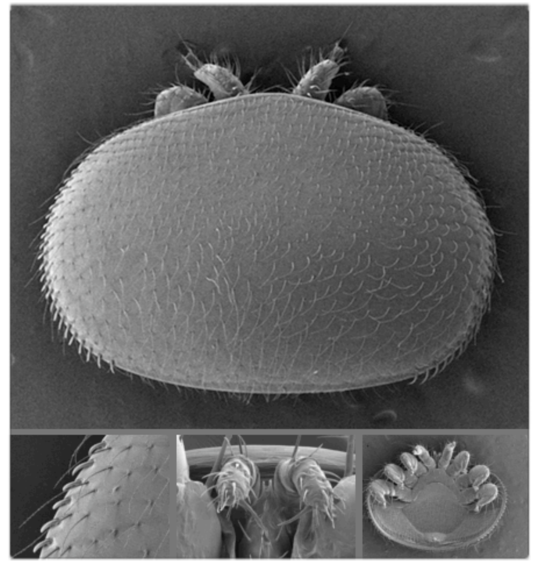
How the *Varroa* mite is changing the way we farm in Hawaii.

UH Honeybee Project Researchers
Ethel M. Villalobos, Mark G. Wright, Scott Nikaido, Tyler Ito, and Jane Tavares

The first time I saw a live *Varroa* mite it was scurrying across a honeycomb full of developing bees. I had expected to find a sluggish, clumsy, " tick", but instead, there it was: a miniature crab-like intruder with agile sideways movements. I tried to gently pick it up with tweezers, but the mite slid right out of my grasp, and disappeared inside an open cell. It was not an encouraging first encounter.



Varroa destructor viewed under a Scanning Electron Microscope. The adult female mite in this image is about 1.5 mm wide. The images at the bottom show details of the pedipalps and mouthparts, a ventral view of the mite, and a close up of the dorsal surface. Photo credit: Jonathan Wright

Varroa destructor is a very successful ecto-parasite of the common honeybee *Apis mellifera*. Although only the size of a large grain of sand, it has spread from Asia to Europe and in the 1980's to the mainland US. The mite was detected for the first time on Oahu in 2007, and found a year later on the Big Island of Hawaii. *Varroa* has negatively impacted honeybee health across the world and will radically change the beekeeping and farming industries of Hawaii.

The *Varroa* mite is a treacherous pest. Protected by a tough carapace edged with blunt spines, the mite's body is flattened to fit tightly between the abdominal segments of adult bees. Once in place, the mite uses its sharp mouthparts to pierce the soft tissues of bees and feed on their blood. Devoid of eyes, *Varroa* finds its hosts through scent, hiding within the cells in the hive and using the developing bees to feed its own young.

Worker bee affected by Deformed Winged Virus. This worker will only be able to perform the "house duties" typical of younger bees, but will not be able to forage for food for the colony. If a large number of workers are affected by this disease, the colony will lose its ability to feed the younger bees. Photo credit: Scott Nikaido

Varroa weakens adult bees and their larvae by feeding on them, but the greatest danger is that the mite is a vector in the transmission of viral pathogens. Much like children in kindergarten sharing a cold, worker bees interact closely with each other and can easily pass diseases to one another; however, the spread of these diseases is much faster, and the virulence is much higher, if the colony is infested with the *Varroa* mite. Preliminary research conducted in collaboration with Dr. Steve J. Martin from the University of Sheffield indicates that certain diseases are now widespread among Oahu's honeybee colonies. Deformed Wing Virus for example, is a disease which warps the worker's wings making them unable to fly, and consequently, unable to bring food for the colony, and it is now frequently observed by the local beekeepers.

Due to the debilitating effects of *Varroa*'s parasitism and the associated transmission of viral agents, the mite is considered to play an important role in the so-called "Colony Collapse Disorder" which is often observed in the mainland US and Europe, but curiously not yet documented in Hawaii. Nevertheless, *Varroa destructor* is an equalizing plague, affecting large scale honey producers, queen breeders, large farming companies, and backyard growers alike, and because honeybees are such an important element of large scale agriculture, the mite's arrival will be felt by all of us, even if only through the increased costs of vegetables, nuts, and fruits.

Control of *Varroa* mite levels is an absolute necessity, and determining what is a suitable Integrated Pest Management Strategy for this pest is one of the UH Honeybee Project main concerns. Without mite treatment managed honeybee colonies succumb within a year or two of infestation. Feral colonies, which provided free pollination services for many, are also destined to die since they cannot be protected from the mite.

Unfortunately for the local beekeepers, the ecological conditions that favor honeybee colony growth, also favor a high reproductive success for the *Varroa* mite. In addition, the European Honeybee (EHB) stock of Hawaii is highly productive and relatively nonaggressive, especially compared with the Africanized hybrids found throughout tropical America. Honey producers benefit greatly from these favorable traits and Hawaii's queen breeders can export tropical queens of pure

Table 1: Tropical fruits and many vegetables need bees to produce adequate seed set The following table indicates the relative importance of bees for tropical fruits and nuts.

Fruit tree	Degree of dependency on bees	Notes
Avocado	High	Yield was tripled through honeybee pollination (Australia)
Lychee	High	Some varieties produced large quantities of nectar and are heavily visited by bees
Longan	High	Honeybee pollination is essential
Rambutan	High	Honeybee pollination doubled fruit production (Thailand)
Starfruit	High	Produces short styled and long styled flowers, need to plant different varieties
Macadamia	High	Honeybees visit macadamia to collect pollen. Must make sure the bees have access to nectar or have honey storages
Guava	High	Yields increased with honeybee visitation
Mango	Medium	Yield is increase by honeybee visits, however, if the tree spacing is large, yields can be poor even with honeybees present
Coffee	Medium	Coffee can self-fertilize but insect pollination results in a 20-30% yield increase (Panama)
Loquat	Low-Medium	Some cultivars are self fertile, others report an 10-17% in fruit set due to bee visits
Persimmon	Low-Medium	Mostly wind pollinated. About 10% increase in fruit set due to bees.

European stock to the rest of the world. However, the *Varroa* mite has a high reproductive success on pure EHB stock. As a result of these unique circumstances the local beekeepers face high infestation levels and the subsequent need for frequent treatments.

The UH bee team worried that mainland recommendations for *Varroa* treatment might not be fully applicable to the local conditions and decided to conduct a long term sampling of *Varroa* levels at the Waimanalo research apiary. Based on our weekly monitoring of mite level fluctuations over the past year we now recommend that colonies in Hawaii should be treated every 4 months for adequate mite control. By comparison, beekeepers in temperate climates, where brood production halts during winter months, can afford to treat only twice a year. The frequent treatments needed in Hawaii mean more work, higher costs, and depending on the nature of the mite control, higher pesticide input to the hive.

A troublesome correlate of the need for multiple treatments per year has to do with the accumulation of toxic chemicals within the hive. Researchers in Europe and the USA have determined that the most common pesticides found in managed hives were miticides, delivered by the beekeepers in their efforts to control *Varroa*. One of the most frequently detected chemicals is CheckMite, which uses coumaphos (an organophosphate), as its active ingredient. Another miticide, used widely in Hawaii during the first year of *Varroa* detection is called Apistan, and it uses fluvalinate, a synthetic pyrethroid, as its main active ingredient. These miticides, although very effective for the first few years, are now known to leave residues in the hive, and negatively impact bee health, including: poor development of queen bees, reduced fertility in drones, and reduction in immune response of worker bees. These detrimental effects appear even when the residues are present in relatively low doses. In addition, to chemical residues, pesticide resistance is becoming alarmingly common in many parts of the world, making the effectiveness of the synthetic miticides seem like a temporary solution at best.

Hoping to avoid the pesticide treadmill and with the benefit of hindsight from other researchers, the UH bee team has been working on testing alternative methods of *Varroa* control. One method recently tested on Oahu was the Drone Comb Removal, a "bio-mechanical" technique that takes advantage of *Varroa*'s preference to use drones (male bees) as hosts. Typically drones are produced only during reproductive season in temperate climates, here in Hawaii, it is always possible to produce a new queen and consequently the colonies produce at least some drones all year round.

Worker bees collect pollen and nectar from a variety of sources, this foraging bee visits a large sunflower at Urban Garden Center in Pearl City. Photo credit: Scott Nikaido.

Drone comb removal works by introducing a plastic frame in the hive that encourages the construction of the larger drone cells. The queen then lays large numbers of male offspring in the frame. *Varroa* females flood to the frame because they can produce more young on the large male pupae. At about 3 weeks after the frame is introduced, the cells are capped and have developing bees inside. *Varroa* females and their offspring are also completing their life cycle in the cells. At this point the beekeeper needs to interfere. The drones are removed from the hive and destroyed, along with the parasitic mites they harbor.

This technique although it is time consuming and requires close monitoring of the hives, does not involve any chemicals and is relatively cheap. The technique is most effective when the drone production and *Varroa* infestation rates are high. The UH Honeybee Project has discovered that drone production on Oahu peaks during the months of June to September. During these high drone months, a frame contains an average of 800 drones and approximately 1000 *Varroa* adult females and juvenile mites. Under these kinds of conditions regular drone comb removal can be an effective component in an IPM strategy for small to medium scale beekeepers that can afford to dedicate the time to this kind of procedure.

The UH Honeybee team has also been testing the efficacy of organic compounds, in particular thymol (Apiguard) and formic acid (Mite Away Quick Strip). These organic fumigants do not seem to leave chemical residues in the hive and the mites do not seem to have developed resistance against these treatments. Fumigants however, can cause disruption in the colony's life cycle: as the queen may halt egg-laying and young brood may be sensitive to the gases released by the products. Beekeepers need to learn the best way to introduce these chemicals to minimize possible negative side effects associated with the treatment. Formic acid stands out as unique among Varroa control treatments in that it seems to be able to penetrate capped cells and kill the mites within the cells but leave bee pupa unharmed. This killing selectivity is a great improvement over all other treatments for mite control available at this time and results in a dramatic and rapid decrease in Varroa levels in the hive. We have observed an average mite kill of 1200 mites in the first week post formic acid application, followed by relatively low mite levels within the colony for up to 3 months.

Dory Tolentino (on the left), a vegetable farmer on Oahu, has learned beekeeping through the UH Honeybee Project and is now sharing her experience with other growers in the community.

The type of *Varroa* treatment beekeepers chose is influenced by a number of practical and philosophical concerns including: cost, ease of application, perceived efficacy, and the desire to reduce pesticide input for personal or commercial reasons. In Hawaii there is currently a great deal of interest in finding reliable and affordable organic control methods for *Varroa*. We hope that our research can offer alternatives that can be used as part of an IPM calendar that will reduce the exposure of Hawaii's bees to harmful miticides.

Honeybees however, can acquire pesticides during their foraging trips, especially when visiting agricultural lands. Insecticides, fungicides, and even some herbicides, are being delivered daily by worker bees to their colonies via pollen and nectar. These food resources brought by the foragers are shared among the sister bees and fed to the developing larvae as well. Work conducted in Europe and in the US indicates that even if the toxins found on bee food are present below lethal levels, they can still negatively impact the colony. Researchers in France found that systemic insecticides, those absorbed into the plant's tissues such as imidacloprid, were present in a large number of samples. Imidacloprid has been linked to poor memory performance in foraging bees and may impair the ability of workers to find their way home while foraging. Researchers in the US also showed that imidacloprid and amitraz had significant negative effects on pupal development. Residues of these chemicals can also be found in beeswax, possibly exposing the young larvae to sublethal levels of pesticides during some very critical stages of development.

As bees become scarce, and growers are more aware of their susceptibility to chemicals, more attention is being paid to ways to reduce pesticide input to farms and gardens and to select chemicals with lower toxicity to pollinators. Hawaii farmers still need more training with respect to pollinator safety and the UH Honeybee Project just received an EPA grant aimed at conducting research and outreach work with small scale farmers that plant bee dependent crops. These growers are learning organic beekeeping and re-considering their production practices in order to make their farms safer for their much needed pollinators.

Working with honeybees and *Varroa* has made the members of the UH Honeybee Project more aware of the complexity of the Hawaiian agro-ecosystem. Clearly, much more research is needed to determine the best IPM strategy for *Varroa* control, to investigate the relative contribution of bees to crop pollination in Hawaii (see Table 1) and to clearly document the impact of pesticides on bee health. But if there is a silver lining to the *Varroa* invasion, it is that the producers are now interested in learning more about their bees, and the growers are willing to make concessions to protect these much needed insects.

Additional resources and suggested readings

The UH Honeybee Project website: http://www.ctahr.hawaii.edu/wrightm/Honey_Bee_Home.html
You can also contact the project team members via email at UHbeelab@gmail.com or the author, Dr. Ethel M. Villalobos at emv@hawaii.edu

For general reading on the subject of bees, bee decline, CCD, pesticides, and agriculture, we recommend the following books:

- A Spring Without Bees: How Colony Collapse Disorder Has Endangered Our Food Supply by Michael Schacker (2008)
- The Buzz About Bees: Biology of a Superorganism by Jürgen Tautz (2008)
- Fruitless Fall: The Collapse of the Honey Bee and the Coming Agricultural Crisis by Rowan Jacobsen (2008)

Recent scientific work on *Varroa*, bees, and pesticides

Chauzat, M.P. et al., 2006. Survey of Pesticide Residues in Pollen Loads Collected by Honey Bees in France. Journal of Economic Entomology 99 (2), 2006.

Chauzat, M.P. et al., 2009. Influence of pesticide residues on honey bee (Hymenoptera: Apidae) colony health in France. Environmental Entomology, 38 (3): 514-523.

Frazier, M. T., et al. 2008. What Have Pesticides Got to do with it? Amer. Bee J. 148:521-523.
Gouldson L.C., and B. Darvill, 2008. The decline and conservation of bumble bees. Annual Review of Entomology, 53: 191-208.

Medina, L.M. & S.J. Martin, 1999. A comparative study of Varroa jacobsoni reproduction in worker cells of honey bees (Apis mellifera) in England and Africanized bees in Yucatan, Mexico. Experimental and Applied Acarology 23: 659–667.

Thompson, H.M., Brown, M.A., Ball, R.F., & Bew, M.H. 2002. First report of Varroa destructor resistance to pyrethroids in the UK. Apidologie 33: 357-366