College of Tropical Agriculture
and Human Resources
University of Hawai'i at Mānoa

Sustainable Agriculture
May 2013
SA-6

Farming With Bees: The Synchronization of Pollinator Plantings to Increase Production of Cucurbit Crops

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Pollinators are an important part of our environment and agriculture production. In our natural environment many plants would go extinct without pollinators contributing to their reproduction process. In agriculture 35% of our food crops are dependent upon pollinators. Where pollinators are absent, farmers go to great extremes to produce high-value crops, like hand-pollinating vanilla to produce the valuable pods (NRCS 2008). While there are many other insect pollinators visiting our crops, honeybees are the most recognizable pollinators and the ones most commonly used by farmers. Honeybees happen to be the most effective pollinator insects for most crops.

Cucurbit crops are especially dependent on insects for successful pollination to occur. Cucurbit crops like watermelon are monoecious, meaning they have separate male and female flowers on the same plant. The pollen is very sticky and must be moved by a pollinator for pollination to occur.

Top: Bees are necessary to pollinate cucurbit crops. Above: Insufficient pollination leads to misshapen fruits.

Another distinct characteristic among the watermelon plants is their flowering pattern. The male flower opens first, followed by the female flower 7–10 days later. The female flower opens early in the morning and is open most of the day; however, it is only open for one day, so if the bees are not in the field, the flower does not get pollinated and will be aborted once it closes (Rubatzky and Yamaguchi 1999). Not only is time a factor during pollination for this crop; the amount of pollen that must be transferred is a factor, with 500 to 1,000 grains of pollen transfer required for successful fruit set. Each viable seed in a watermelon is a result of the successful pollination of that individual seed.

Problem

Producers on Moloka'i have voiced concern about experiencing misshapen cucurbits as a result of the declining number of pollinators on the farm. Some think this decline is due to the movement of feral hives further from the epicenter of

Published by the College of Tropical Agriculture and Human Resources (CTAHR) and issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, under the Director/Dean, Cooperative Extension Service/CTAHR, University of Hawai'i at Mānoa, Honolulu, Hawai'i 96822.

Buckwheat is planted in 10' x 10' plots to provide a critical mass of flowers.

the farm to find food sources year round. This is having a great impact on the production of our cucurbit crops, especially watermelon, with some farmers experiencing anywhere from 30 to 40% of the crop affected by poor pollination. Since watermelon blooms only open in the morning and close in the afternoon, it is very important that pollination occur during this time. Watermelon blooms can serve as a source of nectar and pollen, but because of the low density of flowers, there is a need to increase bee activity by increasing the density of flowers in the field during the critical period. Companion planting may be one way to do this.

Approach

As a result of Moloka'i producers reporting high levels of misshapen watermelons, there is interest among growers in planting buckwheat as a companion plant to attract pollinators to their fields. This study was conducted to define the relationship between buckwheat and honeybees. Buckwheat (*Fagopyrum esculentum)* was selected as the companion crop to evaluate for its potential to attract pollinators. Buckwheat is a broadleaf, annual crop generally utilized as a cover crop for suppressing weeds, increasing soil organic matter, reducing soil erosion, and improving plant soil nutrition availability. It's also known for its ability to attract beneficial insects for bio-control pest management and other pollinators for plant reproduction (NRCS 2008). Consequently, buckwheat is a good candidate as a companion plant to attract pollinators. It can be managed with predictable results due to its fast rate of maturity (4–5 weeks from seed to flower) and ready availability to farmers (Valenzuela and Smith 2002).

A preliminary field trial was conducted with a watermelon producer on Moloka'i. A row of buckwheat was planted alongside a row of watermelon. Both crops were planted simultaneously. Because buckwheat flowers earlier than watermelon, flowering was not synchronized. In other words, the buckwheat finished flowering before the watermelon began flowering. As a result, a buckwheat synchronization study was undertaken to develop a pollinator attractant management system.

The goal of the study was to improve the synchronization with increased pollinator field population with the pollination period of their crop.

Hawai'i's Honeybee History

- In 1857, the first successful hives arrived on O'ahu.
- By 1894, Hawai'i exported its first shipment of honey (8 gallons) to the U.S. Mainland.
- In 1897, production allowed the export of 109,000 pounds of honey.
- Peak production occurred in 1918, with some 2.4 million pounds of honey produced. Beeswax was another very important byproduct being exported, with 61,000 pounds shipped in 1939.
- The first honeybees arrived on Moloka'i in 1898, and the apiary for the American Sugar Company was started. It eventually became the world's largest producer of honey.
- Later Moloka'i Ranch Ltd. played a large role in the honey industry, with over 2,400 colonies.
- American Foulbrood disease hit in 1937, and honey production virtually ceased.
- Over time on-farm pollination dropped and pollination contract services entered the scene.
- In the last 5 years Small Hive Beetle and Varroa Mite have arrived.

Watermelon and buckwheat are planted side by side for easy access by bees.

Blossoms and seeds occur simultaneously; by 39 DAS most seeds are formed.

Synchronization Study

The objective of this study was to determine the population dynamics of honeybees and the the relationship between the buckwheat and honeybees as the buckwheat matures.

In order to determine the proper time to plant the buckwheat, we first had to study the lifecycle of the plant and the relationship between the plant and the pollinators. This relationship proved very complex as it was determined that the buckwheat plant served as both a nectar and a pollen source for most pollinators. Although dozens of different types of pollinators visited the crop, the focus was on the honeybees, as in the absence of other pollinators, the most important group of pollinators, and the group most easily managed by growers.

Methodology

The study was conducted at the College of Tropical Agriculture and Human Resources's Moloka'i Applied Research and Demonstration Farm, located in Ho'olehua, HI, at 21 8'7.06 N, 157 5'48.31" W. Four plots of buckwheat were planted in the summer and again in the winter.

Each of the 4 plots was 10 feet by 10 feet^2. Buckwheat was seeded at 75 pounds per acre by raking. Microsprinklers were used to apply irrigation at a rate of 5,000 gallons per acre per day. Nitrogen fertilizer was applied 14 days after seeding (DAS) at the rate of 50 pounds N per acre. Once flowering began, honeybee population densities in the 4 buckwheat plots were counted at 30-minute intervals during the day, in both the summer and winter plantings. Summer buckwheat was seeded on August 10 and winter buckwheat was seeded on December 8, 2012. For both trials, the project ended at 39 DAS as the buckwheat transitioned into seed-formation phase and only few honeybees visited the remaining blossoms.

Results

Relationship between honeybee visits to buckwheat blossoms and time of day.

Honeybee population densities were collected for 19 days, starting from 20 DAS in both summer and winter trials. Every day in both summer and winter trials, honeybees began to visit buckwheat blossoms plus or minus a few minutes from sunrise. Honeybee populations reached their peak visiting about 2.5 hours after sunrise in both trials. In chronological time, the summer and winter peaks were 1 hour apart (8:30 am and 9:30 am, respectively). There was a big difference between summer and winter in the peak bee population visiting the buckwheat blossoms. At the peak time of day, the summer buckwheat had 2.2 times more honeybees than the winter crop (Fig. 3). From these numbers it can be estimated that 1 acre of summer buckwheat blossoms could draw an average of 64,000 honeybees at 8:30 a.m. and in the winter period could attract 29,000 at 9:30 a.m. While the total numbers of honeybees were less in the winter crop, a higher population of bees remained on the blossoms after 11:00 a.m. in the winter. The drop in winter honeybee populations may not be related to the effectiveness of buckwheat at attracting honeybees in

Buckwheat flowers offer abundant pollen and nectar for honeybee nourishment.

the winter, but rather could be related to the total drop in honeybee populations in the environment. Fewer blossoms occur in the wild during the winter months, and fewer blossoms means less food and nutrition for honeybees. At the trial site, a drop in honeybee population in nearby managed hives was also observed during the winter months.

This information confirms what farmers have long observed concerning honeybee activities in their fields in the mornings.

Relationship between the growth rate of summer and winter buckwheat and honeybee population

Climatic conditions greatly affect the metabolic and maturation rates of plants. In general a plant matures faster in warmer temperatures and slows down under cooler temperatures. Plants take fewer days to mature during a season of longer days and more days to mature when days are shorter. Therefore plants mature faster during the summer season than they do in the winter (USNO 2013). In Hawai'i the longest day occurs on June 21, with a day length of 13 hours and 26 minutes, and the shortest day is on December 21, with a day length of 10 hours and 50 minutes, a difference of 2 hours and 26 minutes.

In comparing summer and winter honeybee visitation rates on buckwheat, rates peaked at 27 DAS at a cumulative day-length of 293 hours for the summer planting and peaked at 31 DAS in the winter planting, which was exposed to 392 hours of day-length. At 27 DAS the summer crop averaged 1.7 honeybees per square foot, and at 31 DAS the winter crop averaged 1.3 bees per square foot (fig. 4). While the winter buckwheat crop had 99 more cumulative hours of day-length exposure, it took 4 days longer to reach peak in attracting honeybees, which suggests that cumulative ambient temperature (in heat units) is more important than cumulative day-length hours.

In this study, the average temperature for the winter buckwheat planting was 70.4˚F, almost 6 degrees lower than the average temperature for the summer planting period. The combination of reduced day length and lower temperature slowed the growth and maturity rate of winter buckwheat planting, thus delaying the peak of honeybee visitation and possibly contributing to the lower numbers of honeybees visiting the blossoms.

Conclusion

Cucurbit farmers have experienced yield reduction due to poor pollination. They have experienced an increasing amount of flower and fruit abortion, as well as mis-

Fig. 1

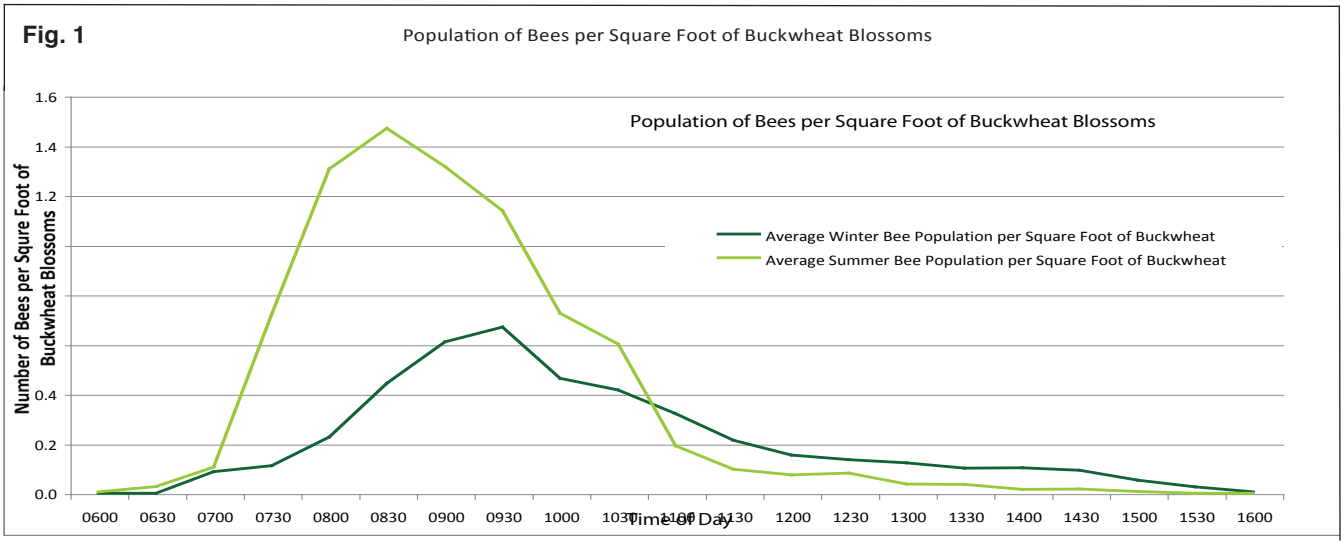


Fig. 2

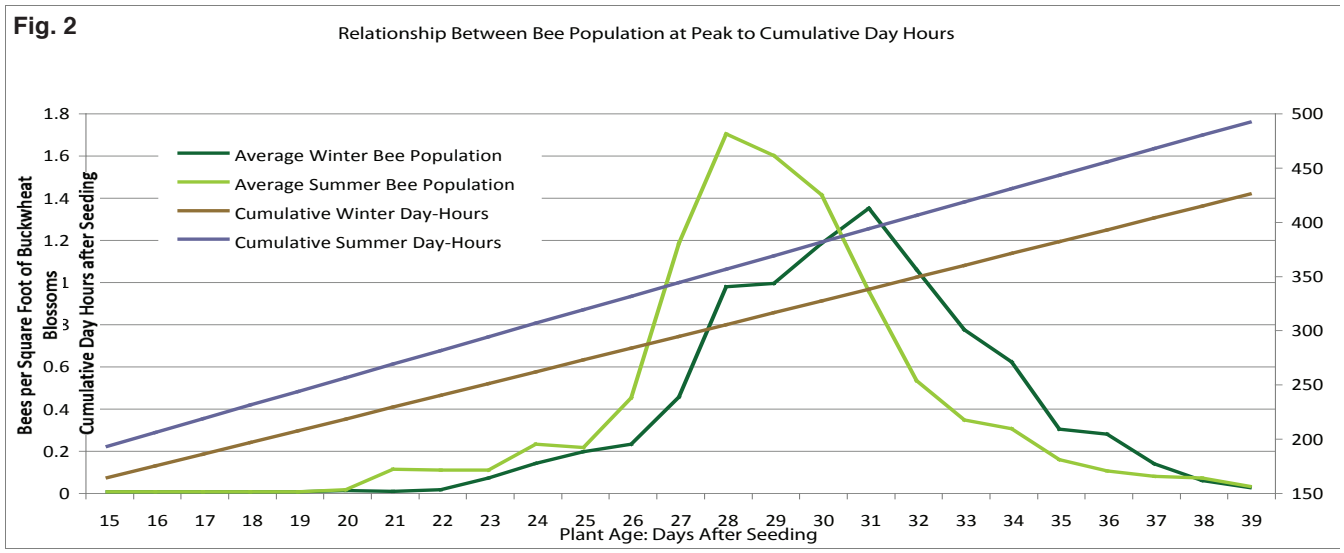
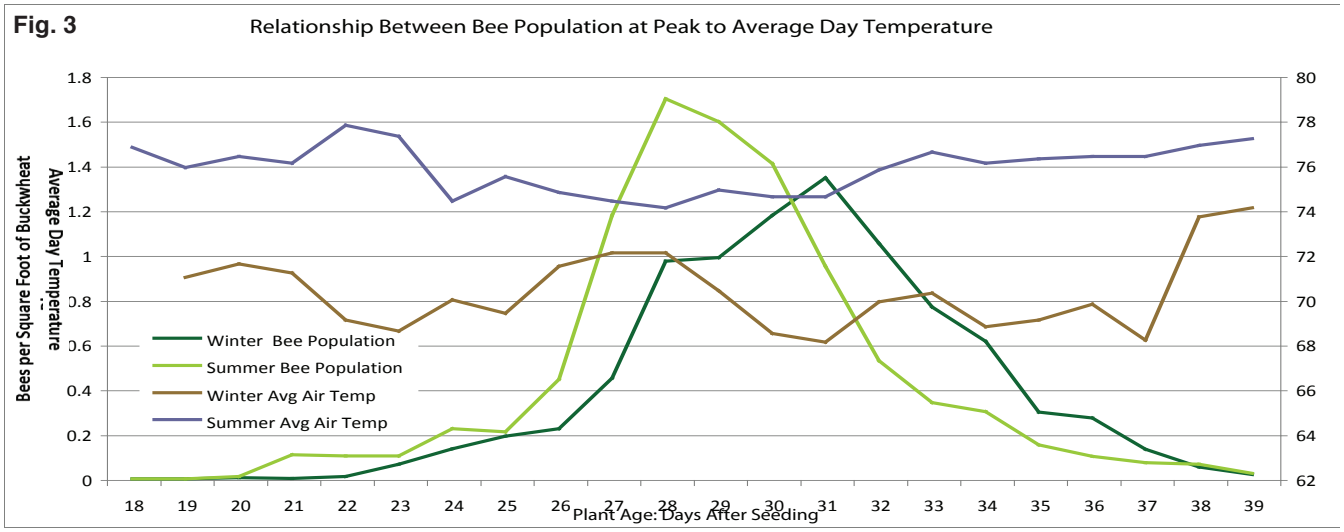


Fig. 3



Bees are not the only pollinators that are attracted to buckwheat.

shapen fruits, all attributed to inadequate transfer of pollen from male to female flowers. Field observations and demonstrations indicated that buckwheat is a good companion plant to attract honeybees. Farmers have installed companion plantings of buckwheat alongside their cucurbit crops to attract honeybees into their fields. While farmers were successful in attracting increased numbers of honeybees to their crop with buckwheat companion plantings, blossoming phases were not synchronized. As a result of this study, farmers have a better understanding of synchronizing blossoming of their crop with companion plantings to attract pollinators into their field when they are needed. They now can improve pollination of early blossoms to develop early fruit that can be harvested as early as possible and get out of the fields before pest populations begin to increase and take hold on their crops. The next phase of this project is to improve our understanding of when early female flowers appear in selected cucurbit crops in order to improve synchronization with peak visitation of honeybees on buckwheat.

Observations and Recommendations From Trial Results

1. In summer, a population of 64,000 honeybees could potentially be attracted to an acre of buckwheat blossoms on peak days.
2. In winter, a population of 29,000 honeybees could potentially be attracted to an acre of buckwheat blossoms on peak days.
3. During the summer days, honeybee population peaks at 8:30 a.m., 2.5 hours after sunrise.
4. During the winter days, honeybee population peaks at 9:30 a.m., 2.5 hours after sunrise.
5. As a guide, in the summer, buckwheat should be seeded 21–27 days before early female flowering of cucurbit crops.
6. As a guide, in the winter, buckwheat should be seeded 24–31 days before early flowering of cucurbit crops.
7. Do not conduct field activities that might reduce honeybees' pollinating activities before noon.
8. During the winter honeybees stay in the buckwheat field longer than the summer.
9. Honeybees appear on buckwheat blossoms plus or minus minutes of sunrise.
10. Do not apply overhead sprinklers before noon, as observations indicate that honeybee field activity is reduced or ceases during rainy periods.
11. Both day length and ambient temperature influence the rate of buckwheat maturity. Therefore the strategy of using buckwheat as a pollinator companion plant is to seed them at least 21–27 days before early crop female flowers appear on watermelon in the summer and 24–31 days in the winter.

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Acknowledgements

Mahalo to Faith Tuipulotu, agriculture technician, for participating in collecting tedious data on honeybee population on the buckwheat blossoms. We also gratefully acknowledge Dr. Ethel Villalobos and Dr. Koon-Hui Wang for reviewing this manuscript. Thanks go to the USDA, NRCS Plant Materials Center, Ho'olehua, Moloka'i, Hawai'i, for providing daily temperature data for Ho'olehua, Hawai'i.