Suppressing Mite Reproduction

SMR

An Update

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Breeding honey bees for resistance to *Varroa* (*Varroa destructor*) has been a goal since *Varroa* began to move into the worldwide population of honey bees. At times this goal seemed unreachable. However, we now know that resistance to *Varroa* does exist in honey bees, and it seems to exist in more than one form.

This article describes one mechanism of resistance that we have studied for the past seven years. It is a trait of the honey bee that suppresses the reproduction of *Varroa* mites. We call it the SMR trait. The gene or genes affecting this trait are probably present in populations of honey bees all over the world, and we used traditional breeding methods to increase the frequency of these genes in our local bees. We will describe the SMR trait and explain how bee breeders and beekeepers may benefit from having this trait in their bees.

Beginning the breeding program

Our goal was to produce honey bees that are genetically resistant to *Varroa*, and we defined mite resistance in honey bees as a slower growth or a decline of the mite population in a colony. Therefore, we began by developing ways to measure mite populations. We also measured four characteristics of honey bees that other researchers had linked to mite resistance. These were hygienic behavior (bees uncap dead or diseased brood cells and remove the contents), grooming behavior (bees bite and remove mites that are free-living on adult bees), duration of the capped period of worker brood (mites have less time to reproduce), and nonreproducing mites (mites enter the brood cell but do not produce progeny). This early work was designed to show which if any of these four characteristics were related with the growth of mite populations in our bees.

In our test group of about 60 colonies (test queens from the USA, mostly from Louisiana), nonreproducing mites was the only characteristic that correlated with the number of mites in the colony at the end of the test. To estimate the level of nonreproducing mites in a colony, we examined at least 20 mite-infested cells that contain worker bees at the pupal stage (purple eyed or older). For example, a colony estimate of 80% nonreproduction meant that we had found nonreproducing mites in 16 of the 20 mite-infested cells that we examined in that colony. In our tests in Louisiana and Michigan, colonies with a higher percentage of nonreproducing mites tended to have fewer mites.[6]

We then learned that nonreproducing mites was a heritable trait of the honey bee.[3] We estimated heritability for this trait by measuring mite reproduction in a group of colonies that had known genetic relationships. When measurements of a trait are more similar among colonies of bees that are genetically related than among colonies that are unrelated, then the trait has a genetic component. If relatedness has no effect on the expression of a trait, then the trait is not heritable and selection for the trait would not be possible.

Heredity in the honey bee was responsible for about 44% of the variance that we observed in mite reproduction. Environmental factors such as temperature, colony to colony migration of mites, colony location, measurement error, etc. probably accounted for the other 56%. However, a heritability level 44% is high enough to suggest that selective breeding for the trait should succeed, and it did. With selective breeding, we reduced mite reproduction to less than 10% in worker brood. Thereafter, we used the term "suppression of mite reproduction" (SMR) when referring to a characteristic of the honey bee and the term "nonreproduction" when describing mites.

Nonreproducing mites have been reported in bee populations throughout the world. When examining natural resistance to *Varroa* by honey bees in Tunisia,[9] Uruguay,[10] Argentina,[2] and Brazil,[1] resistance was associated with a high occurrence of nonreproducing mites. These resistant populations may have been caused by the SMR trait of the honey bee. Thus, the SMR trait may be widespread and relatively common. One could probably find the SMR trait anywhere in the world by inseminating each of 30 queens with single drones collected from 30 unrelated colonies. Single-drone inseminations are good for detecting traits at the colony level, but multiple matings are usually preferable thereafter.

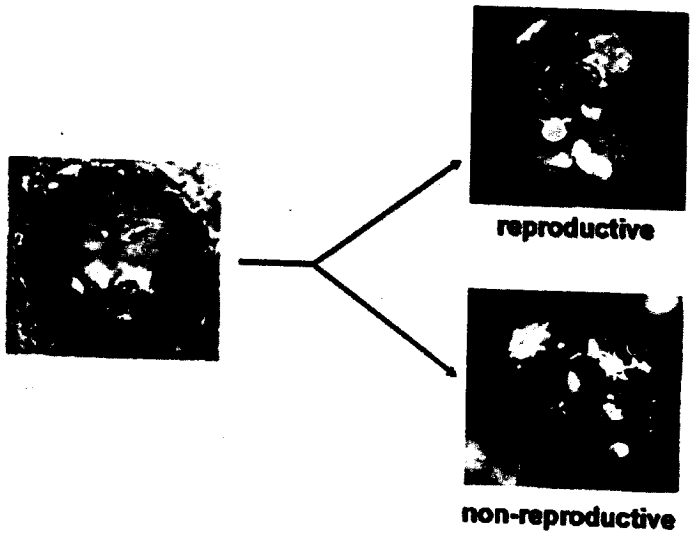
Background information on SMR bees

In a normally susceptible colony, a mite produces as many as four daughters and one son while in a worker cell. Rarely will all the progeny survive. A daughter mite will die if she has not reached adulthood by the time the host bee emerges from the cell; all males die at this time regardless of maturity. A typical mite-infested cell in a susceptible colony will produce one or two adult daughters during the 12-day period in a capped worker cell.

Bees with the SMR trait will prevent mites from successfully producing progeny. In colonies with SMR bees, mites enter the cells as if to reproduce, but they

do not produce progeny that survive. They may lay no eggs, lay eggs that do not hatch, or delay their egg laying so that none of the progeny has time to mature before the bee emerges from the cell. However, the important category, and fortunately the simplest to measure, is mites that lay no eggs[7]. See the May 2001 issue of *Bee Culture*[8], or the website http://msa.ars.usda.gov/la/btn/hbb/jwh/vrepro/vrepro.htm for more details and pictures of both nonreproductive and normally reproductive mites (Fig. 1).

The SMR trait is a delayed effect, so it is sometimes called SMRd to distinguish it from an immediate SMR trait (SMRi) that also exists in bees. Mite reproduction is not suppressed in the first cycle of brood when a queen with genes for SMRd is introduced into a susceptible colony. It takes about 6 weeks for a colony to suppress mite reproduction.



Field tests of SMR queens

We wanted to know if the SMR trait would provide an acceptable level of resistance when SMR queens were free-mated with unselected drones. The test consisted of three groups of colonies (colonies with SMR queens, with control queens, or with SMR x control queens).

Five commercial queen producers were involved in this project. We provided SMR breeder queens to the queen producers, and they sent us SMR daughter queens that had free-mated with unselected drones at their location (SMR x control). They also sent us some queens from their commercial stock, also free-mated, to serve as controls (control x control). We added a third group to the test, SMR queens that were artificially inseminated with SMR drones (SMR x SMR). In 1999 and 2000, we tested about 80 of these queens in Baton Rouge.

We found that colonies with SMR x control queens (free-mated daughters of SMR breeder queens) expressed a significant level of resistance to *Varroa*.[4,5] These colonies had fewer mites than colonies with control queens but more mites than colonies with pure SMR queens (SMR x SMR) (Fig. 2). In a separate test, Spivak et al.[11] had similar results: fewer mites in colonies with free-mated SMR queens than in colonies with control queens.

With additional selective breeding, we found that the SMR trait continues to be additive. Therefore, bee breeders can increase mite resistance even after they have diminished the SMR trait by mating SMR queens with drones at their location. For example, the daughter queens from a free-mated SMR queen would have about 50% of the SMR genes (higher than 50% if drones at the location had some genes for the SMR trait, but for the sake of this example we assume they had none). If these queens are mated to SMR drones, the colonies would be 75% SMR. We made and tested this cross and, on average, fewer than 20% of the mites were able to reproduce after they entered a worker cell. Therefore, in bee breeding, the SMR trait seems to have a simple additive effect.

Most of our work with SMR has involved small colonies in the summer in Louisiana. These colonies had no drones, and it is well known that varroa mites prefer to reproduce in drone brood. To keep experimental number of variables, we intentionally eliminated drone comb in our early experiments. When we encouraged drone production in SMR colonies, we found that mites had a higher rate of reproduction in drone cells than in worker cells. However, mites had a lower rate of reproduction on drones in SMR colonies than on drones in control colonies.

A cooperative project with Glenn Apiaries

Because of the benefits associated with the SMR trait, we have established a Cooperative Research and Development Agreement (CRADA) with Tom Glenn at Glenn Apiaries in Fallbrook, California, (http://members.aol.com/queenb95). The purpose of this agreement is to provide SMR breeder queens to anyone who wants them at a cost of $50 per queen. We (USDA-ARS at Baton Rouge) are responsible for selecting breeding stock and sending it to Glenn Apiaries; Glenn Apiaries has agreed to raise queens and drones, artificially inseminate the queens, and sell and ship the queens.

The SMR queens (SMR queens mated to SMR drones) produced by Glenn Apiaries are intended to be breeder queens only. These queens should produce colonies that are resistant to mites. A colony with an SMR breeder will have normally reproductive mites for a few weeks but should have nonreproductive mites in six weeks. Sometimes the brood becomes very spotty in colonies with SMR breeder queens, even though the queen may start out producing a very solid brood pattern. This does not always happen, and we don't know why it happens, but we're trying to find out. As a result, a colony with an SMR breeder queen may not grow rapidly enough to become a productive field colony. However, queens that were free-mated daughters of these breeder queens (SMR x control) did not have this problem.[4]

From a beekeeper's perspective

The SMR genes are commercially available as SMR breeder queens (see above) or as free-mated queens from other various queen producers. Free-mated SMR queens supplied by commercial queen producers will be variable, depending not only on the skill of the queen producer, but also on chance: how well the daughters of the SMR queens combine with the drones at a particular location. The degree of mite-resistance and the quality of the queens will also depend on the breeding

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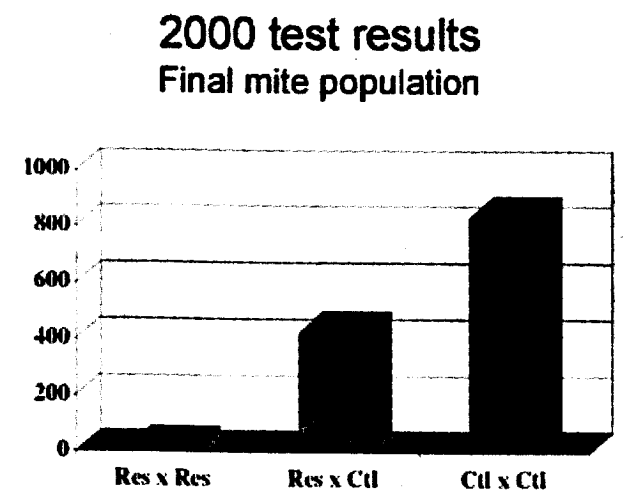

(crossing, backcrossing, and selection) done by the queen breeder.

SMR is not a stock, a population, or a race like Carniolan or Italian bees. The SMR trait is a group of genes (it may be only two additive genes) that can be put into any population of bees.

Conclusion

We are in a transition period where honey bees in the USA are still susceptible to *Varroa*, and we want to make them resistant as quickly as possible. Our plan is to insert mite-resistant genes into this population of bees without losing the genetic diversity and the beekeeping qualities that we now have. The release of the SMR trait is our attempt to assist bee breeders in making their bees resistant to mites and to increase the frequency of mite-resistant genes in our nationwide population of bees.

However, this transition presents a dilemma. If beekeepers stop using miticides and rely totally on mite-resistant bees, they risk losing their bees as well as their income. On the other hand, why should beekeepers buy mite-resistant bees if they are planning to treat them with miticide? There are various reasons. For some, mite resistant bees will be a first step in their effort to increase the frequency of mite-resistant genes at their locale. Others will attempt to reduce and in some cases free themselves from using miticides, and they need to monitor their colonies to verify that mite populations remain low. Still others may use mite-resistant bees as a second line of defense against mites that may become resistant to pesticides.

There is much yet to be learned about mite resistance and about the SMR trait. Free-mated SMR queens have done well in Baton Rouge. However, bees that are resistant to mites in Louisiana may not be resistant at some other locations. Resistance may vary because of different climatic conditions, food resources, management systems, and even differences in the virulence of mites. Therefore, we recommend that beekeepers use caution as they modify their present methods of controlling mites. BC

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