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Influence of floral resource plants on control of an armored scale pest by the parasitoid *Encarsia citrina* (Craw.) (Hymenoptera: Aphelinidae)

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Abstract

We tested the hypothesis that control of an herbivorous pest would be improved by providing floral resources for adult natural enemies. The herbivore was euonymus scale, *Unaspis euonymi* (Comstock) (Homoptera: Diaspididae), a serious pest of woody ornamental plants. The experimental landscape consisted of 3×3 m plots, each containing a central bed of *Euonymus fortunei* (Turcz.) that was infested with the scale. Floral resource plants were cultivars of four species that overlapped in bloom periods to provide a continuous supply of floral resources during summer: *Trifolium repens* L., *Euphorbia epithymoides* L., *Coreopsis verticillata* L. var. 'Moonbeam,' and *Solidago canadensis* L. var. 'Golden Baby.' Plots contained either low or high densities of all four species, or no resource plants. Densities of euonymus scale were typically lower in plots containing resource plants than in plots without them. Parasitism by *Encarsia citrina* (Craw.) (Hymenoptera: Aphelinidae) was rarely influenced by the experimental treatments, flower biomass, whole-plant biomass, or scale density, but in some cases was inversely correlated with density of scales within a generation and in the subsequent generation. Parasitism occasionally reduced densities of scales in plots containing resource plants, but this effect apparently was related to vegetative, not floral qualities of plants. A steady increase in parasitism rate over the three-year course of the experiment across the entire landscape was associated with decreasing density of scales, suggesting a numerical response by the parasitoid population. These findings suggest that the parasitoid is capable of effectively controlling euonymus scale in ornamental landscapes where environmental conditions are favorable.

Keywords: Conservation biological control; Habitat manipulation; *Unaspis euonymi*; *Encarsia citrina*; *Euonymus fortunei*; *Trifolium repens*; *Euphorbia epithymoides*; *Coreopsis verticillata*; *Solidago canadensis*

1. Introduction

Much attention has been given to the beneficial effects of floral resource plants on natural enemies in agroecosystems (e.g., Altieri and Whitcomb, 1979; Cowgill et al., 1995; Idris and Grafius, 1995; Zhao et al., 1992). Floral nectar and pollen are fed upon by predaceous insects such as syrphids (Carreck and Williams, 1997; Hickman and Wratten, 1996; White et al., 1995), coccinellids (Freeman Long et al., 1998; Nalepa et al., 1992; Pemberton and Vandenberg, 1993), and lacewings (Freeman Long et al., 1998). Adult parasitoid wasps also may visit flowers to obtain nectar and/or pollen that provide essential nutrients and energy, and improve survival, fecundity, flight ability, and vigor in general (Baggen and Gurr, 1998; Begum et al., 2004; Carreck and Williams, 1997; Elton, 1966; Foster and Ruesink, 1984; Hougardy and Grégoire, 2000; Idris and Grafius, 1995, 1997; Jervis et al., 1993; Lee et al., 2004; Leius, 1960, 1963; Shahjahan, 1974; Steppuhn and Wäckers, 2004; Syme, 1975; Tooker and Hanks, 2000a; Wäckers, 2001, 2004). Floral resource plants may also provide shelter and alternative prey to natural enemies (Landis et al., 2000). Incorporating floral resource plants into agroecosystems can enhance

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natural enemy populations (Hickman and Wratten, 1996; Patt et al., 1997a; White et al., 1995), but may fail to result in effective biological control of the target pest if flowering does not coincide with the activity period of natural enemies (Bowie et al., 1995), if corolla structure hinders feeding by adult natural enemies (Patt et al., 1997b), or if natural enemies do not move between resource plants and crop plants (Bigger and Chaney, 1998; Freeman Long et al., 1998).

Conservation biological control also holds promise for managing pests in urban ornamental landscapes. Such landscapes are often poor quality habitats for natural enemies because they are floristically impoverished, dominated by pavement and turf, subject to high temperatures, pollution, and dust, and devoid of resources that are required by adult natural enemies (Dreistadt et al., 1990; Hanks and Denno, 1993; Sperry et al., 2001). Abundance and diversity of natural enemies, and impact on their host populations, is influenced by the composition and structure of the urban plant community (see Ellis et al., 2005). For example, Shrewsbury and Raupp (2000) found higher rates of predation of azalea lace bug in urban plant communities that were taxonomically and structurally diverse. Hanks and Denno (1993) reported that generalist natural enemies of a scale insect were more abundant, and predation rates greater on host trees that stood in woodlots with high plant species diversity and abundance than on trees that were more isolated. Higher rates of predation in the more diverse habitats resulted in lower densities of scales (Hanks and Denno, 1993). Similarly, generalist predators of a different scale species were more diverse and abundant, and scale populations were correspondingly lower, on pine hosts that occurred in park-like settings with high plant species diversity than on pines in depauperate urban landscapes (Tooker and Hanks, 2000b).

In this study, we test the potential for using floral resource plants to enhance control of euonymus scale, *Unaspis euonymi* (Comstock) (Homoptera: Diaspididae), an economically important pest of ornamental plants in urban landscapes (Kosztarab, 1996; Van Driesche et al., 1998a). This pest apparently originated in Asia and has been introduced into many temperate regions of the world, including the United States (Drea and Carlson, 1987; Gill et al., 1982; Jefferson and Schultz, 1995). In Indiana, euonymus scale completes two generations per year, and a partial third generation does not survive the winter (EJR, pers. obs.). Euonymus scale commonly infests *Pachysandra* (Buxaceae) and many species of Celastraceae, especially *Euonymus*, including species used extensively in urban landscapes (Jefferson and Schultz, 1995). In heavy infestations, waxy covers of the scale encrust stems and leaves of host plants and greatly reduce aesthetic quality. Localized chlorosis results from penetration of intracellular layers by the stylets and probing of parenchyma cells, the primary target in leaf tissue (Sadof and Neal, 1993). Heavy infestations can reduce photosynthetic leaf area, stunt growth, and result in early leaf senescence and abscission, branch dieback, and eventual death of the plant (Cockfield and Potter, 1986, 1987).

Euonymus scale is attacked by a suite of natural enemies, including predaceous coccinellid and nitidulid beetles, hemisarcoptid mites, and species of aphelinid wasps that have been imported from Asia as biological control agents (Houck and OConnor, 1990; Van Driesche et al., 1998b). An aphelinid parasitoid of euonymus scale that is broadly distributed in the northeastern and central United States has been identified previously as *Aspidiotiphagus* sp. (Bryan et al., 1995), but is probably *Encarsia citrina* (Craw.) (see Matadha et al., 2003). This wasp has a worldwide distribution and is highly polyphagous, attacking a large number of coccid species (Chumakova, 1965; Malipatil et al., 2000; Taylor, 1935). The wasp is a primary, solitary endoparasitoid, though superparasitism is common for several host species (Taylor, 1935). *E. citrina* is capable of parasitizing both male and female euonymus scales, and shows a preference for younger scales (Matadha et al., 2005). The wasp is proovigenic and only females are known (Cooper and Oetting, 1987; Malipatil et al., 2000). At least two generations occur per year in Indiana; emergence of adults in early May and early July appears synchronized with that of first-instar euonymus scales (EJR, pers. obs.).

In an earlier paper (Rebek et al., 2005), we reported that arthropod natural enemies were more abundant in euonymus beds that were surrounded by floral resource plants than in beds without these plants. In the present paper, we test the hypothesis that this general increase in the abundance of natural enemies in the presence of floral resource plants will translate into suppression of populations of euonymus scale by associated natural enemies.

2. Materials and methods

2.1. Study plots and plant species

Research plots were established in the summer of 1999 in a turf area adjacent to the Purdue University Nursery in West Lafayette, Indiana. Forty-four plots were arranged in four columns that were 6 m apart and 11 rows that were 3 m apart. Two corner plots were eliminated from study to establish 14 replicates of three treatments (see below). Ten rows of plots were used for long-term studies on abundance of natural enemies ($N = 30$ plots) while four rows that were separated from long-term plots by 6 m were used for shorter-term studies on natural enemy abundance and floral bloom phenology ($N = 12$ plots; see Rebek et al., 2005). Each study plot contained a central 1-m^2 bed of *Euonymus fortunei* (Turcz.) var. 'Coloratus,' container grown and purchased from a local nursery, planted on 22 cm centers (20 plants per bed). Prior to planting, we inoculated euonymus plants with mobile first-instar euonymus scales in the greenhouse by attaching scale-infested euonymus cuttings to each plant (see Sadof and Raupp, 1991). Euonymus beds were surrounded by a ~10-cm layer of composted wood mulch that was amended each spring. All plants grew vigorously and we trimmed them each fall to maintain the original border with the wood mulch. Areas