

Effect of floral and extrafloral resources on predation of *Aphis spiraecola* by *Harmonia axyridis* on Apple

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Abstract. Flowering companion plants and plants producing extrafloral nectar are being proposed to enhance biological control in apple (*Malus domestica* Borkh.) orchards. This experiment evaluated the impact of floral and extrafloral resources on predation of spirea aphid (*Aphis spiraecola* Patch) on apple by adult *Harmonia axyridis* (Pallas) under greenhouse conditions. Predation of spirea aphids was not affected by the presence of flowering buckwheat (*Fagopyrum esculentum*) as compared with either buckwheat with flowers removed or an uninfested apple shoot. However, there was a significant reduction in predation of spirea aphids on an apple shoot in the presence of a peach shoot with extrafloral nectar glands compared with either a peach shoot of the same cultivar without nectar glands or an uninfested apple shoot. These findings demonstrate that alternative food resources potentially could interfere with rates of biological control and, therefore, need to be carefully evaluated before incorporating in an orchard design. More studies are needed to adequately gauge the net effects of adding floral or extrafloral resources in orchards for conservation biological control.

Key words: Aphididae, Coccinellidae, companion plant, conservation biological control, peach, spirea aphid

Introduction

The addition of plants that provide floral nectar and pollen or extrafloral nectar has been investigated in many agricultural systems as a means for enhancing biological control (Landis et al., 2000). In apple (*Malus domestica* Borkh.) orchards, companion plants have been shown to increase the abundance and diversity of arthropod parasitoids and predators (Bugg and Waddington, 1994; Wyss, 1996; Brown

and Glenn, 1999; Bostanian et al., 2004). Increased biological control in the presence of companion plants has also been reported (Leius, 1967; Wyss, 1995; Stephens et al., 1998). Extrafloral nectar glands increased the abundance and activity of arthropod predators and parasitoids in peach (*Prunus persica* Batsch) orchards compared with peach orchards of the same cultivar lacking nectar glands (Mathews, 2004). Interplanting of extrafloral nectar-bearing stone fruit trees into an apple orchard has also increased the diversity of predacious arthropods on apple (Brown and Schmitt, 2001). Peach extrafloral nectar has been shown to increase longevity and fecundity of predators and parasitoids of orchard pests (Hagley and Barber, 1992; Limburg and Rosenheim, 2001; Shearer and Atanassov, 2004). The presence or intensity of interactions between foraging for prey and foraging for alternate food sources merits further studies.

Harmonia axyridis (Pallas) (Coleoptera: Coccinellidae) is a recent addition to the North American fauna (Chapin and Brou, 1991) and it has rapidly dominated several agricultural systems (Tedders and Schaefer, 1994; LaMana and Miller, 1996; Colunga-Garcia and Gage, 1998) including apple (Brown and Miller, 1998). Predation by adult *H. axyridis* has recently been documented to be important in controlling spirea aphid [*Aphis spiraecola* Patch (Homoptera: Aphididae)] (Brown, 2004). Buckwheat (*Fagopyrum esculentum* Moench) has been shown to increase the abundance of predators, including coccinellids, in California vineyards (Nicholls et al., 2001) and has been used to increase parasitism rates and arthropod predator abundance in orchards (Stephens et al., 1998; Brown and Glenn, 1999). Adult *H. axyridis* have been observed feeding in buckwheat flowers (MWB, personal observations) and on peach extrafloral nectaries (Pemberton and Vandenberg, 1993; Mathews, 2004).

This study was done to investigate the effect of buckwheat flowers and peach extrafloral nectaries on predation of *A. spiraecola* on apple by *H. axyridis* under controlled conditions. Our hypothesis was that over a short time period the presence of alternative food resources would not affect the rate of predation on aphids.

Materials and methods

The research was conducted at the US Department of Agriculture, Appalachian Fruit Research Station in Kearneysville, WV, USA from 1 July to 19 August 2004. *Harmonia axyridis* adults were collected locally and fed *A. spiraecola* from naturally infested potted apple trees.

Egg masses from these adults were placed into separate plastic containers. Upon eclosion, larvae were transferred individually to a Petri dish and provided with water, honey and pollen (organically certified Bee Pollen, Y.S. Royal Jelly and Honey Bee Farms, Sheridan, IL, USA) and *A. spiraecola* on leaves from naturally infested potted apple. Upon emergence, adults were kept separate from the main colony in a 28×28×28 cm cage. The cage, identical to cages used for experimentation, had a plastic top and bottom, mesh on three sides and the front had a mesh sleeve for introducing insects, food and treatment shoots. Laboratory-reared adults were given the same food as the developing larvae with the addition of peach shoots bearing extrafloral nectar glands prior to the extrafloral nectar experiments. All *H. axyridis* were reared and maintained in a growth chamber at 23±1 °C and 14:10 (L:D) h photoperiod.

Prior to experimentation, individual adult *H. axyridis* were placed into separate vials with moist cotton but no food. They were kept in a growth chamber at the same conditions as noted above for 24 h to produce a uniform state of starvation. Throughout each of the two experiments individual beetles were used only once. Due to a shortage of beetles, some field collected adult *H. axyridis* were used, after 24 h starvation, in the experiment with floral resources.

Floral resources

The experiment was a completely random design with 27 replicates, but data are reported for unequal sample sizes for each treatment due to loss of adult beetles by escape or death. For each replicate, three cages (28×28×28 cm) were used with one of three treatments randomly applied per cage. The first treatment had two similar apple shoots, one with aphids and the other without aphids. The second treatment had an aphid-infested apple shoot with two 10–15 cm sprigs of buckwheat with flowers removed with scissors. The third treatment had an aphid-infested apple shoot and two 10–15 cm sprigs of buckwheat with open flower clusters. The buckwheat was grown in the greenhouse from seed. The buckwheat sprigs were placed in a 100 ml vial of water one day before the experiment because buckwheat cuttings tended to wilt immediately after cutting, but regained turgor after 24 h. Apple shoots were ca. 15 cm long with aphid infestation ranging from 20 to 50 aphids on each infested shoot cut from naturally infested potted apple trees and placed in a 100 ml vial of water. The aphid infestations were on actively growing shoots and were no more than 2–3-weeks-old. There was no effort made to

remove honeydew associated with the aphid colony but any aphid predators on the shoot were removed. The uninfested apple shoots were also actively growing and had no evidence of previous aphid infestation or honeydew.

The three cages of a replicate were placed side by side in a greenhouse that had ambient humidity (70–90% RH) and a temperature of 23 ± 2 °C. The exact number of aphids on the infested shoot was counted at the start of the experiment. For each treatment the pair of plants being tested was placed in opposite corners, randomly determined, of the cage. A single *H. axyridis* adult was placed at the center of the cage. After 4 h the beetles were collected from the cages and placed in separate vials and chilled for sexing. The number of aphids on the infested terminal, and anywhere else in the cage, was counted. The percentage of aphids lost after 4 h exposure was considered to be due to predation and was used as the response variable for analysis.

Extrafloral resources

The experiments using peach extrafloral nectar were done in the same manner and under the same conditions as for the buckwheat experiments. There were 29 replicates, but again due to loss or death of the beetle there were unequal sample sizes among treatments. The first treatment had two apple shoots, one infested with aphids and the other without aphids. The second treatment involved an apple shoot with aphids and one peach shoot without extrafloral nectar glands. The third treatment involved one infested apple shoot and one peach shoot with extrafloral nectar glands. Actively growing peach shoots, ca. 15 cm, were taken from greenhouse potted trees of open-pollinated 'Lovell' seedlings that had segregated into phenotypes with and without nectar glands. The aphid-infested and uninfested apple shoots were selected and maintained as described in the floral resources experiment. The peach shoots were cut from potted greenhouse trees and placed in a 100 ml vial of water just prior to use. The percentage of aphids lost after 4 h exposure to one adult *H. axyridis* was again used as the estimate of predation.

Statistical analysis

A two factor, fixed effect model, analysis of variation was used to analyze the effect of beetle sex, treatment and the sex by treatment interaction on percent predation (SAS Institute, 1998). Type III sum of squares was used for calculating the *F* tests to account for the

unequal sample sizes. Separate analyses of variance were done on the floral and extrafloral resource experiments. Percent predation was square root arcsine transformed to correct for normality and homogeneity of variances. Significant treatment effects were separated with least square means, $p=0.05$.

Results

Floral resources

For the buckwheat experiment, data were collected on 26 replicates from the treatment with 2 apple shoots, 25 replicates from the buckwheat without flowers and 27 from the buckwheat with flowers. There were 33 females and 45 males tested. The treatment effect for buckwheat floral resources was not significant ($F=1.52$, $df=2$, 72 , $p=0.2267$) but females had significantly higher rates of predation than males ($F=6.65$, $df=1$, 72 , $p=0.0120$) (Figure 1). There was no significant sex by treatment interaction.

Extrafloral resources

In the extrafloral nectar experiment, data were collected on 27 replicates from the treatment with 2 apple shoots, 29 from peach without

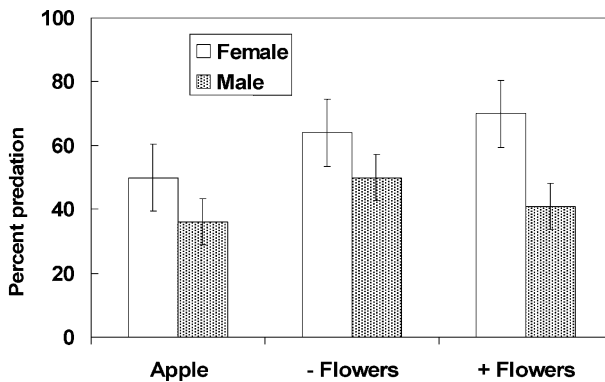


Figure 1. Mean percent predation (\pm SEM) of *Aphis spiraecola* on apple shoots by male and female *Harmonia axyridis* in the presence of a second unfested apple shoot, buckwheat with flowers removed (-Flowers), and buckwheat with flowers intact (+Flowers) in a caged greenhouse experiment. There was significantly greater predation by females than males but no significant treatment effect.

nectar glands and 27 from peach with nectar glands. There were 36 females and 47 males tested. There were significant effects of peach extrafloral resource treatment ($F=7.74$, $df=2$, 77 , $p=0.0009$) and sex ($F=6.58$, $df=1$, 77 , $p=0.0123$), but the sex by treatment interaction was not significant (Figure 2). Both males and females had significantly lower percent predation, 34 and 43% respectively, in the treatment with extrafloral nectar than in either treatment without nectar, ranging from 48 to 77% predation. Female beetles had greater rates of predation than males.

Discussion

Although the results from the floral resource experiment did support our hypothesis of no effect on predation rate, the results from the extrafloral resource experiment did not. The presence of extrafloral nectar reduced predation rate on *A. spiraeicola* by adult *H. axyridis* (Figure 2). This experiment took place at a small-scale and under controlled, greenhouse conditions, for a short period of time. In an orchard environment with greater distances between prey and alternative food sources and more architectural diversity, the interactions between extrafloral nectar, predation and aphids are certainly more complex. While this study demonstrates that the addition of

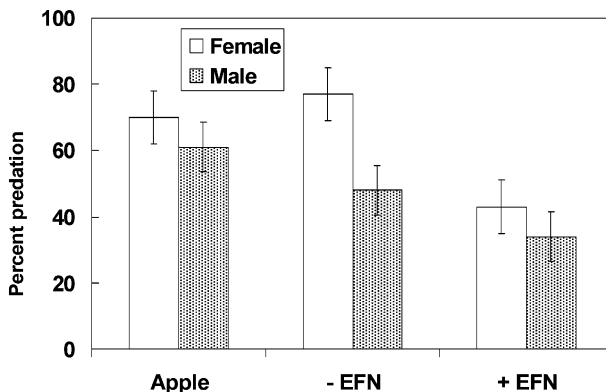


Figure 2. Mean percent predation (\pm SEM) of *Aphis spiraeicola* on apple shoots by male and female *Harmonia axyridis* in the presence of a second unfested apple shoot, peach shoot without extrafloral nectar glands (-EFN), and peach shoot with extrafloral nectar glands (+EFN) in a caged greenhouse experiment. There was significantly greater predation by females than males and significantly lower predation in the treatment with extrafloral nectar present.

alternative food resources to an ecosystem may not have the desired effect of increasing biological control, the numerous intricate interactions within an ecosystem must be understood before a management system should be instituted.

Floral nectar and pollen had no effect on predation of aphids by *H. axyridis* adults in this study (Figure 1). Although larval *H. axyridis* have been shown to feed on corn pollen more than adults (Lundgren et al., 2004) it is the adult stage that is more important in the biological control of aphids on apple in eastern North America (Brown, 2004). Buckwheat was shown to increase parasitism rates of leafrollers (Lepidoptera: Tortricidae) in New Zealand apple orchards (Stephens et al., 1998). A variety of other flowering plants have also been shown to increase biological control in other systems (White et al., 1995; Hickman and Wratten, 1996; MacLeod, 1999; Yong, 2003; Tylianakis et al., 2004). Over a larger and more complex scale of an orchard and for longer time periods the presence of nectar and pollen from buckwheat could help enhance biological control.

The presence of extrafloral nectar had a negative impact on the predation of *A. spiraecola* by starved *H. axyridis* over a 4 h period (Figure 2). The extrafloral nectar, composed of sugars, amino acids and fatty acids (Caldwell and Gerhardt, 1986), could have been more attractive to the beetles than the aphid food source. This could be due to several factors. The beetles were starved when the experiment began so they may have been lured to the sugar-rich nectar. Also, the chemical cues associated with the peach shoots may have masked the presence of aphids for the short duration of the study. Ingestion of extrafloral nectar, however, may ultimately result in an increase in energy for the beetles leading to higher aphid predation in a trial of longer duration. Experiments for longer periods of time are needed to determine the net effects of extrafloral nectar on aphid biological control.

Although not tested in this experiment extrafloral nectar can have other benefits such as retention of predators during prey scarcity and increasing foraging time when both prey and nectar are present. The presence of extrafloral nectar on almonds (*Prunus amygdalus* Batsch) provided a food source for *Chrysoperla plorabunda* (Fitch) (Neuroptera: Chrysopidae) larvae when prey were scarce (Limburg and Rosenheim, 2001). Extrafloral nectar also attracted coccinellids to an apple orchard before aphids arrived (Mathews, 2004) which could lead to the ability to respond quickly to aphids once they colonize the orchard. Resources like extrafloral nectar may be needed in apple

orchards when target prey are not available, allowing retention and attraction of natural enemies throughout the growing season (Stapel et al., 1997).

Both nectar and pollen resources may be effective tools for biological control within apple orchards. However, their net effects within apple orchards must be better understood if they are to be included in the overall orchard plan. This experiment has shown that alternative food sources can result in reduced biological control in a small-scale, short duration, controlled environment. Further long-term research in the laboratory and in full-scale orchard production systems need to be done to evaluate the net effect of additional food resources in a complex natural agroecosystem.

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