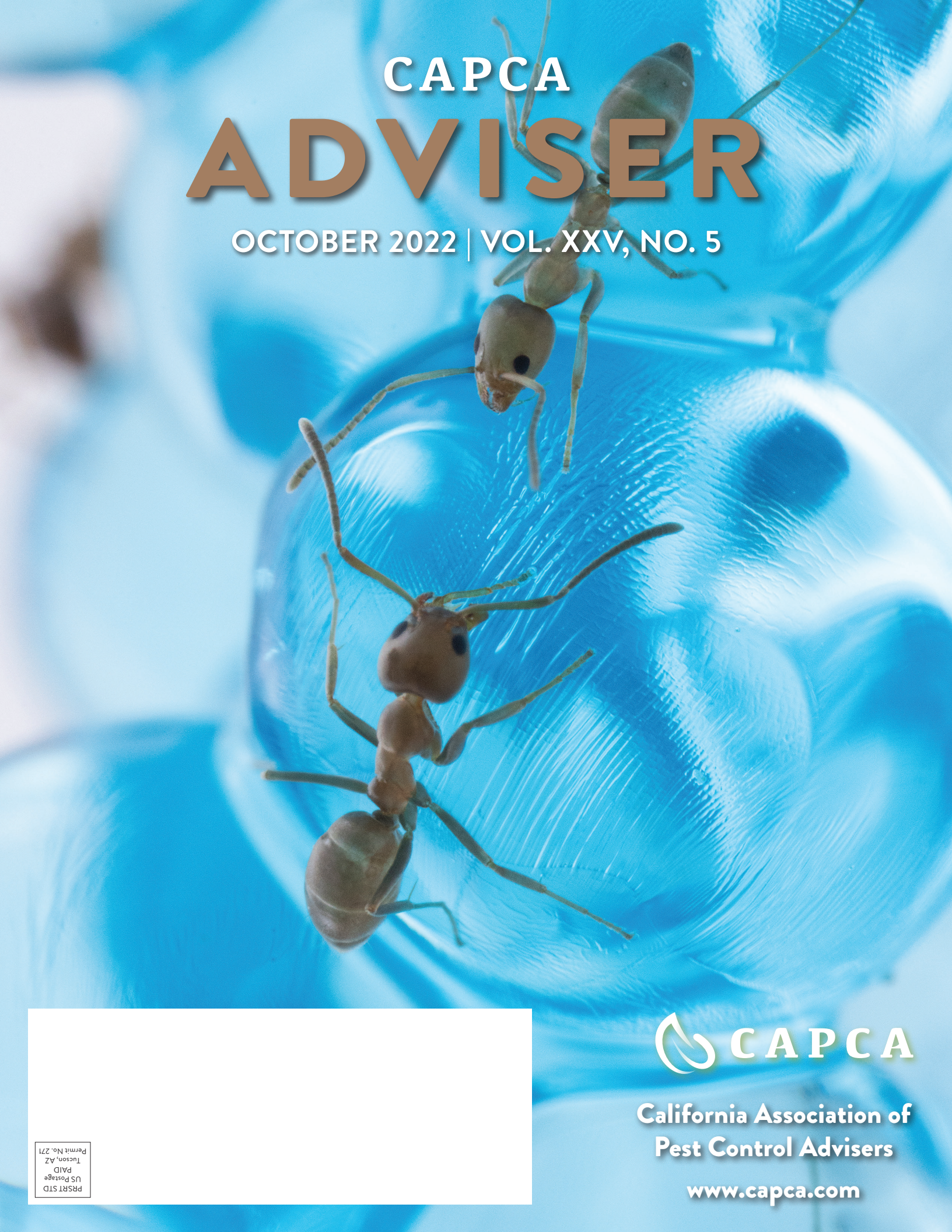

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# Advances in cover cropping for enhancing natural enemies of Asian citrus psyllid in Southern California citrus orchards

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## Can flowering plants enhance biological control of Asian citrus psyllid?

In Southern California citrus, generalist predators such as hoverfly larvae (Diptera: Syrphidae), feed on immature Asian citrus psyllid (ACP). Life table and videography studies have demonstrated that hoverfly larvae cause significant mortality of ACP (Kistner et al. 2017). Hoverfly larvae are predacious, while adults require nectar and pollen for energy and egg maturation, respectively. Incorporating a flowering cover crop (also known as insectary plantings) 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 (Silva et al. 2010). Research conducted by our laboratory demonstrated that flowering buckwheat (Fig. 1A) and alyssum (Fig. 1B) are attractive to predatory hoverflies (Fig. 1C). Coccinellids also feed from buckwheat flowers (Fig. 1D). When incorporated into citrus orchards, these insectary plants increased hoverfly oviposition and predator abundance which resulted in a 10% decrease in the number of immature ACP surviving to adulthood (Irvin et al. 2021). We built on these findings by determining (1) when hoverflies are active in citrus orchards and (2) when and where to sow flowering plants in orchards to attract hoverflies. The work reported here was conducted in a commercial citrus orchard in Mentone, San Bernardino County CA.

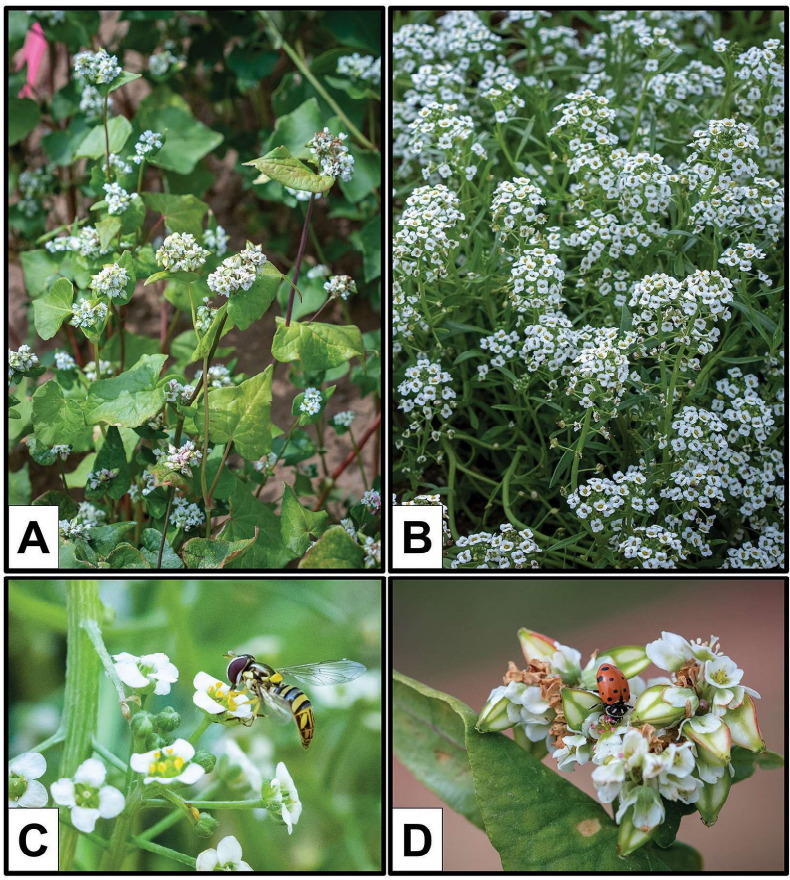


**FIG. 1:** (A) Flowering buckwheat (*Fagopyrum esculentum*); (B) Flowering alyssum (*Lobularia maritima*); (C) Hoverfly adult feeding from an alyssum flower; (D) Predatory ladybug feeding from a buckwheat flower.

## Identifying periods of hoverfly activity

To ensure that cover crop flowering is synchronized with periods of hoverfly activity, we monitored hoverflies from May through November 2021 using two methods: 1) deploying 20 vertically positioned yellow sticky traps every two weeks throughout the orchard, and 2) conducting monthly 3-min timed counts of hoverflies observed on weeds and citrus foliage in 20 areas throughout the orchard. Results from both the trap catches and visual counts demonstrated that hoverfly activity in Southern California is most prevalent in spring and fall and this is when flowering cover crops would be most beneficial to hoverflies (Fig. 2). This finding is important as ACP populations tend to be greater in spring and fall as well (Milosavljević et al.

2021). Extreme summer temperatures may force hoverflies in Southern California into summer dormancy when conditions become unfavorable. This time of year may also be difficult for cover crop growth, not only because of heat, but also for the need for water to sustain these plants.

### When and where to sow flowering plants to enhance hoverflies

Buckwheat and alyssum seed are commercially-available and seed was sown in 10 plots throughout the orchard on March 29th, 2021 at the recommended sowing rate (buckwheat: 3 lb per 1000 square feet; alyssum: 1 ounce per 1,000 square feet) in a 20 x 3.2-foot strip, in the open center between tree rows. Supplemental irrigation was provided. Drought conditions in Southern California in mid-July 2021 restricted water availability to growers which significantly reduced the amount of available water to irrigate cover crops. Sowing flowering plants early spring (late-February) and allowing the plants to die off over the summer before re-sowing in the fall (early-September), would help synchronize nectar production with hoverfly activity, while minimizing water costs to maintain these plants.

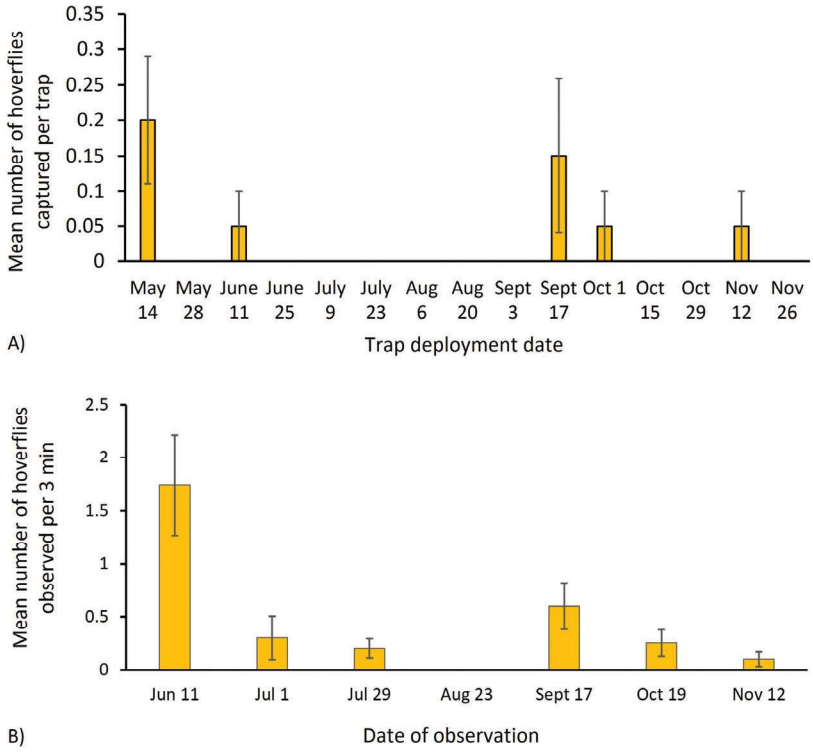


**FIG. 2:** (A) The mean number of hoverflies captured across 20 vertically positioned yellow sticky traps deployed throughout the orchard every two weeks from May 14th through November 26th, 2021; (B) The mean number of hoverflies counted during 3 min. timed observations of weeds and citrus foliage throughout the orchard each month from June 11th through Nov 12th, 2021.

Successful germination of alyssum and buckwheat seeds in UCR potting mix maintained in a greenhouse at UCR

Non-existent germination of alyssum and buckwheat seeds in soil collected from field plots at the study site.

**FIG. 3:** Trial conducted in a greenhouse to compare seed germination rates between pots containing orchard soil and pots containing potting mix. On average, 23.6 ± 3.6 alyssum seeds and 1.0 ± 0.32 buckwheat seeds germinated in UCR potting mix compared with zero alyssum and buckwheat seeds in soil collected from an orchard. We suspect that pre-emergent herbicide residues negatively affect germination rates of cover crop seeds.

Residue of pre-emergent herbicides, such as Simazine and Krovar, may be problematic for cover crop germination when seeds are planted in between tree rows. Germination trials with buckwheat and alyssum seeds that were planted in soil collected from orchards or potting mix clearly showed that orchard soil with pre-emergent herbicide residues negatively affected seed germination (Fig. 3). The effects of pre-emergent herbicides applied to soil between trees may be mitigated by transplanting seedlings or planting seeds within tree lines. When buckwheat seeds are planted within tree lines in spring, germination rates are 2.5 times greater when compared to germination rates for seeds that are sown between rows. Planting seeds within tree rows where there is partial shade, may eliminate the need for supplemental watering to keep cover crops alive.

### Can flowering alyssum enhance populations of hoverflies in the fall?

To assess the effects of cover crops on hoverfly abundance in citrus orchards, plots of transplanted alyssum 20 x 3.2 feet in size and control plots containing no flowering plants were set up between tree rows throughout the orchard in June 2021 (Fig. 4). The number of hoverflies foraging on alyssum flowers were counted during 3-min timed observations in alyssum plots six times across October and November, 2021. Additionally, on these dates, the number of hoverflies foraging on flowering weeds (e.g., see list of weeds in the subsequent section) in control plots was also recorded. On average, 13 times more hoverflies were counted on alyssum compared with weeds in control plots (Fig. 5). This demonstrates that flowering alyssum is attractive to hoverflies, and suggests that providing flowering alyssum in citrus orchards in the fall may attract and retain hoverflies, boosting populations of hoverflies for biological control of ACP and other citrus pests. Consequently, this may also increase the number of overwintering hoverfly pupae to start the spring generation of these predatory insects (Campbell and Davidson, 1924).

### Identifying weed species and abundance of flowers

Flowering weeds in orchards may provide resources for hoverflies and other natural enemies. It is unknown what the densities and species of flowering weeds are in citrus orchards throughout the year under normal orchard

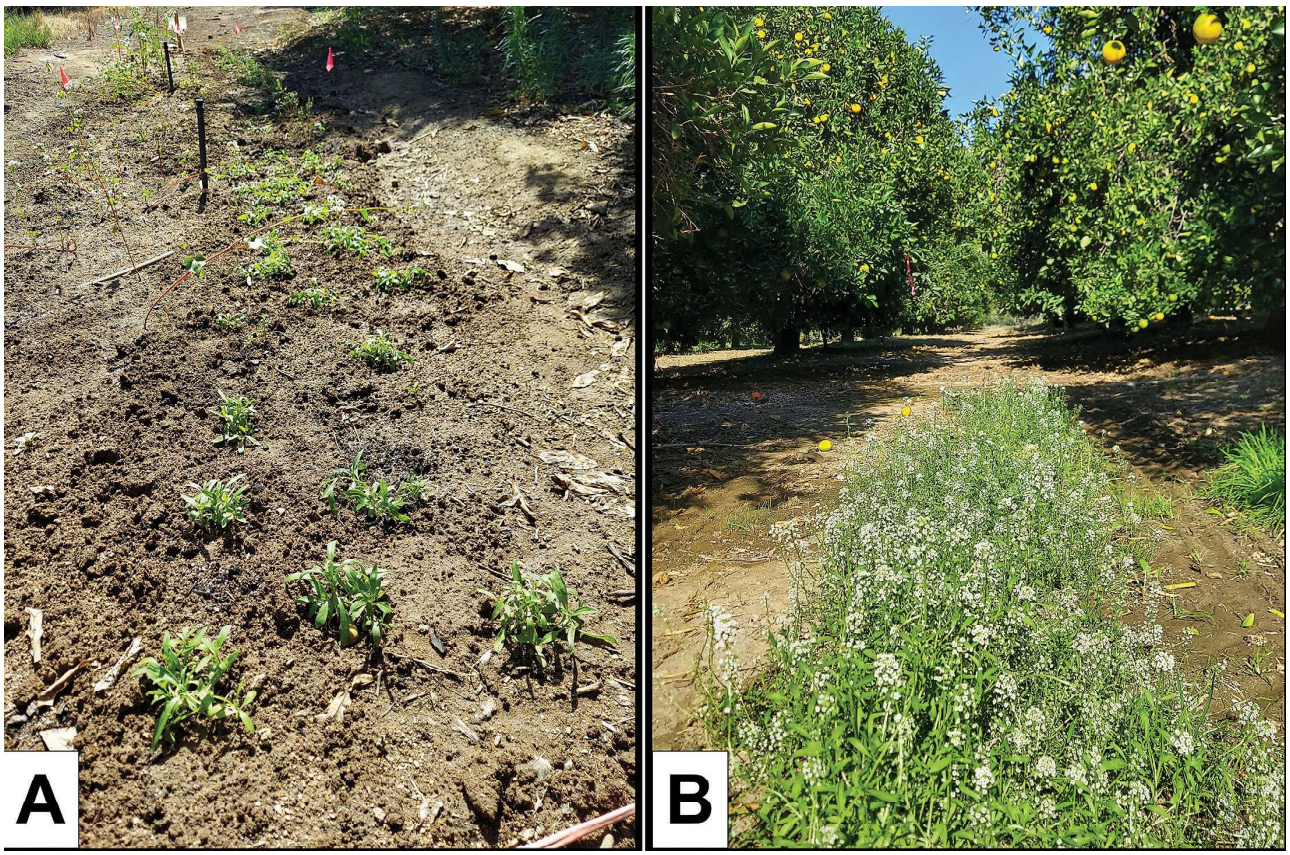


**FIG. 4:** (A) Alyssum plants were transplanted between tree rows in June 2021 and flowered six weeks later. Transplanting was necessary to overcome poor seed germination rates which was possibly due to pre-emergent herbicide residues. (B) Alyssum flowering profusely in fall 2021, which attracted and fed adult hoverflies. Fall and spring are times of year when hoverflies and ACP are most active in citrus orchards.

practices of herbicide use and mowing. To better understand weed biodiversity in citrus orchards we conducted monthly transect walks to determine the identity and number of flowering weeds. Forty transects, each 49 x 3.2 feet long, were conducted monthly at random locations in the orchard over May through November, 2021.

Six main weed species were identified from transect surveys: scarlet pimpernel (*Lysimachia arvensis*), sow thistle (*Sonchus* sp.), mustard (*Brassica nigra*), sweet clover (*Melilotus indicus*), stinking chamomile (*Anthemis cotula*), and prickly lettuce (*Lactuca serriola*) which flowered at different times. However, not all flowering resources function as food sources for natural enemies due to flower morphology that may prevent natural enemies from accessing nectar, or nectar maybe of poor quality (Karp et al. 2018). Surveys suggest that hoverflies prefer foraging on alyssum when compared with weeds (Fig. 5). Additionally, survey results showed that general orchard practices and the hot dry climate removed most flowering weeds from June-Nov (Fig. 6). These findings collectively illustrate the need for providing flowering plants, like alyssum, to sustain hoverflies in citrus orchards.

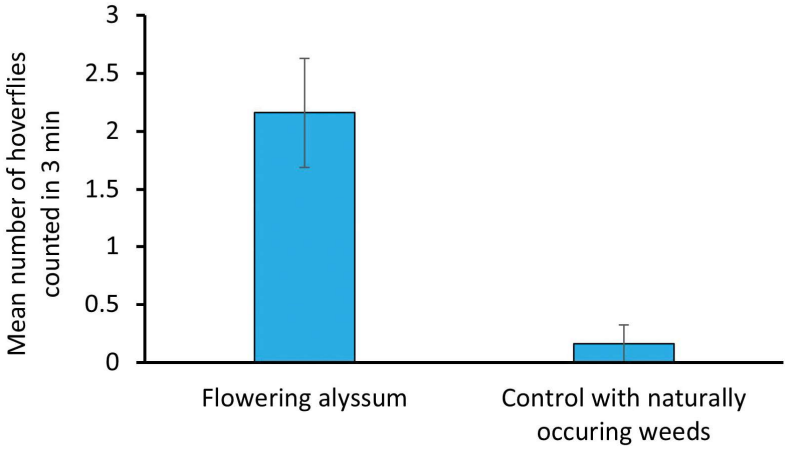


**FIG. 5:** The mean number of hoverflies counted during 3 min. timed observations in flowering alyssum plots compared with control plots containing weeds in a citrus orchard in fall 2021.

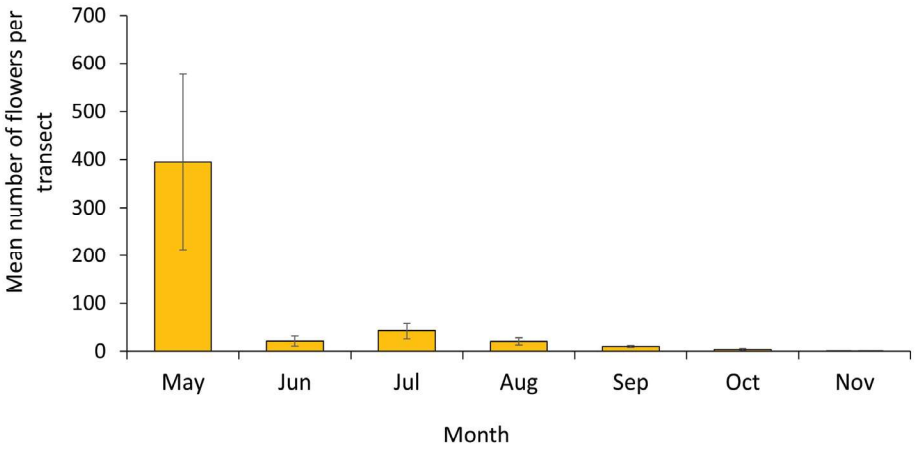


**FIG. 6:** The mean number of flowers on weeds observed along forty 49 x 3.2 feet long transects each month.

We are currently conducting studies in two commercial citrus orchards to determine if increased numbers of hoverflies due to cover crops results in lower pest densities. These field studies are also assessing different methods for passively monitoring hoverflies (e.g., vertical vs. horizontal yellow sticky cards and different types of pan traps), which curiously is something that has so far proven difficult. At the end of this field season we will have a much better understanding of the contributions insectary plantings and hoverflies provide in controlling ACP and other citrus pests and how best to monitor hoverflies with traps.

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