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Using plant volatile traps to estimate the diversity of natural enemy communities in orchard ecosystems

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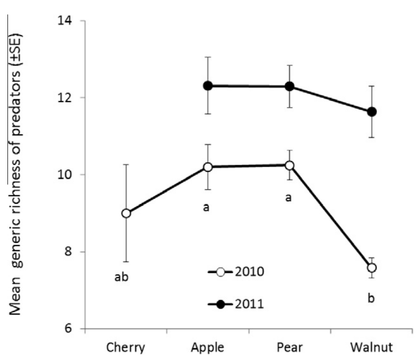
HIGHLIGHTS

- Plant volatile traps were used to estimate natural enemy biodiversity in orchards.
- We compared biodiversity measurements for predator genera among four tree crops.
- Biodiversity of predator and parasitoid species are reported for walnuts only.
- Natural enemy biodiversity was high in orchard crops despite intensive management.

GRAPHICAL ABSTRACT



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ABSTRACT

In this study we used sticky traps baited with plant volatile lures to monitor the biodiversity of natural enemies in orchard ecosystems in the western U.S. We compared the diversity of predator genera from season total trap catches in 37 different orchards (apple, cherry, pear and walnut) over a two-year period (2010–2011) using standardized Hill number biodiversity indices and community similarity profiles. For a subset of 23 of these orchards we were also able to monitor the change in biodiversity of predator genera over the full growing season in the different orchard crops. A total of 37,854 individuals from 31 different genera of foliage-active generalist predators were collected from all orchards combined. Mean sample coverage was high (0.98) and richness, diversity and evenness differed between crops in 2010, but not in 2011. There was more than 90% similarity in the richness of predator genera among crops and among orchards within crops, but a greater level of differentiation was observed among orchards when variation in their relative abundance and dominance in the communities was taken into account. There was a consistent rise in predator generic richness and diversity through the season in both years for apple, cherry and pear orchards, but in walnut orchards, a steep rise from March to May was followed by a decline through the rest of the season. In an additional component of the study, the species level similarity of predator and parasitoid communities was analyzed for total season trap catch data from six walnut orchards. The rarefied species richness of parasitoids was much greater than that for predators, although the diversity, evenness and dominance of the parasitoid species varied considerably among

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orchards. The results from this study highlight the fact that natural enemy communities in orchard ecosystems can be effectively monitored using plant volatile traps, and that these communities are surprisingly diverse despite frequent disturbance from pest management intervention.

1. Introduction

For agriculture to become more sustainable in the future, it will need to meet the challenge of maintaining or enhancing production, improving its resilience, and reducing negative effects on the environment (Foley et al., 2011). To address these issues, greater attention is being paid to enhancing the benefits from natural enemies that provide pest control services in agricultural crops (Jones et al., 2009; Crowder and Harwood, 2014). In general, natural enemies colonize agricultural crops from the surrounding landscape and there is growing evidence that biological control services are reduced to a greater extent in simple versus complex landscapes (Chaplin-Kramer et al., 2011; Letourneau et al., 2011; Veres et al., 2013). In addition, increased use of insecticides in agricultural crops has been shown to result in consistent negative effects on local biodiversity and biological control services (Geiger et al., 2010). To moderate these effects of agricultural intensification, conservation biological control seeks to enhance the activity of natural enemies through habitat manipulation to favor natural enemies over arthropod pests and to protect natural enemies from the harmful effects of pesticides (Jonsson et al., 2008; Crowder and Harwood, 2014; Mills, 2014).

In general, evidence supports a strong linkage between biodiversity and ecosystem function (Cardinale et al., 2006, 2012; Balvanera et al., 2014). Biological control, as a specific ecosystem service, is also considered to be influenced by the biodiversity of local natural enemy communities. From a meta-analysis of the available literature, Letourneau et al. (2009) found a positive effect overall of natural enemy richness on the suppression of herbivore abundance in agricultural habitats. However, the effect of natural enemy richness is not always positive, and some studies have shown either no effect or a negative effect depending on the extent of either functional complementarity or antagonistic interactions among species (Letourneau et al., 2009; Snyder and Tylianakis, 2012; Crowder and Jabbour, 2014). A number of other factors, such as host diversity, complex host life cycles, and host abundance, may also influence the linkage between herbivore abundance and natural enemy richness (Tylianakis and Romo, 2010). More recently, the supposition that species richness is the best measure for estimating the effectiveness of biological control services in agroecosystems has been questioned, with some studies showing that the functional complementarity of enemy species may be better represented by species evenness (Crowder et al., 2010; Crowder and Jabbour, 2014).

Although conservation biological control as an approach to enhancing biological control services in agriculture has received increasing attention in the literature, it has yet to be more widely adopted and implemented by agricultural managers (Cullen et al., 2008; Goldberger and Lehrer, 2016). The lack of adoption can be affected by a wide variety of factors, but a key factor is undoubtedly a lack of progress in developing quantitative measures of the impact of resident natural enemies that are accessible to managers (Macfadyen et al., 2015) and economic evaluations of the contribution of conservation biological control to integrated pest management (Naranjo et al., 2015). In addition, there is a continuing need for the development of monitoring tools that managers can easily use for evaluating the local biodiversity of natural enemy communities in agricultural crops.

While pheromones have been widely implemented for monitoring the abundance and seasonal activity of a variety of crop pests since the mid 1980s (Witzgall et al., 2010), developing new tools for monitoring the activity of natural enemies has lagged far behind. Monitoring for natural enemies remains based on labor intensive approaches, such as host rearing to estimate parasitism and either sweep nets or beating trays to estimate predator abundance (Mills, 2005), methods that are of limited use for making pest management decisions. Fortunately, more recently there has been increasing interest in the potential for using plant- or host-associated volatiles for monitoring and even manipulating natural enemies in agricultural crops (Khan et al., 2008; Jones et al., 2009, 2011; Hare, 2011; Meiners and Peri, 2013). As part of a large, multi-state, project we investigated the use of plant volatile traps for monitoring the biodiversity of natural enemies in orchard crops in the western U.S. and here we present a comparative study of spatial variation among orchard crops and temporal variation through the growing season. In the absence of previous research on this topic, our hypotheses were: 1) that natural enemy biodiversity would be comparable between different orchard crops within the western region, and 2) that natural enemy biodiversity would increase to a maximum mid-season and subsequently decline through the rest of the season.

2. Materials and methods

2.1. Traps and trap deployment

The diversity of the predator and parasitoid communities present in apple, cherry, pear and walnut orchards in the western U. S. was examined using trap catch data that were collected in 2010 and 2011 as part of a natural enemy phenology study described in Jones et al. (2016a). Apple, cherry and pear orchards were monitored in the Wenatchee region and apple and pear orchards in the Yakima region of Washington (WA), cherry and pear orchards in the Hood River region of Oregon (OR), and walnut orchards in the Sacramento valley of California (CA). For the purpose of this study, the data were restricted to the years 2010 and 2011 when traps were deployed in all three western states for the full season. Four apple and three cherry orchards in the Wenatchee region, WA and three cherry orchards in the Hood River region, OR were excluded from the 2011 data set as the combination of plant volatile lures used in these orchards differed from those used in other orchards that year. In addition, the three cherry orchards monitored in the Hood River region, OR in 2010 were excluded as they were not monitored for the full season. Consequently, there were 19 orchard locations in 2010 and 15 in 2011 (Table 2) for which predators and parasitoids were monitored through the season from March through September using traps baited with plant volatile lures. In 2010, large white plastic delta traps with sticky liners (Suterra LTD, Bend, OR) were used and these were replaced with one-sided white or yellow sticky panel traps (Alpha Scents, Inc., West Linn, OR) in 2011. Details of the construction and composition of the plant volatile lures are provided by Jones et al. (2016b).

The traps were baited with one of four lure combinations: acetophenone (Acros Organics, 3 ml per lure, release rate 58.7 mg/d), phenylacetaldehyde (SAFC Supply Solutions, 0.5 ml per lure,