

## Pathogens Infecting Insects and Mites of Citrus

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Integrated pest management (IPM) programs cannot be developed and maintained without adequate knowledge of the biology and roles of both pest and beneficial species in a specific crop agroecosystem. This volume is a significant contribution to citrus IPM because it provides an overview of the pests of citrus and the various pathogens found attacking them, especially those in Florida. This book will be of value to citrus entomologists in other geographic areas because many of the pests and pathogens are cosmopolitan.

This volume contains many color photographs of insects and mites in a healthy state and also infected with entomopathogens so that the reader can diagnose the pests and the pathogens found on all aspects of citrus trees (from roots to shoots). The volume has a foreword that makes the point that citrus, although typically grown as a monoculture, provides a highly diverse and long-term environment that we are only beginning to understand. Next, the book provides an overview of the origins of citrus and citriculture and the importance of biological control in managing citrus pests. It notes that, until very recently, citrus pest management in Florida relied on a diverse array of natural enemies (parasitoids, predators, and pathogens) to suppress insect and mite pests. The recent invasion of Florida's citrus with the pathogen causing greening disease and the permanent establishment of another citrus pathogen, citrus canker, have altered that focus, hopefully temporarily. Currently pesticides are used extensively to control the vector of citrus greening (the Asian citrus psyllid). If alternatives to chemical pesticides are discovered that control this vector, it is hoped that we can return to a more ecologically based pest management program. Next, a chapter on the biology of insect mycopathogens provides key information for entomologists with limited training in invertebrate pathology. Following this chapter, the various pests and their pathogens are described in individual chapters, respectively, for armored scales, soft scales and mealybugs, whiteflies and citrus blackfly, aphids, citrus psyllids, true bugs and sharpshooters, Lepidoptera, termites and ants, citrus root weevils, fruit flies, citrus thrips, grasshoppers, eriophyoid mites, and, finally, tetranychid and tenuipalpid mites. The next 2 chapters deal with an overview of the commercial production of mycopathogens and entomopathogenic nematodes for control of citrus pests, and a final chapter provides a thoughtful and useful summary.

This volume provides key information needed to diagnose, study, and understand the role(s) these pathogens play in the citrus agroecosystem. In the future, it would be helpful if the authors

provided a small guide, suitable for field use, containing the many outstanding and useful color photographs showing insects and mites infected with pathogens. Such a small volume would be useful for researchers and others and enable them to recognize and identify pathogens in the field.

What is the bottom line? Do we know enough about entomopathogens in citrus agroecosystems, one of the most-well-studied in the world, to deploy them in IPM programs? The authors summarize (p. 172):

In summary, it would appear that microbial control is a feasible approach to the control of citrus rust mites and weevils. Inundative biological control tactics can replace chemicals in certain situations; however, there are important biological and ecological factors that need to be better understood before these tools can be used in IPM. Crop protection is achievable, but it is unclear if the additive effect is coming from the supplementation of mass-produced and -applied microbes or by way of natural control. Since the economic advantage of using microbial control is small, it may be better to exploit entomopathogens ecologically, for example, using habitat manipulation. This approach should work very well in a stable ecosystem like citrus.

I would add that this goal remains the ideal, but currently cannot be achieved because citrus greening disease threatens the industry so greatly. Limited management options currently exist, so synthetic organic pesticides are now used at unsustainable rates. Another factor, acknowledged by the authors (p. 175), is that in humid subtropical and tropical citrus-growing regions, plant-pathogenic fungi are pests and "fungicidal treatments, such as copper sprays, are required in the spring to combat the injury caused by them." They further state: "Since arthropod-pathogenic fungi can be suppressed by copper fungicides and other pesticides, IPM strategies that conserve fungal pathogens have been employed by using medium-grade petroleum oil."

The authors conclude (p. 176) with the following points:

Entomologists have realized that pathogens, particularly the mycopathogens, are influenced by a complex of variable abiotic and biotic factors and by various management tactics that may be disruptive to natural controls. Therefore, mycopathogens are not considered the solution to pest control,

but they can play a role in the implementation of citrus IPM. In order to optimize their role in IPM, research is needed on: 1) the interactive mechanisms that influence natural regulation of potential citrus pests. . . . 2) the mechanism(s) that limit host suppression by fungi at high host densities; 3) host/pathogen relationships and changes in arthropod pest abundance in established citrus IPM demonstration plots in citrus groves; and 4) non-disruptive fungicides and chemicals to determine the role of mycopathogens as natural controls.

This book is an excellent addition to the library of any entomologist who would like to know more about biological control, entomopathogens, citrus IPM, or citrus pests. The illustrations are excellent and there are very few production problems. I found some of the figure legends to be less informative than I would have liked (especially when dealing with technical

terms for structures of the entomopathogens) and the text on page 127 is difficult to read because it has black type on a dark grey background. If a future edition is provided (or the field guide is developed), it would be useful to add a size indicator on the photographs so the reader can more readily identify these organisms in the field. But these are minor quibbles; the book is a useful and unique contribution for researchers, and the book cover indicates that it is intended for "anyone with an interest in citrus entomology, including growers, home owners, master gardeners, private consultants, extension IPM specialists. . . ." Because it is a pictorial guide, many of the illustrations will be useful to this broader audience, as well.

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