An Evaluation of Commercially Produced Queens That Have the SMR Trait

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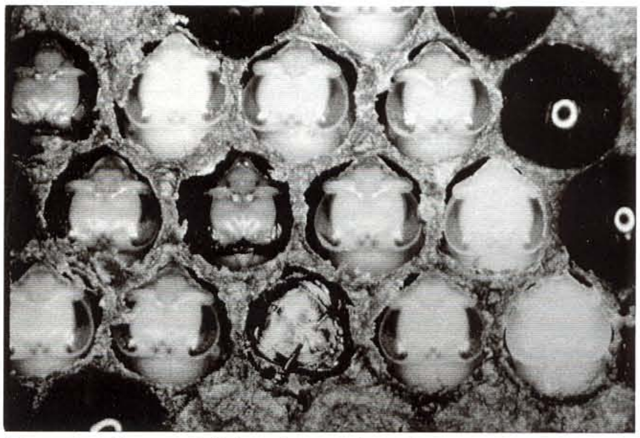
Photos from USDA Honey Bee Breeding, Genetics & Physiology Laboratory Website

During the past 8 years, we have been selecting bees for resistance to varroa mites. Most of this work has focused on a trait of the honey bee that causes mites to be nonreproductive. We found that nonreproduction of mites in brood cells was affected by a genetic component in honey bees. Various nongenetic events (such as the age of the mite, the season of the year, temperature, chemicals, etc.) may also cause mites to be nonreproductive and some of these are usually present to some degree. Because of these nongenetic (environmental) effects, it is common for highly susceptible colonies to have nonreproductive mites at a frequency of 20% or even higher. However, when female mites enter brood cells and fail to reproduce because of a heritable trait of the honey bee, we call it suppression of mite reproduction or SMR. See Harris and Harbo[4] 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.

Although there is still much to be learned about the SMR trait, we have learned the following:

1. It is a heritable trait of the honey bee[1].
2. Selective breeding can bring mite reproduction to zero in worker brood.
3. SMRxSMR colonies (colonies that have SMR queens mated to SMR drones) are highly resistant to varroa[2].
4. The trait is genetically additive, so a colony with only 50% of the SMR trait (such as a colony with an SMR queen mated to drones without the SMR trait) expresses an intermediate level of resistance to varroa[2, 3, 5].
5. 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 bred into any population of bees.
6. The SMR trait has a delayed effect. After a colony is given an SMR queen, the colony will have normally reproductive mites in the brood for about 2 months. If the colony was broodless when the queen was added (such as when queens are installed with package bees), nonreproduction of mites may be detected in about 6 weeks.
7. Sometimes brood production is poor in colonies with artificially inseminated SMRxSMR queens, even though a queen may produce a very solid brood pattern in her first brood cycle. This does not always happen, and we don't know why it happens. Consequently, a colony with an SMR breeder queen may not grow rapidly enough to become a productive field colony. Free-mated daughters of these SMR breeder queens have not had this problem, for tests have shown that colonies with free-mated SMR queens pro-duced as much brood and bees as control colonies (Table 1 and ref. 2)



Brood cells containing tan-colored pupae are examined to measure the percentage of non-reproducing mites. Non-reproducing mites do not produce mature daughters before the host bee leaves the brood cell. We examine mite families from 30 singly-infested cells per colony. Mite families are evaluated for the numbers and maturity of the female offspring to decide if the mother mite will succeed in producing at least 1 mature daughter during the time remaining in the metamorphic development of the bee pupa.

An adult worker bee with damaged wings as the result of developing within a brood cell infected by varroa mites (photo courtesy of Dr. Keith Delaplane; University of Georgia).

A Cooperative Research and Development Agreement

In 2001 the USDA set up a Cooperative Research and Development Agreement (CRADA) with Glenn Apiaries in

Fallbrook, California. The objectives of this 2-year agreement were fourfold: (1) make the SMR trait available to anyone who wishes to use it in their breeding program, (2) provide beekeepers with some immediate relief in their battle with mites, (3) increase the frequency of mite-resistant genes in our population of honey bees, and (4) test a procedure for transferring beneficial genes from the research laboratory to our commercial beekeeping industry. Our hope was that bee breeders will build on what we have started and will use the SMR trait to establish mite-resistant populations of bees at many locations around the country, thereby making our bee population resistant to varroa mites without losing the genetic diversity and the beekeeping qualities of the bees that we now have.

In the CRADA, we agreed to supply Glenn Apiaries with the SMR trait and Glenn Apiaries agreed to propagate, market, and sell queens with the SMR trait that they artificially inseminate with semen from drones that also carry the SMR trait. These queens (herein referred to as SMRxSMR) are intended to serve as breeding material for those who wish to produce queens that have the SMR trait. There is no restriction on what a queen breeder may do with the SMR trait. For example, a queen breeder may get an SMRxSMR queen from Glenn Apiaries, breed the trait into their own productive lines, produce hybrid bees, or simply propagate SMRxSMR queens. The CRADA does not grant Glenn Apiaries sole right to the sale of SMRxSMR queens, so any bee breeder is welcome to participate in the propagation and sale of this trait.

We recommend the use of free-mated SMR queens (daughters of the SMRxSMR breeders) in field colonies. This recommendation is based on tests in 1999 and 2000 that compared three groups of colonies: (1) colonies that have SMRxSMR queens, (2) colonies with free-mated SMR queens (colonies deriving the SMR trait from the queen and unknown traits from the drones with which she has mated), and (3) colonies that have control queens (queens not known to have the SMR trait) (see Fig. 1)[2]. Group 1 (above) had the fewest mites, but group 2 was clearly the best overall.

The CRADA called for us to test this again in 2002, but in a slightly different way. In 2002 we tested free-mated SMR queens that were produced by queen breeders who had purchased breeding stock from Glenn Apiaries. Earlier tests used queens produced by a different group of queen breeders who had received their SMRxSMR breeder queens directly from us. In 2002, 6 different queen breeders each sent us 2 of their free-mated SMR queens and 2 free-mated queens that they produced from a breeder queen of their choice. These represented queens that beekeepers could have purchased in May 2002.

Table 1. Results from a 137-day test that compared commercially-produced SMR queens with commercially-produced queens that had not been selected for the SMR trait. Colonies were evaluated in Baton Rouge, Lousiana. Each colony started with a test queen, 2.4 pounds of bees, about 130 mites, and no brood.

Characteristic	Free-mated SMR (n=11) mean (range)	Free-mated control (n = 13) mean (range)	P[a]
Final mite pop.	1059 (91 – 2859)	2711 (1416 – 4085)	0.006
Mites per 100 cells	14 (0.5 – 43)	32 (18.5 – 53)	0.02
Percent nonrepro. mites	51% (13 – 100%)	29% (11 – 55%)	0.08
Final wt of adult bees (lbs)	4.7 (3.1 – 7.8)	4.5 (2.8 – 6.7)	0.72
Cells of capped brood	5947 (4154 – 10384)	6018 (2313 – 9298)	0.92

a. Probability that the two means estimate the same population. Analysis used PROC Mixed, SAS software.

What can beekeepers expect from a free-mated SMR queen?

We evaluated the commercially-produced queens (free-mated SMR and free-mated control queens) in Baton Rouge in 2002. We also tested 5 SMRxSMR queens to serve as a baseline (Fig. 2). We set up a uniform group of 29 colonies that each contained 2.4 pounds of bees, 130 mites, broodless combs, and a test queen. The initial mite infestation (130 mites per colony) was determined by counting mites in samples of bees taken from a group of naturally infested bees that had been collected and into a large cage and later used to establish the test colonies. The test began on May 24 and ended on October 8 when we measured bee populations and mite populations in each colony.

The results (Table 1 and Fig. 2) are similar to that of our earlier test[2] (compare Figs. 1 and 2). On average, the colonies with free-mated SMR queens ended the test with about half the mite population and the same amount of brood and bees as the colonies with control queens (Table 1). Therefore, we concluded that beekeepers are likely to experience a significant reduction in mite populations when they use free-mated queens that have the SMR trait.

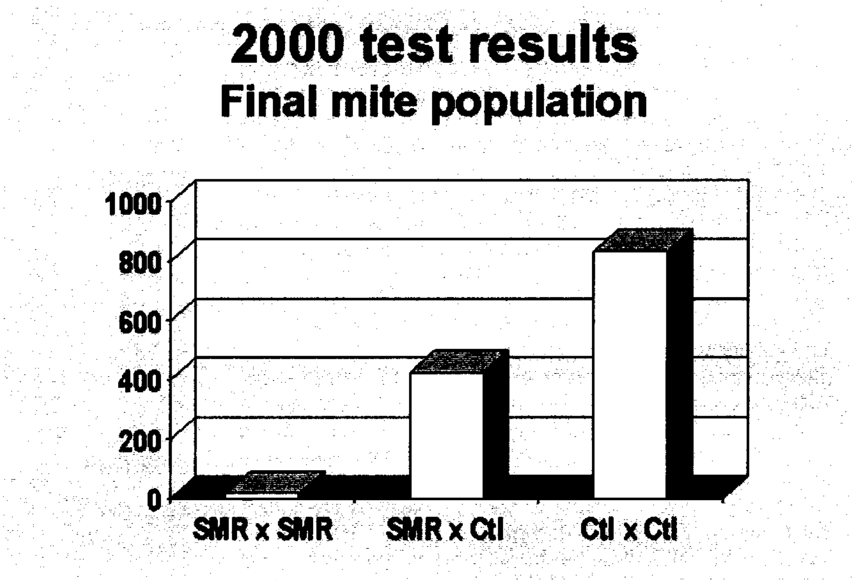


Fig. 1. Test results from 57 colonies that started in May 2000 with 2 pounds of bees, no brood, and about 600 mites. Mite populations refer to the average mite populations at the end of the 115-day test period[2].

Although colonies with free-mated SMR queens ought to have fewer varroa mites than colonies with unselected queens, beekeepers should expect some variability in overall level of resitance to varroa. We cannot explain this variability, and there are many possibilities. Whatever the cause, some of our test colonies with free-mated SMR queens were highly resistant to mites and some were susceptible, and a beekeeper won't know which colonies are susceptible and which are resistant unless they check mite levels. Many beekeepers now use simple field techniques to check mite levels in their colonies, and we recommend that this be continued until we can predict mite resistance with more certainty.

We noticed a source of possible confusion when ordering SMR queens from queen breeders. Glenn Apiaries sells SMRxSMR, but also SMR queens crossed with other stocks of bees, and bee breeders are experimenting with various combinations. It is therefore common for a queen breeder to produce queens from SMRxSMR queens as well as from SMR hybrids. When an SMR hybrid is used as a breeder, the daughter queens will have only half of the genes for the SMR trait, and after free-mating with non-SMR drones, her colony may be only 25% SMR; perhaps not enough to have a measurable effect on the mite population. In time, drone populations may have a higher frequency of SMR genes, and the mating of a queen would then contribute more toward increasing mite resistance in a colony.

Future plans

We are in a transition period where most of the 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 add mite-resistant genes to this population of bees without losing the genetic diversity and the beekeeping qualities that we now have. The release of the SMR trait may assist bee breeders in making their bees resistant to mites and may help to increase the frequency of mite-resistant genes in bee populations in many locations around the country.

We are encouraged with the overall performance of SMR queens that are free-mated with unselected drones, but we can do more. We hope to reduce their variability by combining a second mite-resistant trait with the SMR trait. If the addition of another trait increases mite resistance in free-mated queens, it would probably reduce both the variation and the mean rate of growth of mite populations.

The "trait" that we have in mind is a condition in a bee colony that we call "percentage of mites in brood." Our name for the trait describes how we measure it: the percentage of the colony's total mite population that resides in the brood at any time, as long as all stages of brood are present in ample quantity.

We assume that all mites in a colony are either in a brood cell or on adult bees, so we measure those two subpopulations in each colony and add them to get a total mite population (immature and adult *progeny* in brood cells are not counted). Over the years, we have found, on average, that about 65% of the mites are in brood cells. Colonies with a low percentage of mites in brood have a mite population that tends to remain on adult bees rather than entering brood cells where they would reproduce. By remaining on adult bees, mites delay their opportunity to reproduce, thereby reducing their rate of population growth.

We have been measuring the percentage of mites in brood for as long as we have been working with the SMR trait (about 7 years), but we are only beginning to use it in breeding. This trait should complement the SMR trait because it affects mites while they are outside rather than inside a

A mite family as seen at the beginning of the 15th day of bee development. The four mite progeny are: (1) egg [below mother mite], (2) female deutonymph [lower left of mother mite], (3) male deutonymph [immediately above mother mite] and (4) a female protonymph [farthest above and to left of mother mite].

A mite family as seen on the 17-18th day of the bee's development. The family consists of the mother mite, and her adult son and adult daughter (both located the farthest above the mother mite). The remaining two progeny are female deutonymphs.

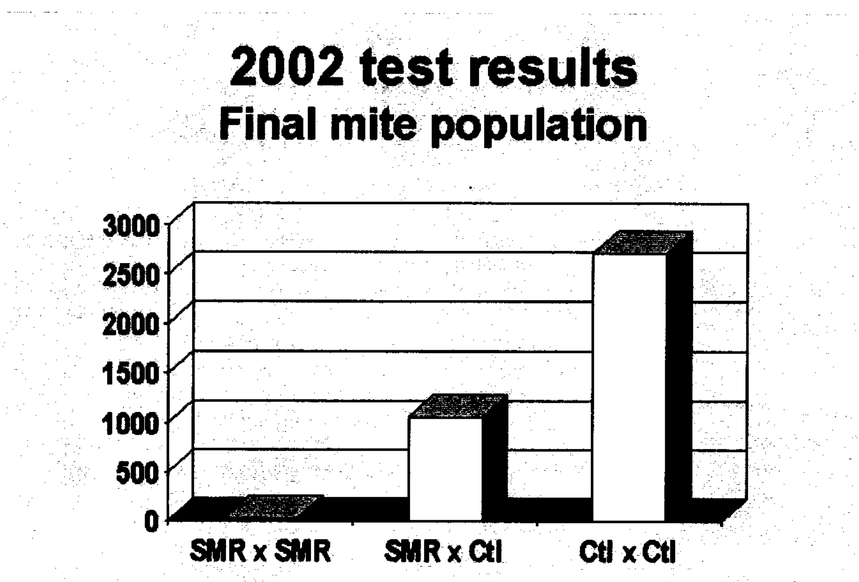


Fig. 2. Test results from 24 colonies described in Table 1 plus five SMRxSMR colonies that were included in the test to serve as a baseline for mite growth. As in the earlier test[2], colonies with SMRxSMR queens excelled in mite resistance, but were sub par in bee population (those 5 colonies averaged 36 mites and 2.5 pounds of bees per colony at the end of the 137-day test period).

brood cell where the SMR trait has an effect. We have learned the following about the percentage of mites in brood: (1) it is affected by a heritable trait in the honey bee[1], (2) environmental factors, such as screened bottom boards, can reduce the proportion of mites in brood, and (3) it is common to find colonies with only 30% of their mite population in brood. We want to know if selective breeding of bees can bring this percentage to zero.

Another objective is to assemble a hybrid bee that is commercially desirable and virtually unaffected by both varroa and tracheal mites. Some of the colonies with free-mated SMR queens were highly resistant to mites and were apparently very good. However, we didn't measure qualities such as tracheal mite resistance and honey production in those colonies. By using the SMR trait and what is known about the heritability of other traits (resistance to tracheal mites, honey production, nonstinging), we intend to demonstrate that it is possible to produce queens that we know (without prior testing) will produce colonies of bees that are totally mite-resistant and productive.

Although our nationwide population of honey bees is probably becoming more resistant to varroa, overall resistance in a population is difficult to measure. Perhaps an increase in the abundance of our feral colonies will provide a yardstick to measure progress. At the colony level, we have been able to select bees for resistance to mites, but we think that we can do more. Research approaches described in the paragraphs above could increase the average level of mite resistance and reduce variability in levels of varroa resistance. Moreover, additional breeding work should enable queen producers to combine other beneficial traits in queens that will be commercially available to beekeepers in the future.

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