Integrated Crop Pollination Bridging Funds

Project No.: **13-POLL13A-Peterson**

Project Leader: Stephen Peterson, Ph.D.
Entomologist
AgPollen LLC
14540 Claribel Road
Waterford, CA 95386
209.338.7110
speterson@agpollen.com

Project Cooperators and Personnel:

Theresa Pitts-Singer, Ph.D., Research Entomologist, USDA-ARS
Derek R. Artz, Ph.D., Research Biologist, USDA-ARS
Nicholas Chase, Apiarist, AgPollen LLC
David Moreland, Almond Producer, Framework Ranch, LLC
Darrell Digiovanni, Almond Producer, Farm Management, Inc.
Tom Chance, Almond Producer, Chance Bros.
Project Apis m. (PAm)

Objectives:

The following objectives were carried out in the central almond producing region of Stanislaus and Merced Counties, California:

1. Plant three bee forage seed mixes and evaluate establishment rate, bloom timing, bee visitation and costs.
2. Release blue orchard bees (BOBs), *Osmia lignaria*, as supplemental pollinators in almonds and measure flower visitation rates compared with honey bees (HBs).
3. Examine the effect of managed bee pollinators on fruit set and yield in almonds.
4. Measure BOB reproduction rate in almonds.
5. Assess the costs and benefits of supplemental pollination with BOBs.

Interpretive Summary:

- Drought conditions over the winter of 2013-14 caused late-planted, unirrigated bee forage plantings to fail. Earlier planted plots of a wildflower mix and mustard mix were more successful and it was found that both bloomed heavily in March and April. The mustard mix produced more flowers per m^2 and attracted more HBs but was finished blooming sooner than the wildflower mix.
- Pollination efficacy of the HB and BOB was evaluated in eight orchards. BOBs were released as emerged adults during the early stages of almond bloom at a rate of 324 females per acre in four orchards. Establishment ranged from 6 to 23%.
- HBs were observed visiting flowers at an average rate of 0.12 bees per flower per hour. No BOBs were seen during the sampling of flowers but were readily observed returning to nests with almond pollen and mud.
- All eight orchards in the study were treated with fungicides twice during bloom from February 17 to 26.

- Fruit set was improved where BOBs were present, averaging 34% in the HB-only orchards compared to 43% in the regions supplemented with BOBs.
- Recovery of female BOB offspring is estimated to range from 7 to 21%, depending on the orchard.

Materials and Methods:

Objective 1

Three different forage mixes (**Table 1**) were planted adjacent to an almond orchard in Stanislaus County. The ground was prepared in the fall by disking three times. Seeds were sown using a Schmeiser no-till drill on November 19, 2013.

Table 1. Composition of seed mixes, acres planted and seeding rates for each.

	Wildflower seed mix	**PAm mustard mix**	**PAm Capay clover mix**
Flower species in mix:	Baby blue eyes California blue bells California poppy Chinese houses Five spot Great Valley phacelia Lacy leaf Phacelia	Braco white mustard Canola Daikon radish Nemfix mustard	Alyssum Crimson clover Frontier balansa clover Hykon rose clover Nitro Persian clover
Acres planted:	0.40	1.19	0.46
Seeding rate (lb./A):	20.4	6.2	22.2

In addition, 20 plots (6 x 9 ft each) at the ends of almond rows were seeded by hand with the Wildflower mix at a rate of 13.1 lb. per acre on November 7, 2013. These plots were irrigated by the almond micro-emitters when the trees were watered.

Plant density was measured on by counting the number of plants in 40 1-m^2 quadrats in each plot.

On March 11, blooming plots of the PAm wildflower mix (which includes *Alyssum* but does not include *Phacelia*) and PAm mustard mix were found at the Chance Bros. ranch in Merced County. There were 0.09 acres of the wildflower mix along a berm in a flood irrigated orchard and 0.25 acres of the mustard mix along a border road. These plots were sown by hand November 2, 2013; 17 days earlier than the previously described border plots were planted. HBs and wild bee visitation samples were made in these plots and in an unenhanced control plot using standardized timed samples (100 m transect, observed for 20 minutes).

Objective 2

Four plots in separate almond orchards in Stanislaus and Merced counties were selected for supplemental pollination with BOBs. Each of these orchards had a normal complement of HBs for pollination (2 hives per acre). Nesting sites were deployed in 5-acre blocks, approximately 660 x 330 ft, starting 16 rows into each orchard (**Figure 1**). These nesting sites consisted of grooved wooden laminates with corrugated plastic roofs (**Figure 1**, inset) hung in the trees at a

rate of 15 per acre (75 total per plot). Each of these nesting sites had 64 cavities suitable for nesting. A total of 7,963 BOB females and approximately 16,000 males were incubated at 22°C beginning on February 5. Bees were collected as they emerged and held in refrigeration until the orchards had sufficient open blossoms for the bees. 90% of the females emerged for an actual release rate of 324 females per acre. Bees were released in the center of the BOB blocks on 2 dates in each orchard with the first release occurring February 18-20 and the second release occurring February 20-21 depending on the orchard. The first release consisted of most of the male population and 14% of the females and the second release consisted of 86% of the females. A sample of nesting sites was examined at night on February 25 and March 5 to estimate female establishment.

Seen in **Figure 1** below, sampling bee visitation, fruit set, and yield was done in Nonpareil variety rows 2, 10, 30, 40 and 60 (+/- 1 row). The BOBs nested in rows 16 to 45, thus sample rows 30 and 40 were in the BOB blocks. Samples were taken on 5 trees in each sample row. During bloom, bee visitation to almond flowers was measured by watching a group of flowers (average = 21.6) for 20 seconds in four areas of a tree (top interior, top exterior, bottom interior, and bottom exterior). The four control orchards, with HBs only for pollination, were sampled in an identical fashion. These observations were conducted when the temperature was above 13°C, with winds less than 2.5 m/s, between 10:00 am to 4:00 pm.

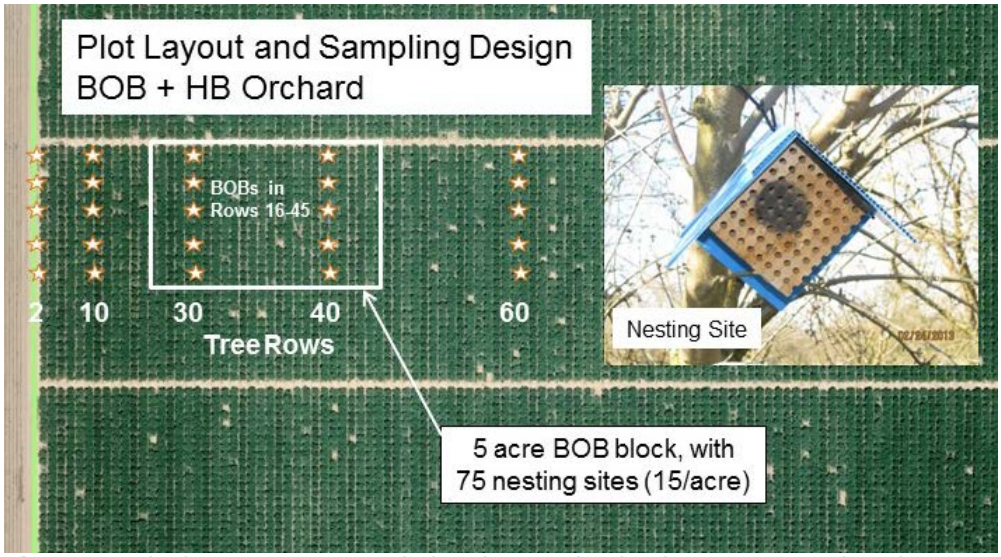


Figure 1. Plot layout, trees sampled and a wooden laminate BOB nesting site.

Pesticide application records were obtained from each orchard in the study. Completed nests were counted weekly. Nests were retrieved from the orchards on April 24 and held at a constant 26°C. Samples of offspring were opened to determine stage of development and when >90% had been adults for 3 weeks the population was cooled to 15°C, then to 10°C each for one week and then the population was cooled to a wintering temperature of 4°C on July 30.

Objective 3
Early in bloom (February 18 - 24), 2 branches, approximately 1 m in length, from 5 trees in the 5 sample rows were tagged and the number of blossoms or flower buds were counted (average = 67.3 blossoms). Later when fruits were developing and most fruit drop had occurred (April 29 - May 1), the fruits on each tagged branch were counted and the proportion of fruit set was calculated.

Yield will be sampled when the Nonpareil nuts have been shaken and swept into rows (estimated to be the week of August 11). A 15-cm swath from near the trunk of each tree sampled for fruit set (25 per orchard) will be collected, the nuts counted. A sample of 50 nuts will be shelled and weighed to estimate yield from each row.

Objective 4
Completed BOB nests were counted in the orchards when nesting was finished. A sample of nests were opened once the offspring had reached adulthood and females, males, and dead or parasitized cells were counted.

Objective 5
Costs of HB rental will be compared with the costs of bees, nesting units, labor for BOB management.

Results and Discussion:

Objective 1
Planting the border plots was delayed until November 19 due to dry conditions. It was thought at the time that it would be best to plant just before a rainstorm was forecast. It rained November 20 (0.79 in), and two weeks later, seedlings of the flower species had emerged, but then the weather continued to be extremely dry. In fact no rain fell from December 8 to January 29. The original plan was to not irrigate the plots because in previous years, these seed mixes had performed well relying only on natural rainfall. On January 15, an irrigation system was installed that covered 0.39 acres, but by that time, most seedlings had died. On April 17, there were 1.32, 0.58, and 0.05 plants/m^2 in the wildflower mix, PAm mustard mix, and PAm Capay clover mix respectively.

The end-row plots were irrigated immediately after planting, and periodically thereafter, but no wildflower seedlings were found in these plots. It is likely that a pre-emergent herbicide residue was present there and prevented germination.

At the Chance Bros. ranch in Merced, the PAm wildflower mix bloomed well from mid-March through April with a density of 5.35 plants per m^2. California poppy bloomed heavily from mid- to late April, baby blue eyes and California bluebells peaked in early April, and the *Alyssum* had abundant blossoms throughout March and April (**Table 2**). The Mustard mix bloom reached a peak in early April and had a density of 14.8 plants per m^2.

Table 2. Number of flowers per m^2 (*Alyssum* inflorescences) at Chance Bros. ranch, 2014.						
	PAm Wildflower Mix					**PAm Mustard Mix**
Sample Date	**Calif. Poppy**	**Five spot**	**Baby Blue Eyes**	**Calif. Bluebells**	***Alyssum***	***Brassica***
3/12/2014	0.35	0.35	5.25	0.9	10.4	88.5
4/3/2014	8.4	0.6	19.8	4.7	25.2	345.1
4/24/2014	13.6	0	0.05	0.45	11.2	0.85

HB foragers were most abundant in the mustard mix in mid-March and early April, but by April 24 the mustards were finished blooming while the wildflower mix was still attracting HBs to poppies and *Alyssum* (**Figure 2**).

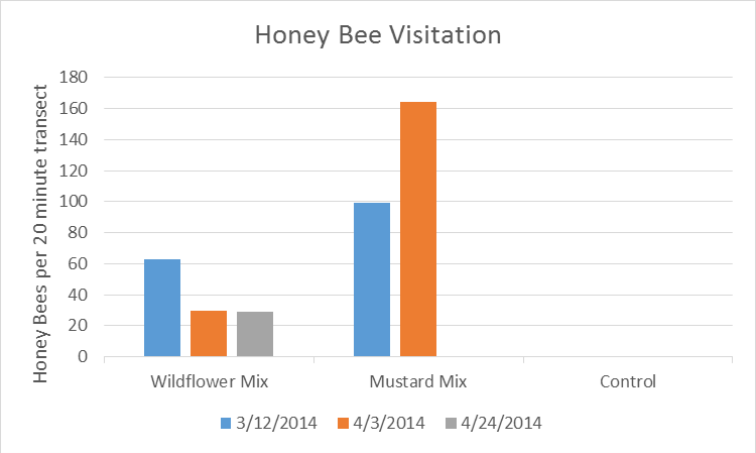
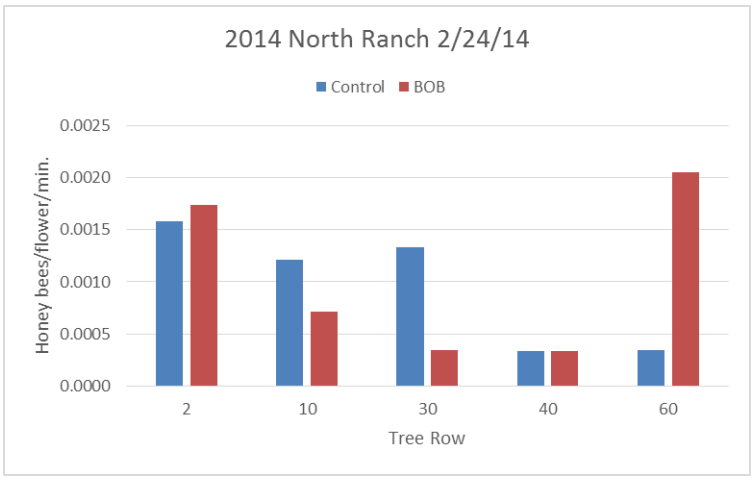


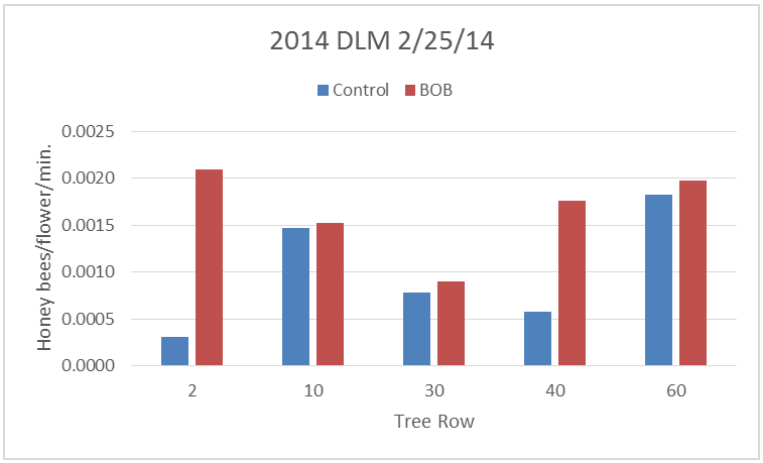
Figure 2. Honey bees visiting flowers in a 100 m transect observed for 20 minutes.

Costs to plant and maintain bee forage enhancements were recorded and will be incorporated into the ongoing economic assessment as part of the USDA-NIFA Specialty Crop project and results will be reported to the Almond Board

Objective 2

Bloom for variety Nonpareil began approximately from February 11 to 19, peaked February 20 to 26 and was finished by March 2 to 10, depending on the orchard. BOB releases were made between February 18 and 21. Night counts on February 25 indicated that between 6.4 and 23.3% of the females had established in the nesting sites, which was poorer than observed in 2013. Bee visitation was observed on February 24, 25, 27, and March 5 in 7 of the 8 orchards. While BOBs were observed readily at the nesting sites returning with almond pollen and mud, none were seen at the flowers during the bee visitation sampling. HBs were observed relatively frequently at flowers (**Figure 3**). An overall average of 0.117 HBs per flower per hour were observed. At this rate 8.55 hours of bee flight hours would be required for each flower to be visited once.





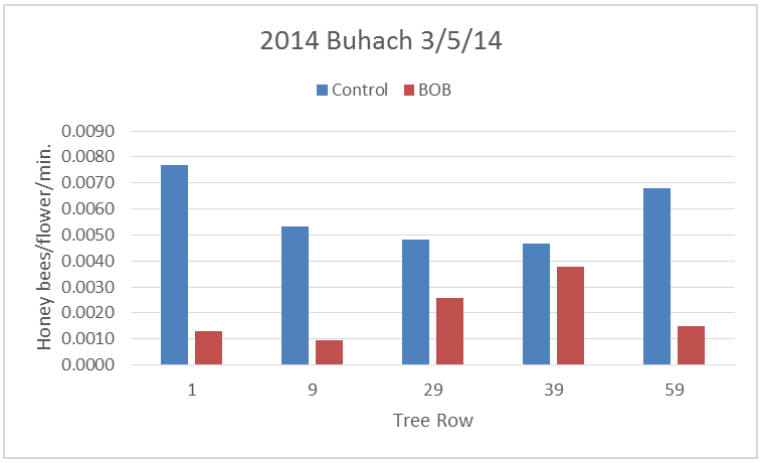


Figure 3. Honey bee visitation rate at almond blossoms in control (HB only) and BOB (BOB + HB) stocked orchards during bloom.

Fungicides were applied twice in all orchards during bloom (**Table 3**). Pristine was the second application in each case. It is not known if these applications interfered with female BOB establishment since all orchards were treated.

Table 3. Fungicides applied during bloom.		
Orchards	**Date**	**Fungicides Applied**
North Ranch Control and BOB	2/17/14 2/24/14	Quash and Vangard Pristine
DLM Ranch Control and BOB	2/18/14 2/25/14	Quash and Vangard Pristine
Merced Control and BOB	2/19/14 2/27/14	Rovral and Basic Copper Pristine
Buhach Control and BOB	2/18/14 2/24/14	Rovral and Basic Copper Pristine

Objective 3

Despite the low establishment rate of BOBs, the proportion of fruit set was higher overall in the BOB orchards, and the difference was most pronounced in rows 30 and 40 (**Figure 4**). Average fruit set in the control orchard rows 30 and 40 was 34.1% compared to 43.1% in the BOB orchards. A two-factor analysis of variance showed a significantly higher proportion fruit set in the BOB orchards compared to the controls (F = 5.02; 1, 30 df; P = 0.0326). A full statistical analysis is pending on this data set.

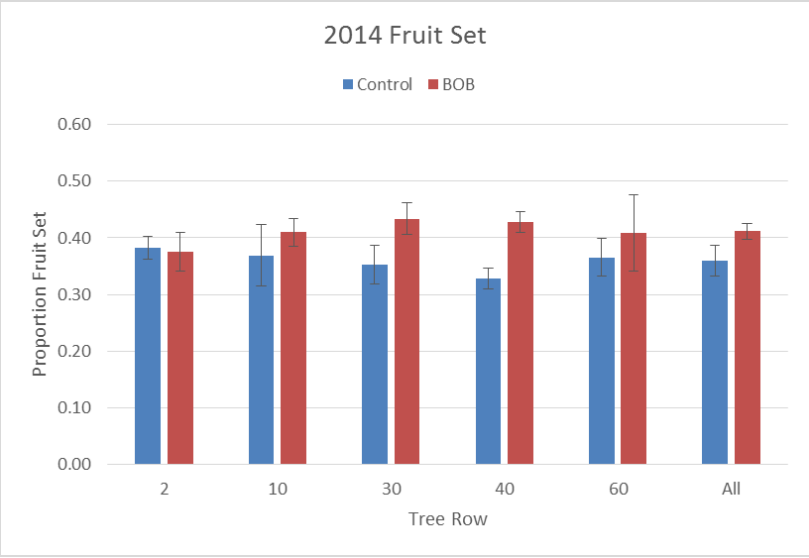


Figure 4. Proportion of fruit set in control (HB only) and BOB (HB + BOB) orchards (mean with standard error bars).

Objective 4

Completed nests ranged from 91 to 268 per orchard. A sample of nests showed 1.25 female cocoons per nest on average. The low number of nests produced resulted in estimated

offspring recovery ranging from 7 to 21% (**Table 4**). The highest recovery was in the Buhach orchard where bloom was earliest, but was adjacent to a peach orchard that bloomed after the almonds were finished.

Table 4. Completed BOB nests and estimated population recovery.

Orchard	Completed Nests	Estimated Female Offspring	% Recovery
North Ranch	91	114	7%
DLM	127	159	10%
Merced	134	168	10%
Buhach	268	335	21%
Total	620	775	12%

Objective 5.

HB hive rental, and BOB management labor and equipment inputs for incubation, nest construction, cocoon stripping and storage have been recorded and will be incorporated into the ongoing economic assessment as part of the USDA-NIFA Specialty Crop project and results will be reported to the Almond Board.

Research Effort Recent Publications:

None.

References Cited:

None.