Biological Control 102 (2016) 1–6

Contents lists available at ScienceDirect

Biological Control

journal homepage: www.elsevier.com/locate/ybcon

From planning to execution to the future: An overview of a concerted effort to enhance biological control in apple, pear, and walnut orchards in the western U.S.

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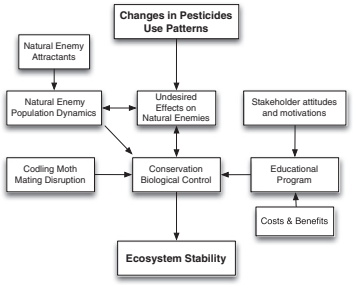
HIGHLIGHTS

- We highlight the overall accomplishments of the articles in this special issue.
- Multi-tactic approaches that address key issues of biological control are needed for adoption.
- Outreach success requires biological knowledge be delivered in multiple venues.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 19 November 2015
Accepted 28 March 2016
Available online 30 March 2016

Keywords:
Conservation biological control
Plant volatiles
Pesticide effects on natural enemies
IPM decision-making

ABSTRACT

We embarked on a large project designed to help enhance biological control in apple, pear and walnut orchards in the western U.S., where management programs were in the midst of a transition from older organo-phosphate insecticides to mating disruption and newer reduced-risk insecticides. A "pesticide replacement therapy" approach resulted in unstable management programs with unpredictable outbreaks of spider mites and aphids. Our project was designed to provide growers and pest managers with information on the effects of newer pesticide chemistries on a suite of representative natural enemies in both the laboratory and field, potential of new monitoring tools using herbivore-induced plant volatiles and floral volatiles, phenology of the key natural enemy species, economic consequences of using an enhanced biological control program, and value of an outreach program to get project outcomes into

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http://dx.doi.org/10.1016/j.biocontrol.2016.03.013

Economic analysis
Outreach

the hands of decision-makers. We present an overview of both the successes and failures of the project and of new projects that have spun off from this project to further enhance biological control in our systems in the near future.

1. Introduction

Integrated pest management (IPM) programs in tree crops in the western U.S. have been in a state of flux for the past 25 years, starting with the development and implementation of mating disruption (MD) for the management of codling moth (*Cydia pomonella* [L.]) in the early 1990s. Mating disruption greatly reduced the need for broad-spectrum "cover" sprays (typically azinphosmethyl or AZM) for codling moth and at least opened the door for increased use of conservation biological control (Brunner et al., 2005). Growers have rapidly adopted codling moth MD in the state of Washington and the latest figures suggest that >90% of the apple and pear acreage now uses this approach. The second major factor that has contributed to the flux in IPM programs was the Federal Food Quality Protection Act (FQPA) of 1996 that mandated the U.S. Environmental Protection Agency to re-review registered pesticides with the goal of increasing the safety margin of residues found in food crops, particularly those likely to be included in the diets of infants and children (Anonymous, 2006). As part of this re-review process, particular emphasis was placed on the evaluation of organo-phosphate (OP) insecticides, which had been a mainstay in tree fruit production since the mid-1950's (Jones et al., 2010b). While the loss of some OP's was a non-issue to tree fruit IPM programs, the loss of AZM for control of codling moth presented an extreme challenge to the status quo. Inevitably, this required the identification and use of alternate insecticides, because even IPM programs using MD typically requires at least one insecticide application early in the season (Brunner et al., 2005) when MD is less effective for control of codling moth (Jones and Wiman, 2012).

While the FQPA initially restricted and later eliminated many of the OP's used in western tree fruit production, it indirectly stimulated the registration of a large number of "reduced-risk" insecticides that were slated to be OP replacements. This bounty of new insecticides provided a set of powerful tools that would allow better management of pesticide resistance in our key pests. Unfortunately, there was little information on the effects of these new materials on the natural enemy communities that had been shaped over a 50+ year period by OP use (Jones et al., 2009). Although the reduced-risk insecticides tended to perform well in small-scale experimental tests, in large-scale commercial use many of the new materials resulted in increased aphid and mite populations to the point that the western orchard systems became relatively unstable with respect to secondary pests.

The genesis of this effort to enhance conservation biological control in western orchards was in 2006, when four of us published a white paper to introduce the idea that we were at a crossroad in the transition from pre-FQPA to post-FQPA IPM programs for apples in Washington state and that the future stability of these programs would require the enhancement of biological control (Jones et al., 2006). Our contention was that biological control was more important than most people realized and that we needed to focus on which natural enemy species were the most effective (especially among the predators whose roles were less clear), when they were most active during the growing season, and how selective the newer classes of insecticides were for effective integration of natural enemies into our management programs.

We began to address these questions with support from the Washington Tree Fruit Research Commission in 2007–2009, focusing our efforts on evaluating field spray programs in apples, predation intensity on codling moth and leafrollers, tachinid parasitism of leafrollers, and phenology models for some of the natural enemies. An ideal opportunity to intensify this work presented itself when the United States Department of Agriculture (USDA) announced its Specialty Crop Research Initiative (SCRI) program in summer 2008. This grant program allowed large multiple-commodity, multi-institution, multi-state projects to pursue "tra ns-disciplinary" approaches with the proviso that they address practical industry-based solutions to improve the competitiveness of American agriculture. Our successful proposal to the USDA-SCRI program allowed us to expand our previous efforts in Washington to include the states of California and Oregon, and to broaden our initial focus on apples to include walnuts (California) and pears (Oregon and Washington), two additional tree crops that shared codling moth as the key pest in their IPM programs. This larger project focused on several issues that we felt could be addressed during the five-year period of the grant, and that we considered to be the most important roadblocks for enhancing biological control in western orchard systems (Table 1). Although at its heart the team for the USDA-SCRI project had a strong entomological focus, we knew that there were valuable reasons to include other disciplines that were better suited to answering questions about the costs and barriers to adoption of different IPM management strategies. In addition, the members of the team were united in the desire to make sure that the outreach effort provided growers and IPM consultants with the information generated from the project and that this information would not simply disappear when the five-year grant period ended.

2. Overview of project and results

In this special issue there are thirteen additional papers that detail the results of our research and outreach efforts from the USDA-SCRI project. While these papers do not report on every aspect of the project, they have been selected to provide a broad overview of the objectives of the complete project (Table 1). Here we provide a summary of the highlights of each contribution by grouping them into one of five categories: (1) pesticide effects on natural enemies; (2) use of plant volatiles to monitor natural enemies; (3) evaluating the importance of codling moth predation; (4) economics and barriers to adoption of conservation biological control; and (5) the outreach program.

2.1. Pesticide effects on natural enemies

The main premise for the project was that for those tree crops in the western U.S. that share codling moth as a primary pest, IPM programs could be made more effective and stable through greater recognition of the value of the pest control services provided by resident natural enemies. For conservation biological control to be fully integrated with a combined mating disruption – insecticide program for management of codling moth and a pesticide program for management of plant diseases, the selectivity of OP replacements and other pesticides commonly used in western orchards was of primary concern. Consequently, there are five