



Vineyard proximity to riparian habitat influences Western grape leafhopper (*Erythroneura elegantula* Osborn) populations



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ABSTRACT

The purpose of this study was to evaluate the impact of vineyard proximity to riparian habitat on the biological control and population densities of the Western grape leafhopper, *Erythroneura elegantula* Osborn (Hemiptera: Cicadellidae). Natural enemy and pest populations were monitored over a two-year period at multiple vineyard sites adjacent to riparian habitat in northern California. At each site, natural enemy and pest population data were collected along a transect that extended from the riparian habitat into the vineyard. Additionally, a subset of the original research sites were further evaluated for crop vigor, pest density and parasitism rates between the vineyard edge and interior. Results from this study indicate that lower *E. elegantula* egg deposition and nymph abundance at the vineyard edge were primarily due to reduced crop vigor at the sampled sites and that the most likely cause for these changes were differences in microclimate and soil fertility that were found to be associated with proximity to the riparian habitat.

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1. Introduction

In agricultural landscapes, fragment patches of natural habitat can serve as reservoirs of arthropod biodiversity (Fahrig, 2003; Tscharntke and Brandl, 2004) and can provide a source population of natural enemies that seasonally colonize crop fields (Ekbom et al., 2000; Duelli and Obrist, 2003; Tscharntke et al., 2007). Previous studies have demonstrated that crop fields adjacent to natural habitat have increased natural enemy populations (Kajak and Łukasiewicz, 1994; Pfiffner and Luka, 2000; Schmidt and Tscharntke, 2005; Öberg and Ekbom, 2006; Sackett et al., 2009) and natural enemy impacts on pests (Altieri and Schmidt, 1986; Tscharntke et al., 2002; Thomson and Hoffmann, 2009) which can ultimately lead to decreased pest densities (Nicholls et al., 2001; Paredes et al., 2013). Alternately, natural habitats can also have a negative impact on crop production (Zhang et al., 2007), for instance providing refugia for crop pests (Jeanneret, 2000; Roschewitz et al., 2005; Thies et al., 2005), promoting intra-guild predation amongst natural enemies (Gardiner et al., 2011), or

reducing crop nutrient levels, vigor or yield (Marshall and Moonen, 2002; Kuemmel, 2003). Studies evaluating the influence of natural habitats on vineyard pest densities have shown both positive (Nicholls et al., 2001; Hogg and Daane, 2010, 2011; Thomson and Hoffmann, 2013) and negative effects (Botero-Garcés and Isaacs, 2004; Sciarretta et al., 2008). While it is clear that biological control of pests is related to crop proximity to natural habitat (Krueß and Tscharntke, 1994; Bianchi et al., 2006; Chaplin-Kramer et al., 2011; Veres et al., 2013), outcomes are species specific and determined by various factors (Hunter, 2002; Fischer and Lindenmayer, 2007) including dispersal ability (Duelli and Obrist, 2003; Fahrig, 2007), functional guild (Straub and Snyder, 2006), spatial scale of analysis (Steffan-Dewenter et al., 2002), and patch size, isolation and density-area relationships (Hanski, 1998; Ricketts et al., 2001; Hambäck and Englund, 2005).

Proximity to natural habitats can influence crop quality due to changes in microclimate (Chen et al., 1995, 1999) and/or competition with non-crop plants (Nuberg, 1998). Herbivorous insects are sensitive in a variety of ways to changes in host-plant quality (White, 1974; Mattson, 1980; Price, 1991; Waring and Cobb, 1992). Plants or plant modules under abiotic stress tend to reduce protein synthesis which can lead to increased availability of nitrogen in plant tissue and also effect the production of secondary metabolites used for plant defense (Rhoades, 1979; White, 1984; Mattson and Haack, 1987), including volatile organic chemicals (VOCs) to attract natural enemies (Nordlund et al., 1988; Ode, 2013). Responses vary and VOC production can either increase

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(Takabayashi et al., 1994; Xin et al., 1997; Schmelz et al., 2003) or decrease (Gouinguéné and Turlings, 2002; Olson et al., 2009). On the other hand, insect herbivores are also known to prefer overly vigorous plants or plant modules, especially species whose reproduction and development is intimately linked with the plant host (Price, 1991). In such cases, herbivorous insects modify oviposition strategy based on perceptions of host plant quality (Awmack and Leather, 2002) and studies have demonstrated linkages between host plant quality, herbivore abundance and natural enemy populations (Fox et al., 1990; Stadler and Mackauer, 1996). Insect preference for and performance on overly stressed or vigorous plant hosts varies by guild (Larsson, 1989) and previous studies have shown that sap feeders (and mesophyll feeders in particular, such as *Erythroneura* leafhoppers) appear to be more sensitive to changes in plant quality than other guilds (Koricheva et al., 1998; Huberty and Denno, 2004). As such, studies in various agroecosystems have demonstrated leafhopper response to changes in crop water stress (Leigh et al., 1974; Hoffman and Hogg, 1992; Schowalter et al., 1999) and nutrient levels (Coyle et al., 2010; Iqbal et al., 2011; Joern et al., 2012). This is no different in vineyards, where *Erythroneura* leafhoppers have been found to prefer vines with higher irrigation levels (Trichilo et al., 1990; Daane and Williams, 2003) and nitrogen content (Mayse et al., 1991; Daane and Costello, 1998).

The Western grape leafhopper, *Erythroneura elegantula* Osborn (Hemiptera: Cicadellidae), feeds on grape leaves and can negatively affect crop yield and quality (Daane et al., 2013). The key parasitoids of *E. elegantula* are *Anagrus erythroneurae* S. Trjapitzin & Chiappini and *Anagrus daanei* Triapitsyn (Hymenoptera: Mymaridae). These tiny (<1 mm) wasps attack the eggs of *E. elegantula* and closely related leafhopper species (Daane et al., 2013). Spiders are the primary generalist predator of vineyard *Erythroneura* species, and they typically comprise more than 90% of the predator community in vineyards (Costello and Daane, 1995, 1999). Other predators that are known to attack *E. elegantula* include soldier beetles (Cantharidae), minute pirate-bugs (*Orius* sp.), green lacewings (*Chrysoperla* sp.), convergent lady beetle (*Hippodamia convergens* [Guérin-Méneville]), big-eyed bugs (*Geocoris* sp.), brown lacewings (*Hemerobius* sp.), damsel bugs (*Nabis* sp.), and hover fly larva (Syrphidae) (Daane et al., 2013). While generalist predators can contribute to biological control of *E. elegantula* (Hanna et al., 2003), parasitism by *Anagrus* wasps typically has a greater impact on the abundance of this pest (Daane et al., 2013).

A key to the relationship between *Anagrus* wasps and *E. elegantula* is their differential overwintering biology. In the fall, *E. elegantula* adults enter into reproductive diapause and overwinter in or near the vineyard in protected habitats (e.g., leaf litter) (Daane et al., 2013). *Anagrus* wasps overwinter as eggs or larvae in the eggs of other leafhopper species, and these alternate leafhopper hosts

are typically found in natural habitats outside of the vineyard (Doutt and Nakata, 1965; Lowery et al., 2007). The *Anagrus* species attacking *E. elegantula* in vineyards (previously referred to as *Anagrus epos* Girault) are known to overwinter on wild blackberry (*Rubus* spp.) (Doutt and Nakata, 1965; Lowery et al., 2007) and prune (*Prunus* sp.) (Kido et al., 1983) and vineyard proximity to patches of *Rubus* spp. has been associated with increased *Anagrus* densities and *E. elegantula* parasitism rates (Doutt et al., 1966; Doutt and Nakata, 1973; Ponti et al., 2005).

In California's North Coast wine grapes, the development and expansion of production acreage has resulted in landscapes predominantly composed of vineyards intermixed with some small patches of highly fragmented natural habitat (Heaton and Merenlender, 2000). These patches primarily consist of oak woodland and riparian habitat. While oak woodland can harbor spiders that seasonally colonize vineyards (Hogg and Daane, 2010), overwintering habitat for *Anagrus* wasps is most likely found in riparian areas, which typically contain significant patches of *Rubus* spp. (Doutt and Nakata, 1973). Whereas previous studies have identified a link between riparian habitat, *Anagrus* densities and parasitism of *E. elegantula* in vineyards (Doutt et al., 1966; Doutt and Nakata, 1973), no replicated field trials have been conducted to more closely evaluate this relationship and elicit the specific mechanisms that determine leafhopper densities in vineyards adjacent to riparian habitat. While it has been demonstrated that *Erythroneura* leafhopper densities tend to be lower in vineyards with increased habitat diversity, the ecological mechanism can vary (Daane and Costello, 1998; Nicholls et al., 2000, 2001; Hanna et al., 2003). In some studies, the presence of non-crop habitat was thought to support increased natural enemy populations which led to enhanced parasitism and predation of leafhoppers (Nicholls et al., 2000, 2001; Hanna et al., 2003) while in other studies it was suggested that changes in crop vigor due to competition from non-crop habitat led to reduced leafhopper egg deposition on less vigorous vines (Daane and Costello, 1998). In this study, natural enemy and pest densities, as well as parasitism rates and crop vigor, were monitored in multiple vineyards adjacent to patches of riparian habitat in California's North Coast wine grape region in order to better determine how *E. elegantula* densities are influenced by vineyard proximity to riparian habitat.

2. Methods and materials

2.1. Study sites

Field sites consisted of vineyard blocks >0.8 ha (2 acres) adjacent to riparian habitat in Sonoma County, California, USA. There were 3 study sites in 2010, 5 sites in 2011 and 3 sites for follow-up work in 2013. All vineyard blocks were at least 5 years

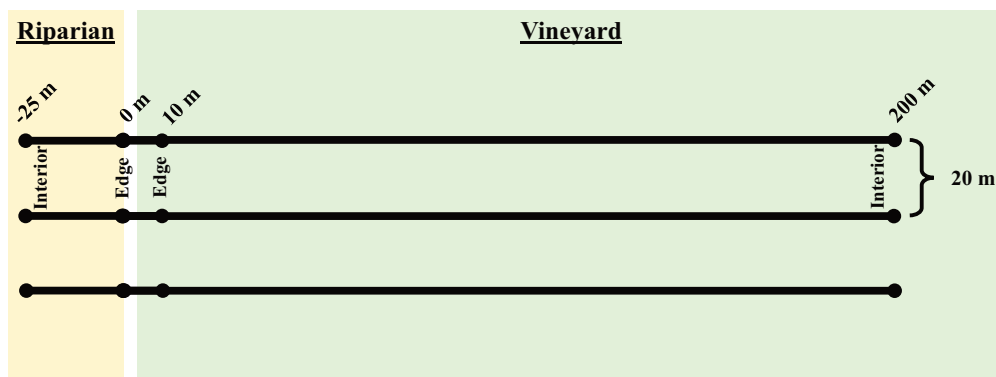


Fig. 1. At each study site three transects were established 20 m apart and each transect extended 25 m into the riparian area and 200 m into the vineyard.

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