PROJECT: Assembling and synthesizing information on melon pollinator health to develop best management practices.

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Summary: This project combines field collections with information synthesis to provide growers with information on the pollinator communities in melon crops, floral biology of melons, and strategies to conserve pollinators and pollination services from managed and wild bees.

Objective 1: Review and synthesis of literature on melon pollination and best management practices for pollinators in cucurbits.

1. Pollination biology of melons.

Successful melon production requires insect-mediated pollination (Bohn & Davis 1964, Mann 1953). The large, sticky pollen grains produced by melon flowers cannot be moved by wind (Mussen et al. 1997), but are readily transferred by pollinators, particularly bees. *C. melo* flowers can be perfect, and produce only nectar, or staminate, and also produce pollen. Bees are more likely to visit and spend about 50% longer on perfect flowers versus staminate flowers (Mann 1953). The majority of nectar production occurs during the first half of the day (Mann 1953), and individual flowers typically are only open for a single day before senescence (Mussen & Thorp 1997). For optimal fruit development to occur, an estimated up to 500-1000 pollen grains must be transferred to stigmas; any less pollen deposition results in irregularly shaped fruit (Mussen & Thorp 1997). This approximate pollination requirement is shared by both *C. melo* and watermelon (Delaplane et al. 2000). The amount of bee visitation required to achieve this optimal pollen deposition has not been estimated in *C. melo*, but is estimated as eight honey bee visits in the related watermelon system (Adlerz 1966).

2. Pollinator diversity in melons.

Honey bees (*Apis mellifera*) are the primary managed pollinators used in melon pollination, where an estimated 1-5 colonies per acre are required for adequate pollination (Delaplane et al. 2000). Colonies can be placed in open fields or under row covers (Gaye et al. 1991), but are recommended to be placed within fields to encourage visitation to crop plants rather than alternative forage (Mussen & Thorp 1997). Honey bees cannot be used for melon pollination in greenhouses, as they do not collect pollen under these conditions (Eisikowitch & Dag 2001). Honey bee colonies are recommended to be placed in fields during the first days of the bloom period (Mussen & Thorp 1997), but slight delays (on the order of a week) do not significantly impact crop yields (Eischen et al. 1994).

Although they are not typically managed for melon pollination, there are several non-*Apis* pollinators of melon that are viable alternative pollinators. Several studies even suggest that bumble bees are more effective pollinators of melon, relative to honey bees (but see Dag et al. 1996). For example in *C. melo* L. (var. Makdimon F1), bumble bee-pollinated melons are on average heavier, larger, and have more seeds than when honey bee-pollinated (Dasgan et al. 1997). In oriental melon (*C. melo* L. cv. Sagyejeol-Ggul), pollination by both honey bees and bumble bees had strong impacts on melon quality, but bumble bee pollination increased fruit hardness up 27% (Shin et al. 2007). Bumble bees have also been found to be highly effective pollinators of *C. melo* L. cv. Derish (Fisher & Pomeroy 1989).

In addition to bumble bees, other wild, native bees have promise as melon pollinators. In Israel, the managed carpenter bee *Xylocopa pubescens* produces *C. melo* equal in fruit set, seed number, and fruit mass to honey bee-pollinated melons (Sadeh et al. 2007). In Brazil, sweat bees (*Halictus* sp.), stingless bees (*Plebeia* sp., *Trigona pallens*, *T. spinipes*), and honey bees visit *C. melo* L. and fruit weight is positively associated with visitation frequency by this cohort of species (Tschoeke et al. 2015). In central Spain, sweat bees (in particular in the genus *Lasioglossum*) are frequent visitors to melon throughout the season (Rodrigo Gomez et al. 2016). In our own study, we identified several non-*Apis* visitors to melon (see data below). In the better-studied watermelon system, where non-*Apis* bees are also important pollinators (Brewer 1974), reliance on these “alternative pollinators” in watermelon production is projected to increase with climate change (Rader et al. 2013). Whether this prediction also applies to *C. melo* pollination is currently unknown.

3. Effects of chemical pest controls on pollinators in melons.

Very few studies have explicitly examined pesticide effects on pollinators in melon. Da Silva et al. (2015) found more than twice the amount of unique pesticides found in honey bee honey stores near muskmelon fields relative hives placed in a nearby forest in Brazil (da Silva et al. 2015). Additional laboratory studies have shown that several key pesticides used in melon in this system (thiamethoxam, abamectin, and chlorfenapyr) are extremely toxic to honey bees (Costa et al. 2013). More research is clearly needed in US melon production systems to examine how the unique suites of pesticides used in the US impact pollinators and to develop effective strategies for minimizing harmful impacts on pollinators.

Some general recommendations on how to balance the needs of protecting melon crops from pests while maintaining healthy pollinator populations can be derived from the pollination biology of melon (described above). Pesticides known to have harmful impacts on pollinators should not be applied during flowering periods, or at a minimum should only be applied in late evening or night. Managed honey bee and bumble bee hives should be removed from production areas as soon as the crop has set (Mussen & Thorp 1997). These general practices are outlined in Mussen & Thorp (1997).

4. Existing BMPs for pollinators in cucurbits.

The following are existing BMPs, factsheets, and guidelines for managing pollinators in cucurbits:

Melon.

Documents:
The 2016 edition of the Pest Management Strategic Plan for Cantaloupes, Honeydews, and Mixed Melon Production in California has a brief entry of recommendations for pollinator management practices. The PMSP cites areas for future research which were covered in the literature review above.
https://ipmdata.ipmcenters.org/documents/pmsps/2016%20CA%20Melon%20PMSP.pdf

UC ANR produced one publication on pollination in muskmelons in 1997. This document has not been updated since publication (22 years) and we expect that many recommendations may be outdated.
https://anrcatalog.ucanr.edu/pdf/7224.pdf

A report from the nonprofit Pollinator Partnership was produced that outlined practices for promoting pollinators in multiple crops, including melon.
https://www.pollinator.org/pollinator.org/assets/generalFiles/SecuringPollinatorHealthCropProtection_170529_084505.pdf

The Australian nonprofit Bee Aware produced a brochure detailing the significance and management of pollinators in Australian melon production.
https://beeaware.org.au/wp-content/uploads/2019/06/Melon-pollination-brochure.pdf

Cucumber.

Documents:
Seminis: Best Management Practices for Cucumbers. This BMP document includes a brief section on recommendations for pollinator protection and improving pollination.
https://seminisus.s3.amazonaws.com/app/uploads/2016/11/Best-Management-Practices-for-Cucumbers-Seminis-1.pdf

Watermelon.

Documents:
Recent research from personnel at UC Davis has produced up-to-date guides on pollinator protection and pollination in watermelons. Based on our research, this may be the most useful starting point for producing similar documents on pollination for muskmelons.

http://icpbees.org/wp-content/uploads/2014/05/CA_Watermelon_final.pdf

The University of Florida has also produced a guide on watermelon pollination.

https://edis.ifas.ufl.edu/pdffiles/AA/AA09100.pdf

Squash.

Documents:
The Integrated Crop Pollination (ICP) project produced a document on the importance of pollination in squash, pumpkins, and gourds.
http://icpbees.org/wp-content/uploads/2014/05/Integrated-Crop-Pollination-for-Cucurbita-crops.pdf

Penn State has assembled additional information on squash pollination on this website.
https://extension.psu.edu/pumpkin-pollinators

Other resources.

General references on integrated crop pollination in specialty crops has been assembled by the ICP project. These resources provide information on managing honey bees and alternative pollinators, as well as pesticide exposure mitigation, but does not contain specific guidelines for muskmelons.

Guide to integrated crop pollination

http://icpbees.org/wp-content/uploads/2014/05/Guide_to_ICP_book-FINAL_August2017.pdf

Guidelines and best practices for conserving alternative (native) bee pollinators on farmland

https://www.canr.msu.edu/nativeplants/uploads/files/E2985ConservingNativeBees.pdf

Decision trees for improving pollination with native bees and minimizing pesticide impacts on honey bees and other pollinators

http://icpbees.org/wp-content/uploads/2014/05/Pollinator-habitat-decision-trees-Final.pdf

Ways to reduce bee poisoning

https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/pnw591.pdf

Objective 2: Sampling of pollinator communities in CA melon fields.

For this objective, we performed collections and observations of bee visitations to a trial melon field in a diverse cropping system (the UC Riverside Agricultural Operations Facility). This field was not treated with insecticides and was embedded in a network of many different fruit tree, annual, and perennial crops that provide additional pollinator resources. As a result, the bee community on site was diverse, allowing us to assess the frequency of visitations by non-honey bee pollinators. Honeybees are also on site within the vicinity of the melon field (a full apiary within ½ mile of the melon field) and was used as a baseline for overall pollinator activity. The sampling strategy involved observations and collections across multiple time points to understand what pollinators are visiting flowers and how honeybee activity compares to non-managed visitors.

The following protocol was followed:
Overall sampling period: During peak bloom period (3 weeks), sample melon visitors 3 times per week, aiming for different time periods each time you sample (for example: 7-8 AM on one day, 8-9 AM the second day, 9-10 AM the third day)

Sampling/observation protocol:

- Round 1A: Have one collector walk along around the perimeter of the area, counting the number of honey bees (using a clicker). Stop and count within, for example, a 3-ft length of the row, then move forward to the next 3-ft length and count, and so on. This ensured counting all of the individual honeybees and avoiding any accidental recounts.

- Round 1B: Next, the collector walks along the perimeter and collects any insects they see other than honey bees and cucumber beetles. Only collect and/or document insects observed in contact with reproductive parts of flowers. Collect using vials or a bug vacuum to avoid destroying flowers.

- Next, wait at least 20 minutes until proceeding to 2A and 2B.

- Round 2A: The other collector performs the same steps as in round 1A.

- Round 2B: The other collector performs the same steps as in round 1B.

Collect insects into dry vials on ice in a cooler then kill in the -20 in the lab. Keep in the -20 until ready to pin (no longer than 1 week).

Results of the field collection indicate that alternative pollinators are present during most sampling dates. The percentage of total observations made up by these alternative bee visitors ranges from about 5-50% of all pollinator observations for a sampling date. There is no clear explanation for variation in the ratio of alternative bee pollinators to honey bee pollinators. In a regression analysis, honey bee activity was not a significant predictor of alternative pollinator activity. Date was a significant predictor of honeybee activity, with visitation declining over the course of the bloom period. However, similar declines were not observed for alternative pollinators (Table 1).

Honey bees were generally the most abundant visitors, followed by cucumber beetles (not shown) (Fig. 1). The most abundant alternative pollinator was *Agapostemon* spp. (jeweled sweat bees), which made up 87.6% of visitations by alternative pollinators (Fig. 2). Another key finding is that bumble bees are using melons as pollen and nectar resources. On multiple occasions we observed a relatively rare bumble bee species (*B. californicus*) visiting flowers during early morning observation periods (8-9am) before elevated temperatures occurred later in the day(Fig. 2). Overall, our results suggest that honey bees are the most common visitors, but that alternative pollinators are common enough to potentially contribute to overall fruit set. The efficiency of these alternative pollinators should be explored experimentally, especially that of bumble bees, for which commercial production of western bumble bee species is in progress.

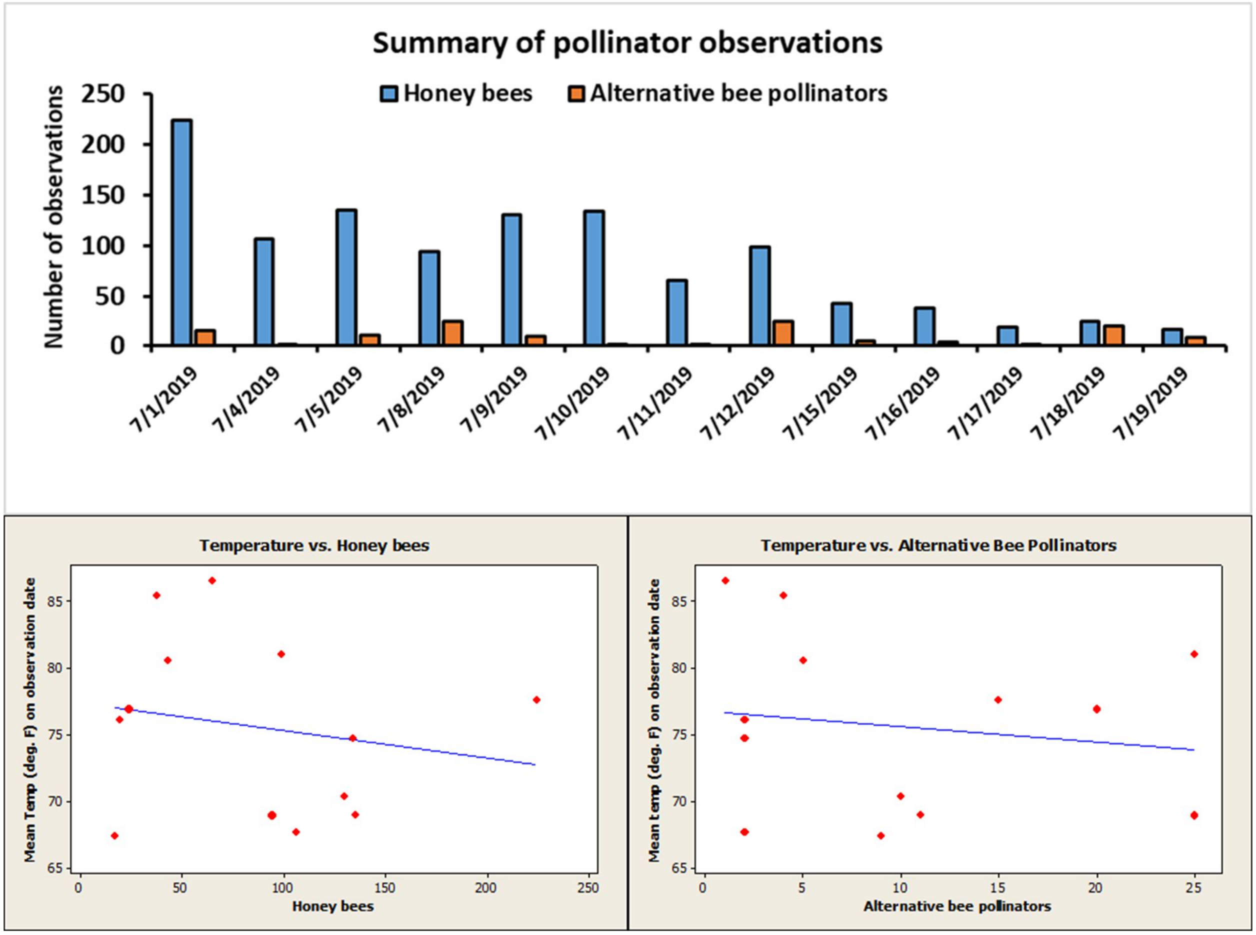

Figure 1: Summary of bee observations over approximately three weeks of the melon bloom period (early to late bloom). Honeybee visitations declined over the course of the bloom period, while alternative pollinator visitations did not exhibit declines over time. Regressions exploring changes in honeybee and alternative pollinator visitations with fluctuations in temperature suggest that temperature is not a significant predictor of bee visits in melons within the ranges experienced during the study.

Honey bees = 430540 + 0.64 Avg temp - 9.86 Date

Predictor	Coef	SE Coef	T	P
Constant	430540	62946	6.84	0.000
Avg temp	0.636	1.245	0.51	0.621
Date	-9.861	1.442	-6.84	0.000

S = 27.3411 R-Sq = 83.0% R-Sq(adj) = 79.6%

Alternative bee pollinators = 3887 - 0.188 Avg temp - 0.088 Date

Predictor	Coef	SE Coef	T	P
Constant	3887	21661	0.18	0.861
Avg temp	-0.1878	0.4285	-0.44	0.671
Date	-0.0885	0.4964	-0.18	0.862

S = 9.40875 R-Sq = 2.8% R-Sq(adj) = 0.0%

Table 1: Regression outputs for bee visitations, with date and temperature as predictors. Date is a significant predictor of honeybee visits to melon flowers.

Figure 2: Representative images of alternative (non-honeybee) pollinators observed in fields of cantaloupe cv. Gold Express. Top row: family Halictidae (sweat bees), tentative identification of *Halictus ligatus*. Bottom row: first three images are family Halictidae, *Agapostemon* spp., last image is of a bumble bee in the family Apidae, tentative identification of *Bombus californicus*. Both species in the Halictidae are ground nesting bees that readily create nests in level, well-drained, vegetation-free soil. *Halictus ligatus* nests communally for protection against parasitic bee species, while *Agapostemon* species are solitary. *Bombus californicus* is considered a "vulnerable" *Bombus* species and it nests in a variety of locations. Of the total percentage of alternative bee pollinators, *Agapostemon* spp. constituted 87.6% and *H. ligatus* and *B. californicus* constituted 6.2% each.

Objective 3: Develop a survey to evaluate current grower practices regarding pollinator management. Our literature survey and evaluation of existing BMPs/guidelines for managing pollination in melons indicates that there are many areas for which additional information from growers is required to move forward. The Integrated Crop Pollination project (a USDA-funded initiative) developed a survey for collecting information on pollination practices in specialty crops (http://icpbees.org/wp-content/uploads/2016/03/ICP_Survey_11-1-2014.pdf). This survey was deployed in 2014 and has yielded publications on grower practices for several crops (e.g., almonds, blueberries). The survey is specifically designed to determine what pollinators are being used, how they are being obtained, how they are deployed, and what challenges growers encounter in ensuring pollination and bee protection from other chemical treatments. This information will be explored in the context of farm size and pest management practices/challenges. We will adapt this survey (example page in Fig. 3) and obtain approval to administer it through respective institutions serving growers in main melon production regions of California.

Those interested in taking the survey during 2020 and contributing to efforts to produce BMPs for muskmelon pollination in California can contact
Dr. Kerry Mauck at kerry.mauck@ucr.edu or 951-827-5444.

The survey will take about 10 minutes and does not include any personal information beyond general farm location, size, and crop diversity.

Figure 3: Sample excerpt from the ICP Specialty Crop Pollination Survey

Pollinator Management	Currently Use	Tried & Discontinued	Never Used
Rent managed honey bees	☐	☐	☐
Purchase and/or manage solitary bees (e.g., mason bees, blue orchard bees)	☐	☐	☐
Encourage wild pollinators with temporary cover crops	☐	☐	☐
Encourage wild pollinators with permanent habitat area (e.g., hedgerows, bee pasture/meadows, pollinator food plots)	☐	☐	☐
Support production of managed bees (e.g., honey bees, mason bees, bumble bees) with cover crop and/or permanent bee pasture	☐	☐	☐
Maintain written monitoring records for bees (e.g., crop scouting for floral visitation)	☐	☐	☐
Create bee nesting sites (e.g., installing bee boxes or leaving areas of untilled soil).	☐	☐	☐
Maintain written monitoring records for bees (e.g., crop scouting for floral visitation)	☐	☐	☐
Other method of pollination management (please describe): ________________________________	☐	☐	☐

Pest Management			
Time insecticide applications to minimize impacts on bees	☐	☐	☐
Make effort to choose active ingredients that have least impact on bees or other beneficial insects	☐	☐	☐
Time fungicide applications to minimize impacts on bees	☐	☐	☐
Reduce number of sprays to protect beneficial insects	☐	☐	☐
Use "smart spray" technology that turns off when no crop plants are present	☐	☐	☐
Use low volume sprayer technology that permits lower rates of active ingredient	☐	☐	☐
Spot spraying instead of treating entire field	☐	☐	☐
Use pheromones for pest mating disruption	☐	☐	☐
Other method of pest management (please describe): ________________________________	☐	☐	☐

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