Biological Control 102 (2016) 93–100

Contents lists available at ScienceDirect

Biological Control

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

Capturing the economic value of biological control in western tree fruit

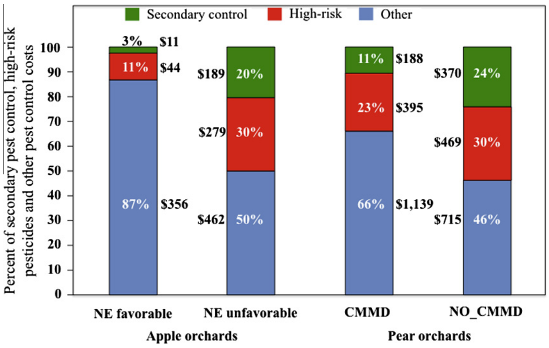
R. Karina Gallardo[a], Jay F. Brunner[b,*], Steve Castagnoli[c]

[a] School of Economic Sciences, Puyallup Research and Extension Center, and the Center for Precision and Automated Agricultural Systems, Washington State University, 2606 W. Pioneer, Puyallup, WA, USA
[b] Tree Fruit Research and Extension Center, Washington State University, 1100 N. Western Ave., Wenatchee, WA, USA
[c] Department of Horticulture, Mid-Columbia Agricultural Research and Extension Center, Oregon State University, 3005 Experiment Station Drive, Hood River, OR, USA

HIGHLIGHTS

- Apple – $1 of high-risk insecticide increased secondary pest control by $0.52.
- Apple – every additional unit increase of the NE risk value increased costs $51/ha.
- Pear – $1 of high-risk insecticide increased secondary pest control by $0.45.
- Pear – every additional unit increase of the NE risk value increased costs $27/ha.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 23 May 2016
Accepted 26 May 2016
Available online 5 July 2016

Keywords:
Economic value
Biological control
Risk value
Integrated pest management
Tree fruit

ABSTRACT

The economic value of biological control in apple in central Washington and pear in northern Oregon was estimated by comparing pest management programs following practices thought to reduce negative impacts on natural enemies to programs following traditional practices. Pest management costs in three apple orchards that had transitioned to the use of codling moth mating disruption (CMMD) plus reduced-risk or organophosphate-alternative pesticides were compared with four orchards that had not adopted these practices. Pest management costs in five pear orchards using CMMD were compared to four orchards not using CMMD. In both cropping systems the impact of pest management programs on biological control was determined by the need to use pesticides to control secondary pests, aphids and spider mites in apple and spider mites and pear psylla in pear. The disruptive nature of pesticides was categorized into four levels from none (0) to high (4) based on data presented by Mills et al. (2016) and Beers et al. (2016), as well as other published information. Some reduced-risk and OP-alternative pesticides proved detrimental to natural enemies and disruptive of biological control in apple and pear. In apple, the use of pesticides with low risk to natural enemies reduced the need to apply controls for secondary pests. In pear, the use of CMMD reduced the need to control secondary pests, spider mites and pear psylla, in summer. The use of pesticides with a high risk to natural enemies increased the cost of secondary pest control by about 50% in apple and pear. A stepwise increase in natural enemy risk values increased total pest management costs by $46/ha in natural enemy unfavorable apple orchards and by $44/ha in pear orchards not using codling moth mating disruption.

1. Introduction

Managed systems like agriculture have long recognized the importance of a balanced approach to addressing pest issues.

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* Corresponding author.
E-mail addresses: karina_gallardo@wsu.edu (R.K. Gallardo), jfb@wsu.edu (J.F. Brunner), steve.castagnoli@oregonstate.edu (S. Castagnoli).

http://dx.doi.org/10.1016/j.biocontrol.2016.05.013
1049-9644/

Integrated Pest Management (IPM) was born out of a crisis arising from the overuse of pesticides (Stern et al., 1959). IPM seeks to integrate biological, chemical, cultural and mechanical controls as core tactics to achieve a sustainable production system (Pedigo and Rice, 2008). Biological control is typically considered a free service that, if managed, can contribute value and sustainability to IPM programs (DeBach, 1964; Kogan, 1998). While economics has always played a core role in the concept of IPM, according to Onstad and Knolhoff (2009) economic evaluations of IPM are rare, with less than 1% of articles published in four journals since 1972 including economic analyses. However, in a more recent review article, Naranjo et al. (2015) documented five examples of economic value specific to conservation biological control.

Recent studies have sought to assign value of habitat diversity as an ecosystem service that enhances conservation biological control (Fiedler et al., 2008; Griffiths et al., 2008; Landis et al., 2000). Losey and Vaughan (2006) estimated an economic value of natural control of insect pests to be $4.5 billion annually for all U.S. crops. Cullen et al. (2008) provide a general discussion of the economics of conservation biological control but reported only one conservation biological control study that included an economic assessment. Headley and Hoy (1987) estimated that the value of conserving a genetically selected population of a predatory mite in almonds would save growers $24–44/ha. Trumble and Morse (1993) reported that a combination of abamectin and augmentative releases of a predatory mite in strawberries provided net returns of $2756-7882/ha compared to no controls.

In high-value perennial crops like apple, walnut, citrus and pear, the impact and potential of biological control is well documented (AliNiazee and Hagen, 1995; Gontijo et al., 2012; Headley and Hoy, 1987; Hoyt, 1969; Hoyt and Caltagirone, 1971; van den Bosch et al., 1979). In the late 1960s, Hoyt (1969) developed integrated mite control (IMC) where the western predatory mite, *Galendromus occidentalis* (Nesbitt), provided biological control of spider mites in an environment where insecticides were used to manage key pests like codling moth, *Cydia pomonella* (L.).

Integrating biological control in pear pest management programs has been more of a challenge than in apple. Pear production faces not only the challenge of controlling codling moth, but must also deal with pear psylla, *Cacopsylla pyricola* Foerster, which is considered to be a pest induced by the use of insecticides (Burts, 1983; Madsen et al., 1963; Westigard et al., 1986). Numerous studies have characterized a complex of natural enemies that attack pear psylla (Gut and Jochums, 1982; Madsen, 1961; Madsen et al., 1963; Nickel et al., 1965; Westigard et al., 1968; Westigard and Zwick, 1972; Zwick and Fields, 1977) as well as intra- and extra-orchard factors that influence biological control (Fye, 1983; Gut and Jochums, 1982; Horton et al., 2002a,b; Madsen et al., 1963; Miliczky and Horton, 2005; Nickel et al., 1965).

As reduced-risk insecticides have entered the market they have been adopted into western tree fruit IPM programs (Jones et al., 2009). While reduced-risk insecticides have made the orchard environment safer for farm workers, their impacts on natural enemies are poorly understood. Jones et al., 2016 provide an overview of a USDA-SCRI project “Enhancing Biological Control in Western Orchard Systems” (EBCWOS), that sought to improve the long-term sustainability of IPM programs in apple, pear, and walnut in the western U.S. The EBCWOS project included an effort to capture the economic value of conservation biological control in apple and pear orchards in the Pacific Northwest. In this paper we used case studies in apple and pear orchards that did or did not follow practices that enhanced conservation biological control. We present an economic analysis from seven apple orchards over three years in north-central Washington and nine pear orchards over four years in northern Oregon to capture the value of conservation biological control.

2. Methods – Case studies in apple and pear

Insecticide and miticide use information was collected from seven apple orchards in north-central Washington over three years, 2007–2009. We grouped these orchards into two categories; orchards 1–3 that were considered natural enemy (NE) favorable because they had transitioned, or were in the process of transitioning, to the use of codling moth mating disruption (CMMD) and reduced-risk or organophosphate (OP) alternative insecticides, and orchards 4–7 that were considered NE unfavorable because they typically did not use CMMD and though they might have adopted use of some OP-alternatives, they continued to use OP insecticides. For pears in northern Oregon, we collected insecticide and miticide use information from nine orchards over four years, 2007–2010. We grouped these orchards based on the use of CMMD. Orchards 1–5 used CMMD plus other pesticides in their pest management programs while orchards 6–9 did not use CMMD, relying solely on pesticides.

Specific information about pesticide use and timing in apple and pear orchards is provided in Appendix A (Supplementary Tables S1 and S2). Any pesticides applied to apple in summer for control of spider mites or aphids were classified as secondary pest control. Similarly, any pesticides applied to pear in summer for spider mites or pear psylla were classified as secondary pest control.

A NE risk category (low, moderate or high) and NE risk value (1, 2 or 3) was assigned to each pesticide based on information developed by the EBCWOS project (Mills et al., 2016). Where we did not have information from the EBWOS project on the effects of a pesticide on natural enemies, we relied on information from other published literature as summarized in the Orchard Pesticide Effects on Natural Enemies Database (OPENED) (Chambers et al., 2014). Information in OPENED was derived from several sources; including data generated from USDA-IFAFS and USDA-RAMP Areawide Codling Moth Control Program II projects, and information from Koppert Biological Systems, International Organization for Biological Control (IOBC), the Washington State University Tree Fruit Crop Protection Guide and publications of the University of California Extension, Cornell University, Ohio State University and Pennsylvania State University. For our study we used an average NE risk value for each pesticide from OPENED and rounded the average value to the nearest integer value (1, 2 or 3) and assigned a complimentary NE risk category of low, moderate or high. The NE risk value allowed us to use a cumulative risk total for each apple and pear pest management program. We chose to assign a zero-risk to pheromones and *Bacillus thuringiensis* (Bt), as these pesticides were deemed to have no impact on natural enemies.

To establish a unit price for each pesticide we obtained information from two major agricultural chemical distributors that supplied orchard producers in Washington and Oregon. Prices we used were based on the average retail listings of 2010 prices from the two companies. The prices we used may slightly overestimate what growers pay since they often obtain reduced prices associated with bids for pesticides or because they receive a reduced price as part of an orchard management service agreement. We determined the unit cost of each pesticide, e.g. dollars per dry weight or fluid volume, and calculated the pesticide cost for each application as the amount used per ha times the unit price of the pesticide. The machinery cost was estimated at $20.38/h and the fuel cost at $12.38/h (Schnitkey and Lattz, 2008). Machinery repairs, maintenance, depreciation, and interest rate were estimated at $8/h (West et al., 2012). Labor cost for applying a pesticide (tractor driver) was set at $15.95/h, assumed to be 10% higher than the accepted labor rate of $14.50/h (Schnitkey and Lattz, 2008). Each grower provided the time required to apply a pesticide. The total per ha cost of a pesticide application included the pesticide cost, machinery cost and labor cost. If more than