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The chemical ecology, genetics and impact of the European earwig in apple and cherry orchards

by

Stephen Robert Quarrell

Tasmanian Institute of Agriculture/ School of Agricultural Science

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Declaration

I hereby declare that this thesis contains no material which has been accepted for a degree or diploma by the University of Tasmania or any other institution, except by way of background information and duly acknowledged in the thesis, and to the best of my knowledge and belief no material previously published or written by another person except where due acknowledgement is made in the text of the thesis, nor does the thesis contain any material that infringes copyright.

Stephen Quarrell

Abstract

This thesis investigates the Australian distribution, invasion biology and genetics of the European earwig, *Forficula auricularia*, its predation of woolly apple aphid (WAA) and intraguild compatibility with the parasitoid *Aphelinus mali* in apple orchards, the impact earwigs have upon sweet cherry production and the chemical ecology of *F. auricularia* with special reference to the isolation of its aggregation pheromone.

F. auricularia was found to be spread across all of southern Australia with records indicating it probably invaded Australia, in Tasmania, over 170 years ago. The mtDNA analysis of Australian and New Zealand *F. auricularia* populations indicated only one of the two known European earwig subspecies is found in these regions and that there are two differing clades of this subspecies within Australia but only one in Tasmania and New Zealand. Comparing these results to samples collected throughout Europe indicates that the genetic diversity of the mainland Australian population is only half that of Europe and the diversity in Tasmania and New Zealand is half that again. Possible European sources for only one of the two Australian clades were found. These results indicate that multiple invasion events are likely to have occurred on the Australian mainland, but this seems less probable within Tasmania or New Zealand.

The investigation into the intraguild compatibility of earwigs and *A. mali* in apple orchards was determined by weekly monitoring of arthropod communities (including WAA, earwigs, *A .mali*) within 5 orchards over two entire apple production seasons. Earwig trap catches were observed to rapidly decline after the imaginal moult at all sites and during both seasons. The thesis shows that trees which possess large earwig trap catches (> 22 earwigs/tree/week) within the first 7 weeks after blossom contain little to no WAA at the end of the season. Trees that contained fewer earwigs had larger WAA infestations unless the first generation of *A. mali* numbers exceeded 0.5 wasps per sticky trap per week. If these beneficial insect targets were not met, extreme WAA infestations occurred, despite other predators being observed feeding on WAA colonies.

Cherry fruit and cherry stem damage assessments were conducted on four commercial cherry varieties; Ron's Seedling, Lewis, Sweet Georgia and Lapin. Assessments of the spatial distribution of earwigs within cherry canopies and the cherry bunch characteristics including

bunch size and position, and the level of cherry fruit or cherry stem damage that may have ensued were determined. Significant differences in the type and frequency of earwig damage were observed between varieties with damage varying between 5-60%. Earwigs were found to be strongly aggregated within large cherry bunches. The greatest damage was observed within these large bunches in all varieties except Ron's Seedling where stem damage occurred irrelevant of bunch size. No predictive relationship between the level of cherry damage and earwig numbers in trunk traps at harvest or those found within the tree canopies at harvest could be found.

Chemical ecology experiments demonstrated earwigs were attracted to substrates pre-exposed to earwigs in both laboratory and field bioassays. The thesis newly identifies numerous headspace volatiles and cuticular hydrocarbons (HC) isolated from aggregating male, female and juvenile earwigs. Some promising synthetic blends consisting of unsaturated HCs demonstrated earwig attraction twice that of controls in the field. However, attraction to these blends was inconsistent across the earwig life cycle and field season. To investigate whether the observed decline in earwig trap catches and the inconsistent attraction to the synthetic pheromone blends was due to pheromone plasticity, sequential sampling of earwig populations while simultaneously sampling the cuticular HCs from the same field populations was undertaken. Results demonstrated that the production of cuticular HCs in *F. auricularia* decline soon after the imaginal moult and that this decline correlates with a decline in earwig trap catches. Although promising aggregating compounds have now been identified, further work, especially on the consistency of their bioactivity is needed.

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Preface

In this thesis, each experimental chapter (chapters 2 - 6) has been prepared in the form of a publishable manuscript with the references placed at the end of each chapter, which have been formatted for their target journal as indicated on the front page of each chapter. Tables and figures have been re-labelled to fit within each chapter. Due to this independence between chapters there maybe overlap or repetition within this thesis. This thesis has been divided into seven chapters. Chapter 1 is a general introduction that reviews European earwig phenology, its use as a biological control agent in apple orchards and its chemical ecology with a focus on previous attempts to isolate its aggregation pheromone. Chapter 2 investigates the current Australian distribution and genetic diversity of *F. auricularia* and attempts to identify the overseas source of its accidental introduction into Australia and New Zealand. Chapter 3 examines the efficacy of earwigs as biological control agents in apple orchards against the woolly apple aphid, *Eriosoma lanigerum* (WAA) and further examines how earwigs and the WAA parasitoid, *Aphelinus mali* interact to suppress WAA numbers below problematic levels. Chapter 4 explores the ecology of European earwigs in cherry orchards and examines their spatial distribution within cherry tree canopies and the potential impact this has on cherry fruit and cherry stem damage. Chapter 5 identifies putative aggregation pheromone components emitted by *F. auricularia* and assesses these compounds for behavioural activity. Chapter 6 investigates the phenology of the cuticular hydrocarbon profiles of *F. auricularia* and how these fluctuations may relate to earwig population dynamics. Finally, Chapter 7 is a general discussion, which integrates the findings from chapter 2 to 6 and makes recommendations as to further research.

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