CITRUS RESEARCH BOARD

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FLOWERING PLANTS MAY ENHANCE BIOCONTROL OF ACP BY HOVERFLIES

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Project Summary

Incorporating flowering plants in orchards can enhance populations of natural enemies by providing them with nectar and pollen. Flowering plants were evaluated for their attractiveness to predatory hoverflies and their potential for reducing Asian citrus psyllid (ACP) survival on citrus. Alyssum and buckwheat were attractive to four hoverfly species. Larvae of the dominant hoverfly species, Allograpta obliqua*, are voracious predators of ACP. Compared to control plots lacking flowers, alyssum enhanced oviposition[1] by female* A. obliqua *and predator abundance, which decreased the number of ACP nymphs[2] surviving to adulthood.*

Figure 2. Experimental plots of irrigated alyssum, buckwheat, phacelia and California poppy at Agricultural Operations at the University of California, Riverside. Plots were used to assess flowering phenology, plant growth characteristics and attractiveness to natural enemies.

Figure 1. Allograpta obliqua: A) Adult laying eggs among Asian citrus psyllid (ACP) colonies; B) Adult drinking nectar from an alyssum flower; C) 1st instar larva eating an ACP nymph; D) 4th instar larva eating an ACP nymph.

Introduction

Generalist predators[3], especially hoverflies (Diptera: Syrphidae) found in California citrus, feed on immature ACP; and life table[4] and videography studies have demonstrated that hoverfly larvae cause significant mortality of ACP (Kistner and Hoddle 2015; Kistner et al. 2017). Hoverfly larvae are predacious, while adult flies require nectar and pollen for energy and egg maturation, respectively. Incorporating flowering plants in orchards is one way to enhance natural enemy populations with the intention of improving pest control by providing natural enemies with shelter and food (Liang and Huang 1994; Silva et al. 2010). However, not all species of flowering plants can be utilized by natural enemies. Research on what species of flowering plants to use and where, how and when to deploy them is necessary for growers who want to use this approach for enhancing populations of predators and parasitoids of citrus pests.

Flowering Plants That Are Attractive to Hoverflies

Flowering timing and attractiveness of four flowering plants (buckwheat, alyssum [**Figure 1B**], phacelia and California poppy) were investigated to determine whether they have potential for enhancing hoverflies and other natural enemies of citrus pests, such as ladybugs, parasitoids[5] and predatory wasps (**Figure 2**). Buckwheat, alyssum and phacelia were selected as these plants are especially attractive to adult hoverflies, thereby enhancing hoverfly abundance and reducing aphid populations in cereals, vegetable crops and orchards (Gontijo et al. 2013; Smith et al. 2008). California poppy and phacelia also were selected because they are California natives that are attractive to predators and parasitoids in California (Lundin et al. 2018). Native plants may have additional advantages because they are adapted for growth under local conditions and may be more resistant to insects, diseases and drought.

Results showed that alyssum and buckwheat have a short sowing to flowering time (30-33 days), flowering 19-30 days earlier than phacelia and California poppy when planted at the same time in February (**Figure 3**). Quick growing plants are advantageous because they rapidly provide nutrition for natural enemies. Alyssum and buckwheat were attractive to four predatory hoverfly species with 10-20 times more feeding hoverflies observed on these plants compared to that on California poppy (**Figure 4**). No hoverflies were observed feeding from phacelia (**Figure 4**), which may be attributable to phacelia having deep floral cups, thus preventing nectar access to hoverflies.

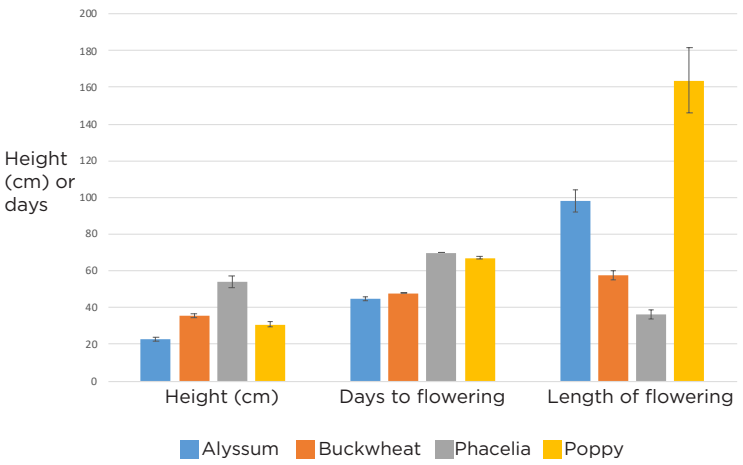

Figure 3. Average height, days to flowering and length of flowering for four plant species that were assessed for their attractiveness to Asian citrus psyllid natural enemies at Agricultural Operations at the University of California, Riverside.

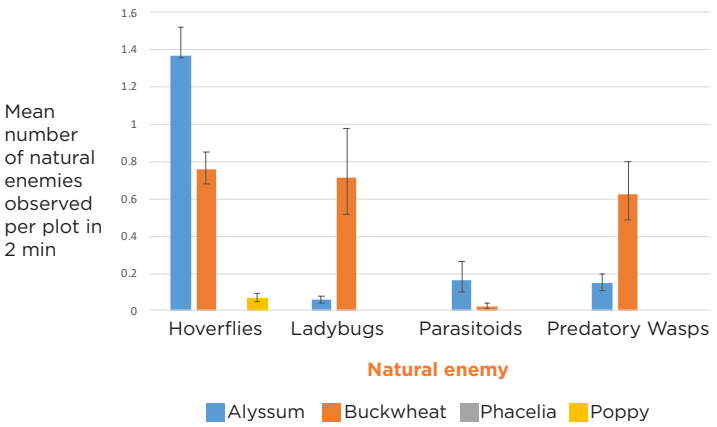

Figure 4. The mean number of hoverflies, ladybugs, parasitoids and predatory wasps counted in flowering alyssum, buckwheat, phacelia and California poppy plots at Agricultural Operations at the University of California, Riverside during two-minute observations every two to four days between April and August 2018.

Although California poppy flowered for 160 days, which was longer than all other plants tested, it only was marginally attractive to feeding hoverflies and failed to attract ladybugs, parasitoids or predatory wasps (**Figure 4**).

Alyssum bloomed for 42 days longer than buckwheat, and the height of alyssum was significantly shorter than the other three species tested (**Figure 3**). Eight times as many parasitoids were observed feeding on alyssum compared with buckwheat, and alyssum attracted twice as many hoverflies when compared to buckwheat (**Figure 4**). However, buckwheat attracted up to 13 times more ladybugs and predatory wasps compared with alyssum (**Figure 4**). Planting a mix of alyssum and buckwheat may extend nectar and pollen availability for hoverflies, and it also may promote a greater diversity of natural enemies of citrus pests.

Alyssum Enhances Hoverfly Populations, Reduces ACP Field Survival

To assess the impact of hoverflies on ACP survival in the field, two floral treatments (flowering alyssum and a control containing no flowering plants; [**Figure 5**]) were set up in blocks of unsprayed oranges and grapefruit at the Biocontrol Grove at the University of California, Riverside (UCR). Plots were separated by at least 100 feet.

Figure 5. Two floral treatments (A) 20 irrigated pots of flowering alyssum and (B) 20 irrigated pots of soil as a non-flowering control, each with four Asian citrus psyllid (ACP) treatments (potted citrus plants [Citrus volkameriana] infested with approximately 100 ACP nymphs placed on top of buckets with four different exposure treatments to natural enemies) set up in an unsprayed citrus orchard at the Biocontrol Grove at the University of California, Riverside in June 2018.

Close-up of experimental plots at UCR's Agricultural Operations.

In June 2018, potted citrus plants (*Citrus volkameriana* less than two years of age) infested with approximately 100 ACP nymphs were used to set up four ACP treatments to assess the effects different groups of natural enemies had on ACP survivorship rates (**Figure 5**):

1. A fine mesh bag excluded all natural enemies. This control treatment provided ACP survival rates in the absence of natural enemies.
2. A coarse mesh bag excluded large predators while allowing entry of small natural enemies such as ACP parasitoids (i.e., *Tamarixia*).
3. No mesh bag or "open" treatment allowed access to ACP colonies by all natural enemy species.
4. In a second open treatment, hoverfly eggs and larvae were removed daily, reared to adults and identified.

All other natural enemies were left on these plants. Each treatment was replicated twice. The numbers of surviving ACP by life stage were recorded for each treatment every other day. No parasitism by *Tamarixia* was recorded during the study period.

A total of 133 hoverfly eggs were laid on the eight citrus plants containing ACP colonies, and all were reared to adults and identified as *A. obliqua*. This result confirms earlier reports about the importance of this natural enemy for ACP control in southern California (Kistner and Hoddle 2015; Kistner et al. 2017). The number of hoverfly eggs laid on potted citrus plants and the abundance of predators (88 percent of which were hoverfly larvae) were 3.5 times and 2.5 times higher, respectively, on potted citrus plants deployed in alyssum plots compared with control plots lacking alyssum. Comparing ACP nymph survival between plant treatments exposed to all natural enemies showed that ten percent more nymphs survived to adulthood in the control plots than in plots containing potted flowering

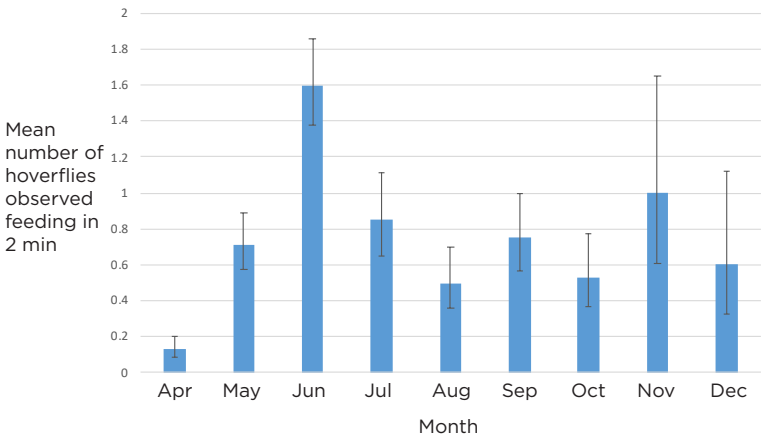

Figure 6. Mean number of hoverflies observed feeding from buckwheat flowers during two-minute observations conducted every two to four days from April through December 2018 at Agricultural Operations at the University of California, Riverside.

alyssum. These results suggest that flowering alyssum enhanced hoverfly oviposition and predator abundance in the field and translated to a ten percent decrease in ACP nymphs surviving to adulthood in these plots when compared with controls. When hoverfly eggs and larvae were removed from citrus plants, survival of ACP nymphs to adulthood increased by 27 percent.

Benefits of flowering plants may be further enhanced in larger commercial orchards because growers would establish them early in the spring and sustain them for several months. Our experiment deployed potted alyssum for two weeks prior to measuring natural enemy impacts. Additionally, the buffer zone between our experimental plots was 100 feet, and it is unknown how far foraging hoverflies disperse from flowers. Consequently, it is possible that hoverflies attracted to plots with flowers may have spilled over into plots without flowers, thus increasing ACP mortality in control plots. Further research is needed to determine the foraging distances of hoverflies in citrus orchards.

Additional studies were conducted from April through December 2018 to determine if the phenology of predatory hoverflies in southern California was synchronized with peak numbers of ACP. Based on two-minute counts, the numbers of hoverflies visiting patches of buckwheat were substantial during spring and fall (**Figure 6**), which are similar to peak activity times for ACP populations. Oviposition by *A. obliqua* (**Figure 1**) on potted citrus infested with approximately 100 ACP nymphs occurred from June through November. In addition, over the two-day observation periods, 1-20 eggs were laid on the experimental plants. In the laboratory, individual *A. obliqua* larvae that hatched from eggs removed from experimental plants were fed a known number (ranging from 100 – 400 nymphs) of ACP nymphs every 48 hours. Individual hoverfly larvae consumed an average of 421 ACP nymphs before pupating (**Figures 1C, D**).

Conclusions

Flowering plants, especially alyssum, are very attractive to adult hoverflies. In the field, the most important hoverfly species attacking ACP nymphs is *A. obliqua*. When alyssum is present, ACP colonies suffer greater levels of predation by *A. obliqua* larvae compared to ACP-infested citrus lacking alyssum. Further research will include using naturally occurring populations of ACP in long-term field trials containing large buffer zones between treatment plots and higher replication. Additionally, further investigation into potential effects of irrigated flowering plants on citrus tree growth, yield or fruit quality is needed to ensure the extra irrigation required to grow and sustain a flowering cover crop in southern California does not indirectly increase pest abundance by increasing tree vigor. Placing flowering plants around field margins or in small patches planted between tree rows and spread throughout the orchard may reduce establishment costs and potential irrigation effects on vigor compared to growing them down an entire row. Further research will be conducted this season to investigate how far hoverflies disperse from flowering plants to help determine optimal space of flower patches.

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Glossary

[1]**Oviposition:** Laying or depositing eggs.

[2]**Nymph:** An immature Asian citrus psyllid (ACP) that has hatched from the egg. ACP passes through five nymphal instars before reaching the adult stage.

[3]**Generalist predator:** A predator that eats a variety of prey species.

[4]**Life table:** A table summarizing mortality, survivorship and reproduction rates of individuals within a population.

[5]**Parasitoid:** An insect whose larvae require a single host for development, which results in host death.

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