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Hedgerows enhance beneficial insects on adjacent tomato fields in an intensive agricultural landscape

Lora A. Morandin[a,*], Rachael F. Long[b], Claire Kremen[a]

[a] Department of Environmental Science, Policy and Management, University of California, Berkeley, 130 Mulford Hall, Berkeley, CA 94720, USA
[b] Agriculture and Natural Resources, Cooperative Extension Yolo County, University of California, 70 Cottonwood Street, Woodland, CA 95695, USA

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ABSTRACT

Within-farm habitat enhancements such as hedgerows could aid pest control in adjacent crops; however, there is little information on whether small-scale restoration impacts pests and natural enemies, and crop damage, and how far effects may extend into fields. We compared restored, California native perennial hedgerows to unenhanced field edges consisting of commonly occurring semi-managed, non-native weeds. Pest and natural enemy communities were assessed in both edge types and into adjacent processing tomato fields. Using sentinel pest eggs, pest control was quantified, and pest pressure and crop damage was compared between field types. Economically-important pests were fewer and parasitoid wasps were more abundant in hedgerows than weedy crop edges. There was no difference in predatory arthropod abundance between edge types, but there was greater predator richness in hedgerow than weedy edges. Predatory lady beetles were more abundant and aphids were lower in fields with hedgerows, up to 200 m into fields, the maximum extent of observations. Fewer of the fields adjacent to hedgerows reached threshold pest levels requiring insecticide application. Benefits of hedgerows to pest control from parasitism extended to 100 m but not 200 m into fields. Farm-scale hedgerow restoration can provide pest control benefits up to 100 or 200 m into fields and multiple hedgerows around fields could enhance pest control throughout entire fields, reducing the need for chemical pest control.

1. Introduction

There is growing evidence showing that more complex or diversified landscapes that have high proportions of non-crop habitat such as forests, field margins, and wetlands, enhance natural enemy abundance and diversity in crop areas (Bianchi et al., 2006; Chaplin-Kramer et al., 2011). The evidence is less clear as to whether greater habitat complexity leads to greater pest suppression in crops (But see, Meehan et al., 2011), the ultimate goal for integrated pest management (Kremen and Miles, 2012).

In addition, there is little information on whether *local* diversification is effective for promoting pest suppression in crops (Griffiths et al., 2008). A recent meta-analysis of studies on within-farm diversification schemes found that diversified crops had enhanced natural enemy populations, greater pest suppression, and lower crop damage (Letourneau et al., 2011). However, they found that plant diversification within fields reduced primary crop yield. Diversification on edges, mainly through addition of floral resources, enhanced natural enemy abundance and parasitism in crops; yet there are few studies in this category and no studies that assessed crop damage and pest control in relation to diversification at field edges.

Recently, Chaplin-Kramer and Kremen (2012) showed that local diversification, from within field (polyculture) and/or around field (hedgerow) sources, can enhance natural pest control, compensating for low-complexity at a landscape level in some situations. It is vital to assess if such small, within-farm diversification strategies can impact pest suppression in intensive agricultural landscapes; because, while growers have little control over diversification at a landscape scale, they can implement local within-farm diversification (Morandin and Kremen, 2013).

Crop edge or hedgerow enhancement, as opposed to diversification within fields (whether intercropping or non-crop diversification), can utilize land that is not suitable for farming, taking little or no land from crop production, resulting in little or no reduced yield. However, it remains unclear whether restoration of a single hedgerow and other small-scale, local restoration strategies can compensate for low complexity at the landscape scale and how far benefits of edge restoration may extend into adjacent fields.

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* Corresponding author at: 1212 Juno St. Victoria, BC V9A 5K1, Canada. Tel.: +1 250 388 0819.
E-mail address: lora.morandin@gmail.com (L.A. Morandin).

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Uncertainty as to how hedgerow establishment will alter pest and natural enemy insect communities, and ultimately pest control and crop yield, remain a major barrier to landowners' willingness to devote time and money to hedgerow restorations and other CBC strategies on their farms (Griffiths et al., 2008; Stamps et al., 2008).

We examined pest and natural enemy arthropod abundance and diversity in Californian native perennial hedgerows of flowering shrubs and grasses that had been planted on field borders in an intensive agricultural landscape to enhance beneficial insect populations and decrease weeds (Bugg et al., 1998). We assessed natural enemy and pest abundance and diversity into crops adjacent to hedgerows or weedy, semi-managed field edge habitats, conducted pest control experiments, and assessed crops for pest pressure and crop damage. We asked four main questions by comparing crop fields with hedgerows versus weedy semi-managed field edges: 1. Do hedgerows increase natural enemy abundance and diversity in field edges and adjacent crops? 2. Are pest populations lower in field edges and adjacent crops with hedgerows? 3. Is pest control enhanced and crop damage reduced in fields with hedgerows? and 4. If so, to what distances do changes in abundances, pest control, and crop damage extend into fields with hedgerows relative to crops with weedy edges?

2. Materials and methods

This study was conducted in Yolo County in California's Sacramento Valley during the 2009 and 2010 growing seasons. The study area is intensively farmed, primarily with rotational field crops including wheat, processing tomato, alfalfa, and seed crops such as sunflower and safflower.

Hedgerow plantings approximately 7 m wide were established at our study sites in 1996–2003 and were comprised of a row of native perennial shrubs, 305–550 m long, bordered by native perennial grasses. Plant species composition for each site varied somewhat but all contained California buckwheat (*Eriogonum fasciculatum foliolosum*), California lilac (*Ceanothus griseus*), California coffeeberry (*Rhamnus californica tomentella*), coyote brush (*Baccharis pilularis*), elderberry (*Sambucus mexicana*), and toyon (*Heteromeles arbutifolia*). These plants were selected because they are drought-tolerant, native California shrubs that are known to provide floral resources for natural enemy insects, and have successive and overlapping bloom periods (Bugg et al., 1998; Long et al., 1998).

Three-meter wide strips of native perennial grasses were planted along one or both sides of the hedgerow to help suppress weeds and create overwintering habitat for natural enemies; species included purple needlegrass (*Nassella pulchra*), nodding needlegrass (*N. cernua*), California onion grass (*Melica californica*), one-sided bluegrass (*Poa secunda*), blue wildrye (*Elymus glaucus*), and creeping wildrye (*Leymus triticoides*). In some sites however, few grasses remained, having been outcompeted by weeds. The primary herbaceous weeds occurring in hedgerows were mustard (*Brassica* spp.), field bindweed (*Convolvulus arvensis*), mallow (*Malva parviflora* and *neglecta*), and bristly oxtongue (*Picris echioides*), and varied among sites.

Within each year we chose hedgerow sites that were adjacent to processing tomato fields, one of the most economically important and common crops in the region, in order to assess pests of tomato and their natural enemies, crop damage, and pest control into fields. For each hedgerow site, we selected a matching control site with a weedy, semi-managed field edge habitat adjacent to a processing tomato crop with a similar planting date, located 1–3 km away. This design promoted independence of pest and natural enemy communities at hedgerow and control sites, while allowing both treatments to span the same environmental conditions across the region. We attempted to get as many control fields with the same operators as hedgerow fields in order to minimize differences in pest control decisions between the two treatments, and were able to obtain half. We chose to compare the hedgerows to this type of semi-managed weedy field margin because it is the most prevalent edge type for crops in our region.

In 2010, two of the hedgerows were the same as in 2009; in one case the same field was used both years and in one case the field on the opposite side of the hedgerow was used (sites dictated by where the tomato crop was planted). Two control edges also were the same in 2009 and 2010, with one field being the same between years and one being on the opposite side of the field edge. Therefore, there were six unique hedgerows and six unique control edges over the two years of the study. We digitized and categorized land in a 1.5 km radius around each site using 1 m resolution orthophotos from the National Aerial Imagery Program (www.fsa.usda.gov/FSA) in ArcGIS (ESRI, 2009). At all sites, at least 85% of land in a 1.5 km radius around the center of the site was annual rotational crops with some smaller areas of orchard crops.

Pest and natural enemy arthropods were assessed in hedgerow and control sites ('sites' herein refers to edges and adjacent crops) four times (sample rounds) during each season with approximately one month between sample rounds, from early May until early August. This time frame spans the summer processing tomato production in our region.

2.1. Sweep samples

Sweep samples were taken four times during each season. A sweep sample consisted of 10, 180° sweeps with a 40 cm diameter net. Two samples were taken in the vegetation, 50–100 m from each end of the hedgerow or control edge (depending on edge length), and two at the center, for a total of six sweep samples at each site and sample round. Sweep samples were taken only when temperatures were $\geq$18 °C, winds $\leq$2.5 m/s and skies were clear, and were always conducted at a hedgerow and its paired control site on the same day. At hedgerow sites, sweeps were taken into the native plant vegetation. Sweep samples were only conducted at edges of fields (hedgerows and weedy controls) and not in fields due to the potential to damage crop plants with this sampling method. We employed different methods to sample insects into tomato fields (see below) and used these methods in the edges as well.

After each sweep sample, insects and any vegetation in the net were carefully transferred from the net to a sealed and labelled bag, and put into a cooler. At the end of the field day, bags were put into a freezer for later processing at which time all insects $\geq$0.5 mm (plus mites and spiders) were removed from bags and transferred to centrifuge tubes with 70% ethanol. Insects were identified that were of economic importance to crops in our region. Identification was to species or higher taxonomic levels (Table 1).

2.2. Sticky card samples

Yellow "Stiky strip" 7.6 cm × 12.7 cm sticky cards (Bioquip) were set out at sites four times each season. Unlike sweep samples, sticky cards could be used on edges and into fields and therefore could provide data in both locations. At each sample round, two sticky cards were placed at each of three field edge locations and along each of two transects into fields, at 10, 100, and 200 m from field edges, 100–200 m apart depending on field size, for a total of six sticky cards along field edges and six in fields. Sticky card wire holders (Bioquip) were used to hold cards above or adjacent to vegetation at all sites except where they hung from hedgerow shrubs with metal shower hangers. After seven days, sticky cards were collected, individually wrapped in plastic wrap, labelled, and put into freezers for later processing.