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The effects of alternative host plant species and plant quality on *Dicyphus hesperus* populations

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HIGHLIGHTS

- Dicyphus hesperus populations may be affected by plant species and nitrogen content.
- Three alternative host plants were paired nitrogen-manipulated tomato plants.
- Greater omnivore emergence and population growth occurred in mullein arenas.
- Tomato plant nitrogen content only affected D. hesperus in mullein arenas.
- Mullein is a superior banker plant, followed by eggplant and finally, pepper.

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ABSTRACT

Biological control can be used to defend important crops against insect pests, including those that are insecticide resistant. Dicyphus hesperus Knight (Hemiptera: Miridae) is a generalist zoophytophagous predator and biological control agent of Trialeurodes vaporariorum (Westwood) (Hemiptera: Aleyrodidae), the greenhouse whitefly. Because D. hesperus is an omnivore, the structure of the plant community and the nutritional value of the plants in the release habitat are likely to affect its establishment and population growth. Fifteen adult D. hesperus (ten females, five males) were placed into arenas that contained a tomato plant (Solanum lycopersicum L., Solanales: Solanaceae) of either high or low leaf nitrogen content and one of three alternative host plants: mullein (Verbascum thapsus L, Lamiales: Scrophulariaceae), pepper (Capiscum annuum L., Solanales: Solanaceae), or eggplant (Solanum melongena L, Solanales: Solanaceae). Adults remained in the enclosures for seven days; following their removal, F_1 generation nymphs, and subsequently, F_1 adults were counted as they emerged and the percent change in population size between generations was calculated. Nymph emergence was affected by the alternative host plant, such that emergence was greatest in arenas with mullein. Tomato nitrogen content only affected nymph emergence in arenas with mullein; more nymphs emerged when low nitrogen tomato was present. The presence of mullein also resulted in larger F₁ adult numbers and a greater change in population size between generations compared to eggplant and pepper. Our results indicate that growing tomato and mullein together, regardless of tomato plant nitrogen content, is beneficial to D. hesperus populations.

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1. Introduction

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Relative to prey, plant tissue is abundant in agricultural habitats. Although the dietary value of plant foods tends to be less than that of prey foods, many predators include plant foods in their diet (Cohen, 1996). Predators that consume both plant and prey foods during a single lifestage are defined as omnivores (Coll and

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as having a largely prey based diet that is augmented with nutrients (and water) obtained from plant feeding (Coll and Guershon, 2002; Castañé et al., 2011). Plant feeding by zoophytophagous omnivores facilitates their survival and persistence when prey is scarce (Bugg et al., 1987; Eubanks and Denno, 1999; Gillespie et al., 2012). Thus, plant feeding gives zoophytophagous omnivores certain advantages over predators in biological control programs, including early establishment in annual field crops, which is necessary to prevent exponential growth of pest populations (Wiedenmann and Smith, 1997).

Guershon, 2002). Zoophytophagous omnivores are characterized

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In 1999, work by McGregor et al. demonstrated that the zoophytophagous omnivore Dicyphus hesperus Knight (Hemiptera: Miridae) was an important predator of the greenhouse whitefly (Trialeurodes vaporariorum (Westwood) Diptera: Aleyrodidae) and the twospotted spider mite (Tetranychus urticae Koch, Acari: Tetranychidae). Dicyphus hesperus has been subsequently investigated as a biological control agent in tomato (Solanum lycopersicum L., Solanales: Solanaceae) greenhouses. It is a generalist that consumes a variety of prey species (greenhouse whitefly, twospotted spider mite, green peach aphid [Myzus persicae (Sulzer), Hemiptera: Aphididae)]; McGregor et al., 1999; VanLaerhoven et al., 2006) and plant species, including mullein, Verbascum thapsus L. (Lamiales: Scrophulariaceae), and several species of Solanaceae (Sanchez et al., 2004; VanLaerhoven et al., 2006). Plant feeding serves to provide *D. hesperus* with water for extraoral digestion, and minerals and nutrients obtained from plant feeding contribute to D. hesperus development, reducing the development time of nymphs by two days (Gillespie and McGregor, 2000). Plant feeding by D. hesperus is generally limited to the stems and leaves of the plant, unless only fruits are available (McGregor et al., 2000), at which time D. hesperus may become a threat to yields of marketable tomato fruits. Female D. hesperus utilize the foliage and stems for oviposition (Gillespie et al., 2004). In the absence of prey, immature D. hesperus may develop to the adult stage, however, reproduction of D. hesperus requires prey feeding unless mullein serves as the host plant (Sanchez et al., 2003, 2004).

Not all plant species (or structures) provide a suitable alternative to prey food for D. hesperus. Therefore, host plant species and quality should be considered when designing biological control programs that utilize D. hesperus, in order to maximize pest mortality and minimize damage to tomato fruits. The identity of the crop species and potential alternative host plants is especially important to consider. For example, certain plant species might be more attractive to the predator than the crop plants that require protection (leading to no or reduced prey mortality on the crop plant; Cortesero et al., 2000), or the host plants might be 'dead end' hosts that do not contribute to growth of the zoophytophagous omnivore's population (Eubanks and Denno, 1999). Conversely, some alternative host plants might help to maximize prey consumption by the zoophytophagous omnivore and contribute to its population growth, as mullein does for *D. hesperus*, even when its prey is absent (Sanchez et al., 2003; Bennett et al., 2009). These 'banker plants' that favour the development and survival of biological control agents (Stacey, 1977; Bennison, 1992), are important to include in biological control programs.

Although mullein is an acceptable banker plant for *D. hesperus* in tomato greenhouses (Sanchez et al., 2003; Gabarra et al., 2004), it would be helpful to producers, who tend to be limited by space, if potential banker plants provided a harvestable product in addition to aiding biocontrol programs. Other cultivated Solanaceae may also serve as *D. hesperus* banker plants. Therefore, we were interested in comparing the potential of eggplant (*Solanum melongena* L., Solanales: Solanaceae), pepper (*Capiscum annuum* L., Solanales: Solanaceae), and mullein as banker plants when grown simultaneously with tomato. The size and growth of *D. hesperus* populations were evaluated to determine the effect of each potential as banker plant in tomato greenhouses.

In Canada, 146,792 metric tonnes of tomato, 111,387 metric tonnes of pepper, and 1560 metric tonnes of eggplant were produced in 2014 (Gauthier, 2015). All three are important and valuable food crops characterized in part by alkaloid secondary metabolites including capsaicin (pepper) and solanine (eggplant) (Cowles et al., 1989; Hori et al., 2011). These allelochemicals have phytotoxic (Sun and Wang, 2015) and insecticidal (Cowles et al., 1989; Williams and Mansingh, 1993; Hori et al., 2011) properties and act as deterrents to oviposition and herbivory. Similarly, mullein contains iridoid glycosides for defense (Alba et al., 2014). In addition to secondary metabolites, mullein, eggplant, pepper, and tomato possess trichomes (glandular and non-glandular) that serve to protect them against herbivory (Abdula-Roberts et al., 2014; Alba et al., 2014). Pepper plants tend to be less 'hairy' than eggplant and tomato; Abdula-Roberts et al. (2014) noted that non-glandular trichomes were concentrated on the leaf veins on the underside of the leaf in the majority of pepper varieties studied.

The quality of the plant material available in an agroecosystem may also impact populations of zoophytophagous omnivores (Eubanks and Denno, 2000; Coll, 1996). Plant quality can refer to the nutritional value of the plant, the presence or absence of defensive metabolites in consumed plant structures, and the toughness or palatability of a plant (Awmack and Leather, 2002). Nitrogen is especially important, as it is often limited in the diets of insects that consume plant tissues (Mattson, 1980). Whitefly populations, for example, grow more rapidly when feeding on plants with excess nitrogen compared to plants with a nitrogen deficit (Jauset et al., 2000). Nitrogen content can also impact insect survival. For example, nymphs of the big-eyed bug, Geocoris punctipes (Say) (Hemiptera: Geocoridae), that were reared on high quality bean pods survived until the third instar, whereas nymphs reared on low quality foliage only survived until the second instar (Naranjo and Stimac, 1985). Therefore, in addition to manipulating the alternative host plant available for D. hesperus, we also manipulated the nitrogen content of the tomato plants to assess the impact of plant nitrogen content on D. hesperus nymph and adult populations, as nitrogen fertilizers are often applied to increase tomato yield in greenhouse agroecosystems.

In the current experiment, we used emerging nymph and adult populations to assess the impacts of alternative host plants and tomato nitrogen content on D. hesperus. We predicted that larger nymph and adult populations would be observed when tomato plants had high levels of nitrogen in their leaves, similar to the results observed by Vankosky and VanLaerhoven (2016). We also expected that high nitrogen tomato plants would contribute to overall growth of *D. hesperus* populations over a single generation. as host plants with high nitrogen content are known to contribute to increased population growth of a number of Hemipterans, including the greenhouse whitefly (Jauset et al., 2000). Based on results published by Sanchez et al. (2004), we predicted that larger nymph and adult populations would be observed when mullein served as the alternative host plant, and that mullein would contribute to a greater rate of population growth than eggplant and pepper. Given the physical appearance of eggplant and similarity in leaf hairiness between eggplant and mullein, we also predicted that eggplant would be a better alternative host plant than pepper.

2. Materials and methods

2.1. Colony maintenance and rearing

The *D. hesperus* insect colony originated in California, U.S.A. where insects were collected from white stem hedgenettle, *Stachys albens* A. Gray (Lamiales: Lamiaceae) (McGregor and Gillespie, 2004; Sparkes, 2012). *Dicyphus hesperus* were maintained in a colony at the University of Windsor where insects were held in cages in a controlled rearing room $(20 \pm 5 \,^{\circ}C)$, with a 16:8 h light:dark diurnal cycle, and $50 \pm 10\%$ humidity) (Sparkes, 2012). All four *D. hesperus* instars were reared on *Nicotiana tabacum* L. (Solanales: Solanaceae) and given *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae) eggs as a source of protein (Sparkes, 2012). *Dicyphus hesperus* adults used in this study were collected from the adult cage of the colony, which housed sexually mature, gravid females that ranged in age from 7 to 10 days.

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