Finding the Resistant Bees

Updates from international experts

by M.E.A. McNeil

"It's easy."
"Easy is relative."
"It's not an easy game."
"Resistance is a realistic goal."

A panel of beekeepers and scientists stretched across a stage before an audience that spilled into the aisles, eager to hear about their subject: resistant bees. Resistant to what — no one had to say *Varroa destructor*. They were at Apimondia, the international conference, this time in Copenhagen, Denmark. And, unlike decades ago when there was a rare presenter on the subject, this congress offered numerous other presentations and posters. This article reports on a sampling from across them.

For context, it's worth looking briefly at the background of one early presenter, John Kefuss. He is the American who, with German researchers, came up with the Bond Method — a term that has since entered the beekeeping lexicon. Note that when he worked his way through Ohio State University, his job in the bee lab of the legendary researcher Walter Rothenbuhler was counting American foulbrood cells. Some strains of bees were killed by a couple of scales, while others tolerated a fully infected frame — AFB-resistant bees. The project was stopped when beekeepers embraced antibiotics.

After Kefuss completed a Ph.D. under Frederick Ruttner in Germany, he established a commercial apiary in his wife's native Toulouse, France. From 1983, after the varroa mite arrived in Europe, he was asked to supply bees for testing chemicals against them — Folbex, Perizin, amitraz, Apistan and Bayvarol. He saw the results as harmful to the bees.

Now that it is understood that bees can have resistant behaviors, it is hard to imagine that it was no more than guess and hope when Kefuss and others began to experiment with the idea. His highly respected doctoral mentor Ruttner said that bees

No one had to ask, "Resistant to what?"

could not be bred against mites "any more than sheep can be bred against wolves." But Kefuss saw, in a project in Tunisia with farmers too poor to treat their hives, signs of resistance. He did not know what caused the effect, but it appeared that it was genetic. From 1993 he tested bees by withdrawing all treatment. Experimentation also went on elsewhere, particularly in Germany and Poland. "By 1996 we knew we could select for varroa resistance," he said.

The term "Bond Method" — from James Bond's 007 principle of "Live and Let Die"— described his protocol of withdrawing treatment or even accelerating it by adding mites. But by 2002, two-thirds of his colonies died out, not feasible for commercial beekeepers. A crossover plan, the Soft Bond Test, limited the number of untreated hives and selected survivors to provide resistant breeding stock.

Kefuss is a kind of reverse snake-oil salesman, peddling the rewards of giving up remedies with a side of good-humored showmanship. He considers this work to bear "a certain moral responsibility to future beekeepers to show that it's not only possible but cheaper to keep bees without chemicals." He stood from the audience at the end of the panel discussion to say that he still has to buy mites to test his bees.

Two Apimondia presenters spoke about other natural-selection projects. The island of Gotland, in Sweden, is the site of an ongoing early attempt to apply evolutionary ecology for natural selection in bees. Started by Ingemar Fries in 1999, some 150 colonies from a variety of Swedish apiaries were evenly infested with mites to create a strong selection force. They were left unmanaged and allowed to

Mea McNeil

The Apimondia panel on Breeding for Varroa Resistance. Left to right: Torsten Ellmann, President, The German Beekeeping Association; Johann Fischer, advisor to German beekeepers and breeders; Pierre Giovenazzo, Professor, Laval University, Québec; Steve Pernal, Head, Canadian Apiculture Research Program; Ralph Buchler, retired Head, Kirchain, Germany Bee Institute; Per Kryger, researcher, Aarhus University; Barbara Locke, researcher, Swedish University of Agricultural Sciences; Stephen Martin, Emeritus Professor, Salford University; Steve Riley, Chair, Westerham Beekeepers, UK; Fanny Mondet, bee biologist, French National Institute for Agricultural Research. Stefan Mandl, also present, is not pictured. He has 15,000 organically kept colonies with 2000 under resistance selection.

Jack Andreoni

John Kefuss, the bee breeder who came up with the Bond Method, live and let die, comments from the audience at Apimondia at a panel on breeding resistant stock. He said that he has to buy mites for a resistant pressure on his colonies.

Jenny Svennås-Gillner

Barbara Locke Grandér, Associate Professor and Director of The Honey Bee Research Centre at the Swedish University of Agricultural Sciences. She is in charge of the experimental bees on Gotland Island.

swarm and die naturally. "That is why it was called a Bond project because it has this live-and-let-die approach," said Barbara Locke Grandér, who now heads the program. "This is a concept that we borrowed from John Kefuss, the treatment-free beekeeper who is here today." Their ideal, she said, was "evolutionary rescue adaptation caused by severe environmental stress" — in other words, bees that could rise to the occasion when pressed to the brink.

Over the first three years, the die-off caused by the mite was 80% of the colonies. "This population has not recovered," she said, "but they manage to survive." They now have mite infestation between 30 and 40% in autumn, "which would normally kill a colony. Somehow they are tolerating these really high infestation rates, so that made me curious about how they handle virus infections." The results from virus monitoring over the seasons showed that the bees tolerate deformed wing virus. They also had reduced sacbrood and black queen cell virus, "viruses not related to mites, but they are important." Although the surviving colonies cope with mites and virus infection, she said, they are too small to swarm.

"What kinds of adaptations do they have, and how can we learn from this population to see what causes them to persist in this environment with really high mite infestation?" she asked. They found that the mites were not reproducing successfully in these colonies. "We don't really know how the bees are influencing the mite reproduction. … This low mite reproduction seems to be independent of other bee behaviors. We know it's a genetic trait." At the same time, sampling over 25 years has shown that the genetic structure of the mites has changed compared to the rest of Sweden, "but we don't really know what that means."

She concluded, "This process called natural selection has come with a very high cost. This isn't strange, because natural selection, it kills. That's the point of it. It's killed over 99% of the species that have lived on this planet. So when you have a little bit of luck and perfect right conditions, you can get some survival." She paused and leaned forward. "It has inspired beekeepers to adapt toward removing chemical treatments in their bees. This is an extreme oversimplification of the natural-selection processes. Natural selection does not always guarantee an improved outcome for longevity. The biggest selection pressure that we have for honey bees is the beekeeper. Treatment-free beekeeping is a possibility, but it requires very diligent and well-educated beekeepers. We should consider more integrated pest management. So let's move away from just not treating and think about how we can keep bees healthy and integrate good breeding practices for more mite resistance." She said that in Sweden beekeepers are attempting to breed for resistance but have found it very, very difficult. Her summation: "Easy is relative."

Natural selection has come with a very high cost.

The Oahu Experience

Evidence of naturally selected resistance at a site in Hawaii invites comparison to Gotland. Stephen Martin is now retired as Chair in Social Entomology in the School of Environmental and Life Sciences at University of Salford, U.K. His background is unique. "I have been doing varroa research for some 40 years now, and I'm fortunate to have traveled the world looking at resistant stocks. All the countries that did not go down the treatment group, the whole of Africa, South America and Latin America that didn't use treatments because of cost or accessibility, they all now have resistance. These bees have the traits, they are able to remove a high proportion of the disease. We know now that resistant bees are in every country and in every environment. It has nothing to do with the type of bee, Buckfast, *mellifera*, whatever. Our job as scientists is to figure out the beautiful complexities of how that works and trying to convince the beekeeper, just trust your bees. We need to learn from the bees and not the other way around."

Asked, from his experience, how resistant stock can be developed, he answered, "Remove the beekeepers from the program." Laughter and applause.

He did a long-term study of the population of bees on Oahu, Hawaii. Varroa arrived there in 2007 — quite late in the migration of the mite. It spread to the island of Hawaii, called the Big Island, where some half a bil-

E. Villalobos

Steve Martin of the University of Salford, England, at one of the Oahu varroa-resistant apiaries.

E. Villalobos

Steve Martin of the University of Salford, England, measuring mite removal behavior in the field in the Oahu study

lion queens are produced each year by the large commercial operations. "The mites came and they lost a lot of bees like everywhere else," said Martin. "And they turned to treatment. This represents what's happening in most of America and Europe. People are locked into this treatment cycle."

However, "What happened in Oahu was very different," he said. "We were very fortunate to be there in the very early days when varroa first came. You couldn't ask for a better natural site for a field experiment I set up myself. And we have been able to go back in the last 15 years and see how things have progressed."

In Oahu there is a small number of managed colonies and a very large feral population. When varroa came, about 65% of the managed colonies collapsed, and the feral population diminished as well. This resulted in a lack of pollinators. The pumpkin crop failed and farmers resorted to hand-pollinating the pumpkins. "There just weren't any honey bees around. The beekeepers went to treatment. Between 2009 and 2013 the situation was like the Big Island — everybody treating, locked in the treatment cycle."

On Oahu, the feral population started to recover in the wild, so some beekeepers collected swarms and found that they did as well as the colonies that they had been treating, although some continued treating. The feral population increased.

"We looked at the traits in the feral bees," said Martin. "We found these traits that everyone has been talking about, very high removal rates when we artificially infected cells, half-chewed-down pupae, increased mite detection. We worked out how the [deformed wing] virus adapted to the honey bee. They found that the virus changed over 15 years; it started as very diverse, evolved into a B strain, and now it has evolved into a recombinant AB virus that is dominating the populations of both Oahu and the Big Island. But the response is "very different in Oahu," he said, "simply because the number of mites has gone down."

To an audience question about the difference between the Oahu bees and the Gotland bees, Martin hazarded a guess. "There is a striking difference. In Hawaii the feral population is very hardy and there is a large amount of forage there, so the carrying capacity on the island is much, much higher than on Gotland. It's a tropical forest, subtropical, they breed all year around. The Gotland population seems to be stuck at some sort of limit. It may be an environmental carrying capacity, I don't know." As for the Oahu bees: "They get better and better over the years."

The biggest selection pressure for honey bees is the beekeeper.

Success in Luxembourg

At another venue, Paul Jungels ceded the mic to his son and partner Victor. "I speak very bad English." They manage Apiculture Jungels, a family business in Luxembourg selling honey "vun der wab an d'glas," from hive to jar, as well as a wide range of hive products from hydromel to furniture wax. Their colonies are mainly located around the forests in the Our Nature Park, a reserve in the Ardennes Region bordering Belgium and Germany, named for the Our River. They are focused on breeding honey bees resistant to the varroa mite. "My dad started in 1968. I took over two years ago. He does the breeding, resistance breeding that he started 12 years ago." It was a slow process. John Harbo's research gave the work impetus.

They work with Buckfast bees, which Paul Jungels got from Brother Adam in the 1980s. "We try to keep all the Buckfast traits, highly yielding, and just add varroa resistance. We have been very successful in that. We still have a lot of honey and we have not been treating for a few years now. So how do we do it? It's about testing the colonies and counting mites."

They have a remaining Buckfast line that is not resistant which they keep for harvesting mites to infect testing hives. They use about 150 mites to initiate uncapping behavior. "We really see that the ones that open the cells when they have the purple eyes and remove the larvae have fewer mites." They have learned to breed from heritable traits, "all of those except grooming which has proven to be not so easily inheritable." Out of 200 selected colonies, the best ones are chosen to be instrumentally inseminated and of those, the best go to the breeding station. "That's how we get it done.

He cited a test by INRE, the French National Institute for Agricultural Research, that showed that treatment suppresses resistant traits. "Now each one of our breeding lines is resistant except one." They also breed drone lines for resistance. Together with hobby and small-scale beekeepers throughout Luxembourg, they have established mating stations stocked with their VSH-related (varroa sensitive hygiene) drones. "That is how we spread the genes. And then they can continue their own selection. In three or four years, within our small group, nobody is treating anymore."

Paul Jungels added, "We don't sell queens. Everybody has to do it yourself. We can work all together, that's

Ralph Büchler

Ralph Büchler

the goal. We are saving €100,000 in treatment for only one year. We are very practical beekeepers."

Victor concluded, "To stop this treating and get going, it's a little bit of work. The process itself isn't too difficult once you know how to do it. Just get going, don't listen to the naysayers."

Teaching resistance in England

Steve Riley chairs the Westerham Beekeepers, a club in the southeast of England with about 130 colonies that are not treated. They started with 27, and, he said, "If we had the knowledge that we have now, we could have done it in three years." They are part of a network of 11 varroa-resistant apiaries. The largest, in Northwest Wales, has just celebrated its 16th anniversary for not treating the 500 colonies there. Some other smaller commercial apiaries belong to the group as well.

They breed from the bees with resistant traits and requeen the rest. "It's understanding the key traits, I think, that's the important thing. They are not so hard to understand. We need to talk about the behaviors, hygienic behaviors in particular, not about treatment-free. Treatment-free is something that occurs as a result of having bees with sufficient varroa-resistant traits. We find all beekeepers fascinated by these behaviors, particularly newer beekeepers. It's a very easy subject to teach." And when he explains that selection for resistance can be thought of like selection against aggression or swarming, "the penny drops very quickly" (a British saying meaning an "aha" or "eureka" moment).

"The percentage of beekeepers in the U.K. who are not treating is about 25% and the number is growing. Progress. Within our club we have people who want varroa-resistant bees, and we have set up an apiary so that no one has to buy non-resistant bees. We have to teach two things: varroa resistant traits, and how to raise your own queens. Just from a U.K. perspective, we got people talking about the subject at just about every regional and national conference — a normalizing effect. And what is happening quite quickly is people working in club projects, starting small, people coming together."

Riley is on the team that launched the education and science website **www.varroaresistant.uk**, and his book "The Honey Bee Solution to Varroa," newly out from Northern Bee Books, was awarded a silver medal at Apimondia.

It's not so easy

Ralph Büchler is now retired as long-term head of the German Bee Institute in Kirchhain, Germany. His research has focused on the selection of honey bees for resilience to pests and pathogens. "Most of the beekeepers in Europe and America don't have resistant bees," he said. "Why don't they have resistant bees? I think they want them, and I think you have all come to this roundtable because you want them."

Just get going, don't listen to the naysayers.

Büchler coordinated the EurBeST project, mandated by the European Commission from 2017 to 2021 to survey varroa resistance in commercially available honey bees. The goal: reducing dependency on chemical treatments. The team was comprised of experts from scientists to breeders that carried out field testing in 11 countries with 150 beekeepers over one season. They surveyed 20 different genotypes and hybrids.

Christine Riley

Steve Riley heads the Westerham Beekeepers in England, part of a consortium of eleven clubs and beekeepers that are breeding resistant bees.

"We did not carry out any varroa treatment over a one-year period," he said. In addition to traditional characteristics like honey production, gentleness and swarming behavior, further assays were performed such as: recapping and SMR, suppressed mite reproduction; VSH, uncapping and removal of infected brood; and hygienic behavior, measured with the pin test — a block of small pins pressed into the brood, an alternative to the liquid nitrogen test. Other measures were made to determine colony strength and infestation.

"After one year, a 10% average infestation level was found in the brood, with, as would be expected, significant differences among the samples." But specifically bred lines maintained lower infestation levels, below 3%, even without treatment.

"Mite reproduction is very variable and influenced by many things. Most probably the most interesting and important thing is that the pin test correlated with infestation levels and with VSH," he said. "So it appears that VSH plays a central role and directly impacts bee infestation and brood infestation."

He pointed out the importance of using populations adapted to local climate and environment. "Can the market be capable of spreading these queens? The limiting factor is that the selection of resistant queens is a long and complex task." The EurBeST report cites the average cost of rearing a varroa-resistant queen bee as £193 compared to the average cost of rearing a non-selected queen bee as £22. And, he added, "Honey bee colonies from populations that are the result of natural selection for varroa resistance sometimes do not perform well in regard to traits that are considered crucial by commercial beekeepers, such as honey production, gentleness, or swarming behavior."

Büchler was a voice of experience less sanguine about the ease of developing resistant stock. "It's not so easy to get these bees tested on a large scale." However, "in Germany and neighboring countries, quite a few are following the Harbo model, and

we see some success with this." He has been keeping his personal apiary without treatment for 10 years. "It is an enormous load of work. There are beekeepers who could learn and they can speed up the selection process."

The challenge of winter

The North Americans on the panel — Pierre Giovenazzo, a professor at Laval University in Québec, and Steve Pernal, head of the Canadian Apiculture Research Program — stated their mutual goal: to establish bees that can weather the harsh Canadian winter and allow beekeepers to be less dependent on imported stock. Their breeding project thus far exemplifies Büchler's caveat that colonies selected for varroa resistance sometimes do not perform well for traits that are considered crucial by commercial beekeepers, like, in this case, survival. "My dream is to give beekeepers in Canada a varroa-resistant stock," said. Giovenazzo. "I'm sorry, I cannot at this time." Their first priority is winter-hardy bees, "then we can begin to breed resistant stock."

They are introducing genomics into their breeding program to define complex resistance behaviors. "Perhaps these markers will be useful in providing breeder queens to the industry," said Pernal. "The best selection event we have is winter. Beekeepers may not have sophisticated selection techniques, but they select from the survivors. Breeding off survivors and breeding off the best producing, many beekeepers are becoming self-sufficient, which is a significant paradigm shift from what they done in the past."

Brood odor and hygiene

Fanny Mondet is a bee biologist at INRE, working mainly with the relationship between bees and mites — "trying to learn how bees can cope with mites," she said.

"When bees survive mite infestations, there are mainly two different ways: tolerance or resistance. When bees are tolerant, they will reduce the impact of the mites on the colony but the number of mites will remain the same as they would be in a non-resistant colony. Resistance is the opposite. It is the ability of the bees to reduce the parasite, the reproduction success of the mites, and this in turn will allow the bees to maintain the level of mites below the threshold."

Looking at the characteristics of resistant bees, there are usually several reasons, she said. Behaviors involved in social immunity can be found at the colony level with swarming, which reduces the mite population, or the individual level with grooming or cleaning infected cells. Less known is the ability of the brood itself to reduce the mite population. "What we know about this is that chemical communication is key. So how do they know there is a mite within the cell? The cell is capped and the mite we know is hiding. How does this work?" She compares the response of T cells in the human body, to identify and destroy infection, to the colony with individual bees that can recognize an infected cell and then kill the larva in it. "This is what we want to understand."

They set about to find out if cells that were infected with varroa had the same odor profile as cells that were not infected. "It was not easy, like going fishing if you don't know if there are any fish." They used gas chromatography to separate the molecules and mass spectrometry to identify them. They found differences. By placing compounds found with infected individuals in brood cells to see if they would be cleaned or not, they have found that in some cases the bees will react. "This allows us to confirm that at least some of these compounds trigger hygienic behavior." They compared the response of colonies for VSH status, and only the VSH bees were able to tell the difference. "This aligns with our understanding that there is a genetic component."

About 5% of the bees can protect the entire colony.

Other researchers have found additional compounds, Mondet said, some more and less volatile. "You have many different compounds that are involved in the message. And what we know about communication and honey bees is that quite often there is a redundant signal — several molecules act together to give the signal. It is complicated to understand because there is a combination, and a question of amount, and also a ratio of amount. So the question was, these bees, do they have something special?"

She cited studies that indicate that there is a very low proportion of bees with these characteristics. "We found that only about 5% of the bees contribute in any way to hygienic behavior.

Fanny Mondet

Fanny Mondet

Yet these low-frequency behaviors can protect an entire colony.

"The take-home message is: We want to understand the mechanisms of social immunity in the colony, and that will help us understand how the individual bees' actions lead to collective protection at the highest level. That will also give us some markers for hygienic bees." The eventual goal is to create an applied test for beekeepers, using these compounds.

Mondet added, "I felt really positive, and I felt really surprised when the question was raised to the audience, how many of you don't treat the bees? I found that it was a lot of beekeepers. It was still a minority of the room, but still a lot of hands were raised. I think it's becoming a bigger and bigger concern. A lot of beekeepers are building initiatives.

"Lastly, to summarize what we have been doing with the beekeepers, we count, count and count mites."

Mea McNeil is a journalist and Master Beekeeper living with her family on their organic farm in Northern California. Her novel "Bee Club" was awarded the gold medal at Apimondia 2025 in Copenhagen. The book is available from Dadant.