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Effect of woody vegetation at the landscape scale on the abundance of natural enemies in Australian vineyards

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ABSTRACT

Undisturbed vegetation within agricultural areas, especially woody vegetation, has been documented to enhance natural invertebrate enemies within adjacent crops, particularly in northern Europe. To test this idea within the context of Australian vineyards, we considered 44 landscapes from two regions, and sampled invertebrates in vineyards central to each landscape five times at monthly intervals using canopy sticky traps. Landscape composition was characterized at 11 spatial scales from 95 m to 3 km radius. We found only weak relationships between woody vegetation and the abundance of invertebrate groups including coccinellids at any spatial scale, regardless of whether the contribution of each scale was considered independently or together using a multiple regression approach. The only consistent pattern was that several families of parasitoids were influenced by woody vegetation at the landscape scale; the abundance of Eulophidae increased with woody vegetation in the landscape, while two families of smaller parasitoids, Trichogrammatidae and Mymaridae, were negatively affected by woody vegetation. We discuss possible reasons for these apparent contrasting patterns between Australian and European studies.

1. Introduction

Natural enemies contribute to pest control, and awareness of their impact is increasing as sustainable food production techniques are promoted. Populations of natural enemies within crops may be reduced by activities within the crop (application of chemicals, mowing, harvesting), or populations may be increased through reinvasion by locally available populations from relatively undisturbed non-crop habitat (Kreuss and Tscharntke, 1994; Zabel and Tscharntke, 1998; Golden and Crist, 1999). Natural enemies use resources provided by non-crop vegetation and seek refuge in undisturbed habitat, hence non-crop vegetation can increase abundance and diversity of a range of predators in adjacent crops. Evidence from numerous studies indicates that natural enemy diversity, abundance and distribution can all be affected by provision of such habitats (reviews in Gurr et al., 2003; Olson and Andow, 2008).

The benefits of vegetation immediately adjacent to crop has been demonstrated both in terms of increased natural enemy abundance and increased pest control (e.g. Landis et al., 2000; Olson and Wäckers, 2007; Thomson and Hoffmann, 2009, 2010). But in addition to adjacent vegetation there is the potential for non-crop vegetation within the broader landscape to enhance the abundance of natural enemies. A common method for assessing responses of natural enemies to vegetation at the landscape scale involves measuring the percentage of various land uses including vegetation in the landscape surrounding the crop (Thies et al., 2005). Associations between non-crop vegetation and numbers of beneficial organisms in field plots are then established at different scales (usually consisting of concentric circles at increasing distance from sampling points). Correlations are used to identify the landscape scale at which the strongest patterns emerge. When a correlation becomes significant at a particular scale, this is taken as suggestive evidence that vegetation or other features at that scale influence populations of beneficials. Following this approach, various landscape features have been linked to natural enemy abundances in a range of studies (Bianchi et al., 2005; Clough et al., 2005; Tscharntke et al., 2007; Schmidt et al., 2008). Woody or herbaceous non-crop vegetation in the landscape is frequently identified as a factor; herbaceous and woody habitats were indicated as important in 80% of the 24 studies reviewed by Bianchi et al. (2006).

Increased predation and parasitism have been linked to higher levels of complexity at the landscape scale in a range of crops (Thies and Tscharnkte, 1999; Thies et al., 2003). For example, structurally complex landscapes (substantial areas of woody habitats and limited agricultural area) increased predation of *Mamestra brassicae* L. (Lepidoptera: Noctuidae) caterpillars (Bianchi et al., 2005), enhanced parasitism of cereal aphids (*Sitobion avenae* F., *Metopolophium dirhodum* Walk., and *Rhopalosiphum padi* L.) (Roschewitz et al., 2005) and larval parasitism of the rape pollen beetle *Meligethes aeneus* F. (Coleoptera: Nitidulidae) (Thies and

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Tscharnkte, 1999). There are some exceptions to these patterns – for instance, parasitoid diversity and rate of parasitism are not necessarily associated with increasing landscape complexity (Menalled et al., 1999). There can also be a lack of consistency in responses in similar organisms in different regions, with landscape scales that enhance natural enemies quite different for the same groups in closely related regions (Rand and Tscharntke, 2007; Schmidt et al., 2008). Many of the spider species of Schmidt et al. (2008) showed significant response to habitat at the landscape scale in only one of the two regions studied. Where significant effects were detected in both regions, the scale of response could differ; for instance in the linyphiid *Bathyphantes gracilis* (Blackwall), the optimal scale in two regions 100 km apart was 1060 and 135 m (Schmidt et al., 2008).

In southeastern Australia, many vineyards are established on previously cleared land, creating a mosaic of pasture, crops and woody vegetation. The woody vegetation consists of 'shelterbelts', planted trees with an understory of shrubs and grasses, or occasional stands of original forested cover (here called remnant vegetation). This vegetation may pre-date the establishment of agriculture in the region or may represent regrowth following clearing, and in both cases reflect the original landscape. Areas of grass are usually planted to exotics with most of it grazed. These vineyards provide an opportunity to test the relationship between vegetation at the landscape scale and natural enemy abundance in an environment that is likely to differ from typical European landscapes with a long history of human influence on agricultural landscapes.

We examined impacts of woody vegetation at the landscape scale on abundance of vineyard natural enemy groups including parasitoids, coccinellids and neuropterans which have previously been reported responding at the landscape scale (e.g. Thies and Tscharnkte, 1999; Elliott et al., 2002; Thies et al., 2005; Rand and Tscharntke, 2007). Canopy invertebrates were sampled in 44 vineyards from two regions, and vegetation effects 95–3000 m from the vineyard were considered.

2. Materials and methods

2.1. Sites

Sampling was undertaken at non-overlapping sites (minimum distance 6 km separating each site) in 44 commercial vineyards from two regions of South Australia: 17 in the Barossa Valley (centered at 34°38′S, 138°53′E), and 27 in the Wrattonbully region (centered at 37°38′S, 140°49′E). Wrattonbully is 400 km south east of Barossa. Each site consisted of a block of the same grape variety (Chardonnay) with 3 m between rows, and rows consisting of vines 2 m apart planted to trellis with poles 5 m apart and of similar size (5–8 ha). Vine size and vigor were similar throughout the blocks. Undervine and inter-row management practices were also similar despite the number of sites considered; soil under the vines was bare earth following application of herbicides, and between the vines was mown grass (mainly perennial rye grass *Lolium perenne* and phalaris *Phalaris* sp., with varying amounts of capeweed *Arctotheca calendula* and clover *Trifolium repens*). Only chemicals of low toxicity to beneficials, based on IOBC ratings (http://www.koppert.nl), and related data – see Thomson and Hoffmann (2006) – were used at the sites, including sulfur (Thiovit®) (at the low dose of 200 g/100 L) and tebufenozide (Mimic®).

2.2. Sampling

In each of the 44 vineyard blocks, we placed five yellow sticky traps to sample coccinellid beetles, neuropterans and hymenopteran parasitoids from the canopy. Sampling points were located in vines along one row, 5 m apart, 50 m from the vineyard edge nearest an access road. The yellow sticky traps were 240 × 100 mm (Agrisense) sheets suspended from the lower wire of a vertical two-wire trellis system, 1 m above the ground. Sampling was repeated five times with traps out for the first week of each month throughout the season to harvest, from October 2006 to February or March 2007; timing of the last collection depended on whether harvest occurred in February or March. Invertebrates collected on yellow sticky traps were assessed *in situ*, using a microscope (Leica MS5) at magnification 20–100×. Coccinellidae and hymenopteran parasitoids, where possible, were sorted to species using CSIRO (1991), Matthews (1992), Ślipiński (2007), Glenn et al. (1997), Paull and Austin (2006) and Stevens et al. (2007).

2.3. Landscape

Methods for describing the landscape context were derived from Steffan-Dewenter et al. (2002). For each of the 44 landscapes, land-use data were analysed within a GIS framework, overlaying aerial photographs from Nature Maps (Department of Environment and Heritage, 2006). Landscape composition was calculated at 11 scales, with radii 95, 130, 190, 265, 375, 530, 750, 1060, 1500, 2120 and 3000 m around each vineyard, the area considered doubling with each subsequent radius. We calculated five measures of landscape composition in addition to the area covered by vineyards: (1) woody vegetation, (2) pasture, (3) high intensity crops (crop other than vines), (4) dams and lakes, (5) houses and other buildings and roads. Measures other than woody vegetation and pasture were poorly represented at each landscape scale, and here we consider the potential relationship between natural enemies and woody vegetation, consisting of various tree species (predominantly *Eucalyptus* and *Acacia*) with complex understoreys of shrubs, small herbaceous plants and grasses, most commonly indigenous. The focus of this study is on potential impact of woody vegetation at the landscape scale, previously shown to be relevant at the local scale (Thomson and Hoffmann, 2010), although we also considered pasture in initial analyses but no strong patterns emerged (data not presented).

2.4. Natural enemy abundance and vegetation associations

Because there were differences between the regions in terms of vegetation and invertebrate groups, the regions were analysed separately. The effect of woody vegetation in the landscape on local invertebrate densities in each region was investigated by comparing abundance (mean of five replicate traps averaged over five months, log transformed for normality) of groups collected from the vineyard (50 m from the vineyard edge) to woody vegetation in the surrounding landscapes.

The effect of landscape composition on abundance of parasitoids, coccinellids and neuropterans was tested separately in two types of analyses: correlation and regression with landscape composition calculated differently. In the correlation analysis we considered the effect of 'total' areas of woody vegetation at a particular scale, which includes inner annuli in the landscape (e.g. Steffan-Dewenter et al., 2002). A relationship between land-use and abundance at a particular spatial scale may be inferred from positive correlations between these variables at that scale. Correlation coefficients were plotted against the 11 scales for which landscape composition was calculated. Spearman's rank correlations were used because the assumptions for parametric tests were not always fulfilled.

For the regression analysis, we considered the contribution of woody vegetation only at that particular scale to avoid collinearity. Because vegetation at different scales is likely to be correlated, associations at one scale will then be reflected at the next scale, and the presence of a significant correlation may not necessarily