to nine insecticides. **Pest Management Science**, Sussex, v. 79, n. 9, p. 3218-3226, sep 2023. DOI: https://doi.org/10.1002/ps.7502. Disponível em: https://onlinelibrary.wiley.com/doi/full/10.1002/ps.7502. Acesso em: 09 novembro 2023.

SIKORA, Edward Joseph; CONNER, Kassie Nicole; JACOBSON, Alana Lynn. Incidence of *Soybean vein necrosis virus* in Alabama soybean fields. **Plant Health Progress**, St. Paul, v. 19, n. 1, p. 76-81, mar 2018. DOI: https://doi.org/10.1094/PHP-10-17-0061-RS. Disponível em: https://apsjournals.apsnet.org/doi/full/10.1094/PHP-10-17-0061-RS. Acesso em: 09 novembro 2023.

SISTEMAS DE AGROTÓXICOS FITOSSANITÁRIOS (AGROFIT). **Relatório De Pragas E Doenças,** 2023. Disponível em: https://agrofit.agricultura.gov.br/agrofit_cons/principal_agrofit_cons. Acesso em: 10 novembro 2023.

SOSA, Mirta Raquel; ZAMAR, María Inés; TORREJON, Silvia Elena. Ciclo de vida y reproducción de *Caliothrips phaseoli* (Thysanoptera: Thripidae) sobre *fabaceae* y *solanaceae* (Plantae) en condiciones de laboratorio. **Revista de la Sociedad Entomológica Argentina**, Buenos Aires, v. 76, n. 3-4, p. 1-6, dez 2017. DOI: https://doi.org/10.25085/rsea.763401.

Disponível em: http://www.scielo.org.ar/scielo.php?pid=S0373-56802017000200002&script=sci_abstract&tlng=en. Acesso em: 09 novembro 2023.

TOGOLA, Abou *et al*. Evaluation of cowpea mini core accessions for resistance to flower bud thrips *Megalurothrips sjostedti* Trybom (Thysanoptera: Thripidae). **Journal of Applied Entomology**, Berlin, v. 143, n. 6, p. 683-692, jul 2019. DOI: https://doi.org/10.1111/jen.12637. Disponível em: https://onlinelibrary.wiley.com/doi/full/10.1111/jen.12637. Acesso em: 09 novembro 2023.

ULLAH, Farman *et al*. Population dynamics and chemical control of onion thrips (*Thrips tabaci*, Lindemann). **Pakistan Journal of Zoology**, Lahore, v. 42, n. 4, 2010. Disponível em: https://www.researchgate.net/profile/Farman-Ullah-14/publication/267844741_Population_Dynamics_and_Chemical_Control_of_Onion_Thrips_Thrips_tabaci_Lindemann/links/54dda15c0cf28a3d93f9db4a/Population-Dynamics-and-Chemical-Control-of-Onion-Thrips-Thrips-tabaci-Lindemann.pdf. Acesso em: 09 novembro 2023.

WAKIL, Waqas *et al*. Development of insecticide resistance in field populations of onion thrips, *Thrips tabaci* (Thysanoptera: Thripidae). **Insects**, Basel, v. 14, n. 4, p. 376, apr 2023. DOI: https://doi.org/10.3390/insects14040376. Disponível em: https://www.mdpi.com/2075-4450/14/4/376. Acesso em: 09 novembro 2023.

WANG, Ze-Hua *et al*. Field-evolved resistance to insecticides in the invasive western flower thrips *Frankliniella occidentalis* (Pergande)(Thysanoptera: Thripidae) in China. **Pest Management Science**, Sussex, v. 72, n. 7, p. 1440-1444, jul 2016. DOI: https://doi.org/10.1002/ps.4200. Disponível em: https://onlinelibrary.wiley.com/doi/full/10.1002/ps.4200. Acesso em: 09 novembro 2023.

ZAINAB, Shafia *et al*. Study of population dynamics and impact of abiotic factors on thrips, *Scirtothrips dorsalis* of chilli, *Capsicum annuum* and comparative bio-efficacy of few novel pesticides against it. **International Journal of Agriculture, Environment and Biotechnology**, New Delhi, v. 9, n. 3, p. 451, jun 2016. DOI: 10.5958/2230-732X.2016.00058.9. Disponível em: https://www.researchgate.net/profile/Sandeep-Kumar-Sathua/publication/304714393_Study_of_population_dynamics_and_impact_of_abiotic_factors_on_thrips_Scirtothrips_dorsalis_of_chilli_Capsicum_annuum_and_comparative_bio-efficacy_of_few_novel_pesticides_against_it/links/577cd0c908aec3b74337b4ce/Study-of-population-dynamics-and-impact-of-abiotic-factors-on-thrips-Scirtothrips-dorsalis-of-chilli-Capsicum-annuum-and-comparative-bio-efficacy-of-few-novel-pesticides-against-it.pdf?_sg%5B0%5D=started_experiment_milestone&origin=journalDetail&_rtd=e30%3D. Acesso em: 09 novembro 2023.

ZHANG, Kun *et al*. Susceptibility levels of field populations of *Frankliniella occidentalis* (Thysanoptera: Thripidae) to seven insecticides in China. **Crop Protection**, Guildford, v. 153, p. 105886, mar 2022. DOI: https://doi.org/10.1016/j.cropro.2021.105886. Disponível em: https://www.sciencedirect.com/science/article/pii/S0261219421003562. Acesso em: 09 novembro 2023.