Topics in Agricultural Entomology XIII

Joacir do Nascimento | Claudiane Martins da Rocha
Daniel Dalvan do Nascimento | Edimar Peterlini
Érica Ayumi Taguti | Joao Rafael Silva Soares
Matheus Cardoso de Castro | Sandy Sousa Fonsêca
Vinicius Ferraz Nascimento| Ricardo Antonio Polanczyk
(organizadores)

Atena Editora
Ano 2022

Topics in

Agricultural Entomology XIII

Joacir do Nascimento | Claudiane Martins da Rocha
Daniel Dalvan do Nascimento | Edimar Peterlini
Érica Ayumi Taguti | Joao Rafael Silva Soares
Matheus Cardoso de Castro | Sandy Sousa Fonsêca
Vinicius Ferraz Nascimento | Ricardo Antonio Polanczyk
(organizadores)

Atena Editora
Ano 2022

Editora chefe
Profª Drª Antonella Carvalho de Oliveira
Editora executiva
Natalia Oliveira
Assistente editorial
Flávia Roberta Barão
Bibliotecária
Janaina Ramos
Projeto gráfico
Bruno Oliveira
Camila Alves de Cremo
Daphynny Pamplona
Luiza Alves Batista
Natália Sandrini de Azevedo
Imagens da capa
iStock
Edição de arte
Luiza Alves Batista

Topics in agricultural entomology - XIII

Diagramação: Natália Sandrini de Azevedo
Correção: Yaiddy Paola Martinez
Indexação: Amanda Kelly da Costa Veiga
Revisão: Os autores

Dados Internacionais de Catalogação na Publicação (CIP)

T674 Topics in agricultural entomology - XIII / Joacir do Nascimento, Claudiane Martins da Rocha, Daniel Dalvan do Nascimento, et al. – Ponta Grossa - PR: Atena, 2022.

Outros organizadores
Edimar Peterlini
Érica Ayumi Taguti
João Rafael Silva Soares
Matheus Cardoso de Castro
Sandy Sousa Fonsêca
Vinicius Ferraz Nascimento
Ricardo Antonio Polanczyk

Formato: PDF
Requisitos de sistema: Adobe Acrobat Reader
Modo de acesso: World Wide Web
Inclui bibliografia
ISBN 978-65-258-0544-3
DOI: https://doi.org/10.22533/at.ed.443220109

1. Agricultura. I. Nascimento, Joacir do (Organizador). II. Rocha, Claudiane Martins da (Organizadora). III. Nascimento, Daniel Dalvan do (Organizador). IV. Título.

CDD 338.1

Elaborado por Bibliotecária Janaina Ramos – CRB-8/9166

Atena Editora
Ponta Grossa – Paraná – Brasil
Telefone: +55 (42) 3323-5493
www.atenaeditora.com.br
contato@atenaeditora.com.br

CIÊNCIAS AGRÁRIAS

Atena Editora
Ano 2022

DECLARAÇÃO DOS AUTORES

Os autores desta obra: 1. Atestam não possuir qualquer interesse comercial que constitua um conflito de interesses em relação ao artigo científico publicado; 2. Declaram que participaram ativamente da construção dos respectivos manuscritos, preferencialmente na: a) Concepção do estudo, e/ou aquisição de dados, e/ou análise e interpretação de dados; b) Elaboração do artigo ou revisão com vistas a tornar o material intelectualmente relevante; c) Aprovação final do manuscrito para submissão; 3. Certificam que os artigos científicos publicados estão completamente isentos de dados e/ou resultados fraudulentos; 4. Confirmam a citação e a referência correta de todos os dados e de interpretações de dados de outras pesquisas; 5. Reconhecem terem informado todas as fontes de financiamento recebidas para a consecução da pesquisa; 6. Autorizam a edição da obra, que incluem os registros de ficha catalográfica, ISBN, DOI e demais indexadores, projeto visual e criação de capa, diagramação de miolo, assim como lançamento e divulgação da mesma conforme critérios da Atena Editora.

DECLARAÇÃO DA EDITORA

The authors are grateful to the São Paulo Research Foundation (FAPESP) for the grant 2022/04343-9

PREFACE

The Graduate Program in Agronomy (Agricultural Entomology) at the UNESP Faculty of Agricultural and Veterinary Sciences in Jaboticabal has always been characterized by its focus on Integrated Pest Management (IPM). Since its foundation, the program has graduated 287 students with a master's degree and 148 Ph.D. students. They are now active in various areas of the public or private sector and contribute to agriculture's economic and environmental sustainability.

This e-book entitled "Topics in Agricultural Entomology - XIII" was made possible through the immense effort of the Organizing Committee, formed by MSc and Ph.D. students from all research areas of our Graduate Program. In its 14 chapters, readers will find information on the most diverse areas of IPM, with a richness of information on both the fundamental and applied aspects of IPM.

As coordinator of the 2022 edition of the Winter Workshop on Agricultural Entomology, it is my pleasure to provide event attendees with an e-book of excellent content, demonstrating the importance of our research to society.

Prof. Ricardo Antônio Polanczyk

FCAV/UNESP

PPG Entomologia Agrícola Coordinator

SUMÁRIO

CAPÍTULO 7

RESISTANCE OF CITRUS PEST MITES TO ACARICIDES

Claudiane Martins da Rocha

Matheus Cardoso de Castro

Daniel Júnior de Andrade

1 | INTRODUCTION

Citrus growers primarily use chemical control to keep pest populations below the economic threshold. However, the inappropriate use of pesticides results in undesirable side effects, such as population outbreaks of secondary pests and the evolution of resistance in populations. The evolution of pest resistance to pesticides has been considered one of the highest threats to the implementation of integrated pest management (IPM) programs. The citrus crop is home to numerous arthropods, including several species of pest mites. Citrus mites are basically controlled worldwide with chemical acaricide applications (Van Leeuwen et al., 2010). However, the continuous use of the same active ingredient can increase the frequency of resistant individuals and compromise the efficiency of products (Omoto & Alves, 2004). Failures in the control of mites after acaricide applications are frequent in the Brazilian citriculture and have been reported for several decades. In this scenario, this chapter addresses the main cases of pest mite resistance in citrus to pesticides published in scientific journals.

2 | THE CITRUS LEPROSIS MITE (*Brevipalpus* spp.)

Transmission of the Citrus leprosis virus (CiLV-C), which causes citrus leprosis, one of the most destructive diseases in citrus, was attributed exclusively to the mite *Brevipalpus phoenicis* (Acari: Tenuipalpidae) until 2015 (Beard et al., 2015; Tassi et al., 2017). An extensive taxonomic review allowed concluding that *B. phoenicis* was a species complex. New species have been described and other species have been recovered since then (Beard et al., 2015). Population surveys of *Brevipalpus* mites showed that *Brevipalpus yothersi* Baker (Acari: Tenuipalpidae) is the predominant species in commercial citrus crops in the State of São Paulo, Brazil, and not the species *B. phoenicis* (Mineiro et al., 2015).

Acaricide applications in orchards of the State of São Paulo and the Triângulo Mineiro region in the State of Minas Gerais, considered the Brazilian citrus belt, are the main method used to control the mite vector of leprosis virus (Miranda et al., 2017). However, the increase in the frequency of resistant individuals in mite populations has been common due to high selection pressure, resulting in decreased control efficiency. Reductions in the efficiency of acaricides lead to an increase in the number of applications, greater environmental contamination, and a reduction in natural enemies and beneficial insects (Omoto & Alves, 2004).

However, in addition to the high selection pressure, certain biological and ecological factors of *Brevipalpus* spp. have contributed to accelerating the evolution of resistance. For instance, the predominant form of reproduction is thelytokous parthenogenesis, in which unfertilized eggs give rise to females. Therefore, the offspring had the same genetic makeup as the parents (Helle et al., 1980). Another important factor is the low dispersion capacity of this mite compared to other mites, which makes it difficult to reduce the frequency of resistant individuals through mixing between populations (Alves et al., 2005).

The resistance of mites *Brevipalpus* spp. has been reported for some active ingredients, such as dicofol, hexythiazox, propargite, lime-sulfur solution, and spirodiclofen (Omoto et al., 2000; Campos & Omoto, 2002; Franco, 2002; Casarin, 2010; Rocha et al., 2021).

Extensive monitoring of populations of *B. phoenicis* from commercial orchards in the State of São Paulo was carried out for the acaricide dicofol. This study revealed variability in susceptibility to this acaricide at diagnostic concentrations of 100 and 320 mg dicofol/L water (Omoto et al., 2000). A 57-fold resistance ratio has been estimated in the dicofol-resistant strain (Omoto et al., 2000). In addition, positive cross-resistance between dicofol and bromopropylate, negative cross-resistance between dicofol and fenpyroximate, and no cross-resistance with fenbutatin oxide and propargite have been observed (Alves et al., 1999).

The frequency of resistance of *B. phoenicis* to the acaricides propargite and hexythiazox was also variable among populations. Survival percentages ranged from 0.0 to 88.3% for propargite and 30 to 94% for hexythiazox (Franco, 2002; Campos & Omoto, 2002). The high estimated resistance ratio for the hexythiazox-resistant strain was higher than 10,000 times (Campos & Omoto, 2002). On the other hand, a resistance ratio of 5.69 times was found for the lime-sulfur solution, and cross-resistance between lime-sulfur solution and sulfur was confirmed (Casarin, 2010).

More recently, the resistance of *B. yothersi* to the acaricide spirodiclofen was detected (Rocha et al., 2021). This study showed variability in the population responses to the diagnostic concentration of the acaricide, and a resistance ratio of 10.6 times was estimated for the resistant strain (Rocha et al., 2021).

3 I THE CITRUS RUST MITE *Phyllocoptruta oleivora*

Small in size, but capable of damaging citrus leaves and fruits, the citrus rust mite *Phyllocoptruta oleivora* (Acari: Eriophyidae) is considered a key pest in Brazilian citriculture. The presence of the citrus rust mite can be observed throughout the year, but the largest populations are observed in hot periods with high relative humidity.

Citrus rust mite control is carried out in Brazil with intensive applications of sulfur and abamectin, which contributed to the selection of resistant individuals (Omoto & Alves, 2004). Populations of *P. oleivora* resistant to the acaricides dicofol and abamectin have been detected in the United States (Florida) (Bergh et al., 1999, Omoto & Alves, 2004). However, research on the resistance of this mite to acaricides has not yet been carried out in Brazil.

4 I THE CITRUS RED MITE *Panonychus citri*

The mite *Panonychus citri* (Acari: Tetranychidae), popularly known as the citrus red mite, is considered in several parts of the world as one of the main species of pest mites in citrus. High levels of infestation can be observed in a short period due to its rapid development and reduced time between generations. In Brazil, the red mite occurs mainly in the dry periods of the year, especially in autumn-winter.

Panonychus citri causes damage to leaves, branches, and fruits although its infestations occur preferentially on leaves, which can lead to high leaf drop. The red mite is one of the most notorious pest mites for its ability to rapidly increase the frequency of acaricide-resistant individuals. It is due to their high reproductive aptitude associated with the selection pressure of numerous acaricide applications (Niu et al., 2011; Pan et al., 2020).

Studies on the resistance of *P. citri* to acaricides have been carried out in several countries, including China, Japan, New Zealand, Taiwan, Turkey, and the United States of America (Gotoh et al., 2004; Hu et al., 2010; Doker & Kazak 2012; Ouyang et al., 2012; Mota-Sanchez & Wise, 2019). Cases of *P. citri* resistance to organophosphates, pyrethroids, organochlorines, keto-enols, and bifenazate have been reported (Chen et al., 2009; Hu et al., 2010; Niu et al., 2011; Van Leeuwen et al., 2011).

There are no reports of resistance related to *P. citri* populations in Brazil. However, population levels of the red mite have increased considerably in recent years due to the intensification in the use of insecticides to control *Diaphorina citri* (Hemiptera: Liviidae) in citrus orchards in Brazil, requiring frequent spraying of acaricides for its control (Yamamoto & Zanardi, 2013; Ribeiro et al., 2014).

5 I RESISTANCE MANAGEMENT

Resistance is an evolutionary phenomenon that depends on complex interactions of three major groups of factors: genetic factors, biological factors, and operational factors. Operational factors are largely under human control, which provides a basis for resistance management (Georghiou & Taylor, 1986).

Among the operational factors, moderation and multiple attack are the most used strategies for resistance management in citrus from a practical point of view (Omoto et al., 2008). Management strategies by moderation seek to reduce selection pressure. It can be achieved by reducing the use of chemical acaricides. In this sense, adequate pest monitoring in the field is essential to guide applications (Omoto et al., 2008). The use of other control methods such as natural and biological products can also contribute to this regard. In the multiple attack management strategy, acaricides are used in rotation or as a mixture (Nauen et al., 2001; Omoto et al., 2008). However, attention should be paid to the use of different modes of action and the absence of cross-resistance between products.

Furthermore, the adaptive disadvantage of resistant individuals compared to susceptible individuals in the absence of selection pressure may contribute to resistance management programs. This fitness cost may delay the increase in the number of resistant individuals in the population and contribute to the return of the susceptibility condition (Roush & McKenzie, 1987; Alves, 2004; Kliot & Ghanim, 2012).

The citrus leprosis mite showed an fitness cost for the acaricide dicofol, with lower fecundity and lower longevity of individuals of the resistant strain (Alves, 1999). A reduction in adult longevity, days of oviposition, and fecundity in the resistant strain was observed for spirodiclofen (Rocha et al., 2021). On the other hand, resistance to hexythiazox was stable under laboratory conditions, but unstable under field conditions (Campos & Omoto, 2006). No fitness cost associated with resistance was observed for propargite and lime-sulfur solution (Franco et al., 2007; Casarin, 2010).

Research on monitoring the resistance of these mites to acaricides, as well as cross-resistance relationships and resistance stability are critical to the success of resistance management strategies. Currently, few products accepted in orange juice importing countries from Brazil are available in the market to control these mites (Fundecitrus, 2022). Therefore, mite control strategies must be implemented aiming at the preservation of existing acaricide products (Omoto et al., 2008). Thus, the adoption of resistance management strategies that aim to delay its evolution is fundamental to guarantee the efficiency and preserve the useful life of acaricides, as the research for the development of new products is long and expensive.

REFERENCES

Alves, E.B. **Manejo da resistência do ácaro da leprose *Brevipalpus phoenicis* (Geijskes, 1939) (Acari: Tenuipalpidae) ao acaricida dicofol**. 1999. 91p. Dissertação (Mestrado em Entomologia) – Esalq, Piracicaba.

Alves, E.B. **Dinâmica da resistência de *Brevipalpus phoenicis* (Geijskes, 1939) (Acari: Tenuipalpidae) ao acaricida dicofol**. 2004. 91p. Tese (Doutorado em Entomologia) – Esalq, Piracicaba.

Alves, E.B.; Casarin, N.F.B.; Omoto, C. Mecanismos de dispersão de *Brevipalpus phoenicis* (Geijskes) (Acari: Tenuipalpidae) em pomares de citros. **Neotropical Entomology**, v.34, p.89-96, 2005. 10.1590/S1519-566X2005000100013

Beard J.J. et al. *Brevipalpus phoenicis* (Geijskes) species complex (Acari: Tenuipalpidae) - a closer look. **Zootaxa** v.3944, p.1-67, 2015. 10.11646/zootaxa.3944.1.1

Bergh, J.C. et al. Monitoring the susceptibility of citrus rust mite (Acari: Eriophyidae) populations to abamectin. **Journal of Economic Entomology**, v. 92, n.4, p. 781-787, 1999. 10.1093/jee/92.4.781

Campos, F.; Omoto, C. Resistance to hexythiazox in *Brevipalpus phoenicis* (Acari: Tenuipalpidae) from Brazilian citrus. **Experimental and Applied Acarology**, v.26, p.243-251, 2002. 10.1023/A:1021103209193

Campos, F, J; Omoto, C. Estabilidade da resistência de *Brevipalpus phoenicis* (Geijskes) (Acari: Tenuipalpidae) a hexythiazox em pomares de citros. **Neotropical Entomology**, v.35, p.840-848, 2006. 10.1590/S1519-566X2006000600019

Casarin, N.F.B. **Calda sulfocálcica em pomares de citros: evolução da resistência de *Brevipalpus phoenicis* (Acari: Tenuipalpidae) e impacto sobre *Iphiseiodes zuluagai* (Acari: Phytoseiidae)**. 2010. 95f. Tese (Doutorado em Entomologia) - Esalq, Piracicaba.

Chen, Z.Y. et al. Susceptibility and esterase activity in citrus red mite *Panonychus citri* (McGregor) (Acari: Tetranychidae) after selection with phoxim. **International Journal of Acarolology**, v.35, p.33-40, 2009. 10.1080/01647950802655293

Doker, I.; Kazak, C. Detecting acaricide resistance in Turkish populations of *Panonychus citri* McGregor (Acari: Tetranychidae). **Systematic and Applied Acarology**, v.17, p.368–377, 2012. 10.11158/saa.17.4.4

Franco, C.R. **Detecção e caracterização da resistência de *Brevipalpus phoenicis* (Geijskes, 1939) (Acari: Tenuipalpidae) a acaricida propargite**. 2002. 78 p. Dissertação (Mestrado em Entomologia) - Esalq, Piracicaba.

Franco, C.R et al. Resistência de *Brevipalpus phoenicis* (Geijskes) (Acari: Tenuipalpidae) a acaricidas inibidores da respiração celular em citros: resistência cruzada e custo adaptativo. **Neotropical Entomology**, v.36, p.565-576, 2007. 10.1590/S1519-566X2007000400015

Fundecitrus (2020) Produtos para proteção da citricultura. Disponível em: <https://www.fundecitrus.com.br/protecitrus>. Acesso em: 20 abr. 2022.

Gotoh, T.; Kitashima, Y.; Adachi, I. Geographic variation of susceptibility to acaricides in two spider mite species, *Panonychus osmanthi* and *P. citri* (Acari: Tetranychidae) in Japan. **International Journal of Acarolology**, v.30, p.55-61, 2004. 10.1016/j.ibmb.2010.05.008

Helle, W.; Bolland, H.R.; Heitmans, W.R.B. Chromosomes and types of parthenogenesis in false spider mites (Acari: Tenuipalpidae). **Genetica**, v.54, p.45-50, 1980. 10.1007/BF00122407

Hu, J. et al. Monitoring of resistance to spirodiclofen and five other acaricides in *Panonychus citri* collected from Chinese citrus orchards. **Pest Management Science**, v.66, p.1025–1030, 2010. 10.1002/ps.1978

Kliot, A.; Ghanim, M. Fitness costs associated with insecticide resistance. **Pest Management Science**, v.68, p.1431-1437, 2012. 10.1002/ps.3395

Mineiro J.L.C. et al. Distribuição de *Brevipalpus yothersi* Baker, 1949 (Acari: Tenuipalpidae) em diferentes hospedeiras e localidades no Estado de São Paulo. In.: Reunião Anual Do Instituto Biológico. **Resumos...** São Paulo: O Biológico 77:84, 2015.

Miranda, M.P. et al. Manejo de insetos e ácaros vetores de fitopatógenos nos citros. **Informe Agropecuário**, v.38, p.1-25, 2017.

Mota-Sanchez, D.; Wise, J.C. **The Arthropod Pesticide Resistance Database.** 2019. Disponível em: <http://www.pesticideresistance.org>.

Nauen, R. et al. Acaricide toxicity and resistance in larvae of different strains of *Tetranychus urticae* and *Panonychus ulmi* (Acari: Tetranychidae). **Pest Management Science**, v.572, p.53-261, 2001. 10.1002/ps.280

Niu, J.Z. et al. Susceptibility and activity of glutathione s-transferases in nine feld populations of *Panonychus citri* (Acari: Tetranychidae) to pyridaben and azocyclotin. **Florida Entomology**, v.94, p.321-329, 2011. 10.1653/024.094.0227

Omoto, C.. et al. Detection and characterization of the interpopulation variation of citrus rust mite (Acari: Eriophyidae) Resistance to Dicofol in Florida Citrus. **Journal of Economic Entomology**, v.87, p.566-572, 1994. 10.1093/jee/87.3.566

Omoto, C.; Alves, E.B.; Ribeiro, P.C. Detecção e monitoramento da resistência de *Brevipalpus phoenicis* (Geijskes) (Acari: Tenuipalpidae) ao dicofol. **Anais da Sociedade Entomológica do Brasil**, v.29, p.757-764, 2000. 10.1590/S0301-80592000000400016

Omoto, C.; Alves, E. A resistência dos ácaros a acaricidas em citros. **Visão agrícola**, v.2, p.82-6, 2004.

Omoto, C. et al. Resistência de *Brevipalpus phoenicis* em pomares de citros do Estado de São Paulo. In: Yamamoto, PT (Org.). **Manejo integrado de pragas dos citros**. Piracicaba: CP 2, p.71-141, 2008.

Ouyang, Y. et al. Spirodiclofen and spirotetramat bioassays for monitoring resistance in citrus red mite, *Panonychus citri* (Acari: Tetranychidae). **Pest Management Science**, v.68, p.781-787, 2012. 10.1002/ps.2326

Pan, D. et al. Monitoring the resistance of the citrus red mite (Acari: Tetranychidae) to four acaricides in different citrus orchards in China. **Journal of Economic Entomology**, v.113, p.918-923, 2020. 10.1093/jee/toz335

Ribeiro, L.P. et al. Comparative toxicity of an acetogenin-based extract and commercial pesticides against citrus red mite. **Experimental and Applied Acarology**, v.64, n.1, p. 87-98, 2014. 10.1007/s10493-014-9810-2

Rocha, C.M. et al. Resistance to spirodiclofen in *Brevipalpus yothersi* (Acari: Tenuipalpidae) from Brazilian citrus groves: detection, monitoring and population performance. **Pest Management Science**, v. 77, p. 3099-3006, 2021. 10.1002/ps.6341

Roush, R.T.; Mckenzie, J.A. Ecological genetics of insecticide and acaricide resistance. **Annual Review of Entomology**, v.32, p.361-380, 1987. 10.1146/annurev.en.32.010187.002045

Tassi, A.D. et al. Virus-vector relationship in the citrus leprosis pathosystem. **Experimental and Applied Acarology**, v.71, p.227-241, 2017. 10.1007/s10493-017-0123-0

Van Leeuwen, T. et al. Parallel evolution of cytochrome b mediated bifenazate resistance in the citrus red mite *Panonychus citri*. **Insect Molecular Biology**, v.20, p.135-140, 2011. 10.1111/j.1365-2583.2010.01040.x

Yamamoto, P.T.; Zanardi, O.Z. Atualização de manejo do ácaro purpúreo *Panonyhcus citri*. **Revista Citricultura Anual**, Cordeirópolis, v.96, p.16-17, 2013.

Topics in Agricultural Entomology XIII

www.atenaeditora.com.br
contato@atenaeditora.com.br
@atenaeditora
www.facebook.com/atenaeditora.com.br

Atena Editora
Ano 2022

Topics in

Agricultural Entomology XIII

www.atenaeditora.com.br
contato@atenaeditora.com.br
@atenaeditora
www.facebook.com/atenaeditora.com.br

Atena Editora
Ano 2022