Varroa – breeding for resistance

Imagine living with *Varroa destructor* (varroa) without putting chemicals in your hives that can harm bees, honey, wax, you and your wallet; this is possible through breeding. Honey bees have natural defences to keep varroa populations below economic thresholds before chemical treatment is necessary. By breeding both queens and drones from well performing colonies that keep mite populations low, we can develop varroa resistance in our commercial stocks. Without focused selective breeding, beekeepers are locked on the ever dangerous "chemical treadmill" which only creates more virulent mites and associated viruses, ultimately doing more harm than good. Breeding is a big job and every beekeeper has a role to play.

How bees fight the mite

Biochemical - bees change their chemical cues to stop the mite life cycle

- **The larvae don't produce cues that signal mites to enter a cell:** Mites usually enter larval cells just as the cell is being capped, and wait for the larvae to pupate to begin reproduction. If the foundress misses the opportunity to enter the cell, she cannot reproduce. Consequently, there is mite non reproduction (MNR).
- **The pupae don't produce the cues that trigger egg laying:** Mites require signals from pupae to lay eggs. Changing these cues can delay or prevent reproduction so the foundress mite doesn't have enough time to produce viable offspring (MNR).
- **The pupae produce signals that they are unhealthy:** This alerts worker bees to remove the unhealthy pupae (hygienic behaviour; HYB). The pupae can also produce specific signals that indicate they are parasitised by varroa which sends an "investigation" signal to workers (varroa sensitive hygiene; VSH). These events lead to MNR.

Mechanical - mites are physically damaged or killed

- Mites can get caught in the silk, or are killed when the larva pupates (MNR).
- If the male is absent, killed, or otherwise unfit then his sisters will be unmated and non reproductive (MNR).
- Workers respond to pupal signals that they are unhealthy (HYB) or infested with varroa (VSH) and uncap the cell (REC). Workers may remove the pupae and varroa or uncapping alone can interfere with mite reproductive success. Both contribute to MNR.
- Workers can groom themselves and others, removing mites from the brood nest, and sometimes damaging or killing the mites (mite biters; MB).

Biological - the bee life cycle changes

- Development time of the bee is shorter than that required for mites to produce viable offspring (Short development time; SDT).
- Colonies reduce the number of available hosts by creating smaller brood areas or generating breaks in the brood cycle by swarming and absconding (natural resistance).

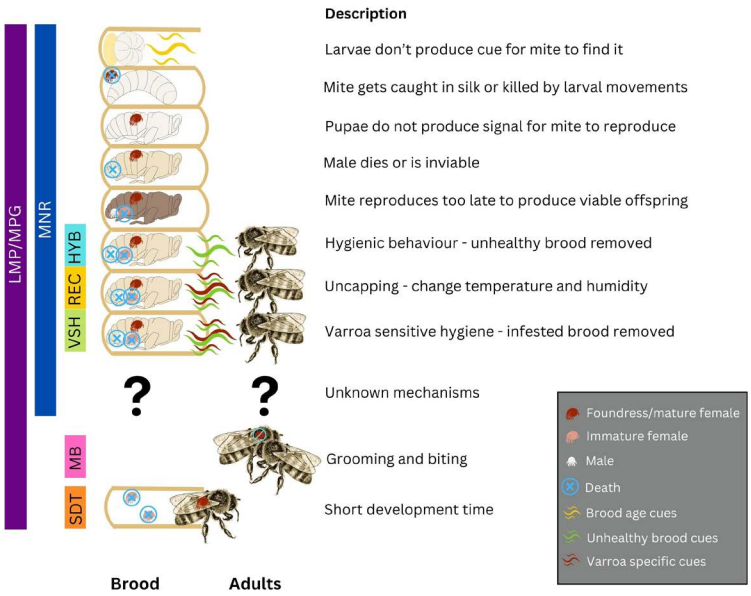

Figure 1. Varroa resistance traits selected for

Varroa resistance traits selected for in breeding programs. Hygienic behaviour (HYB): unhealthy brood signals are detected by workers and they remove the brood, along with varroa if that was the cause of illness; Uncapping/recapping (REC): workers detect signals from the brood that either they are unhealthy or infested with varroa, and remove the pupae and varroa; Varroa sensitive hygiene (VSH): workers detect that a pupae is infested and remove it, along with varroa; Grooming and biting (mite biters; MB): workers groom themselves or others to remove mites, which may cause damage or death of varroa; Short development time (SDT): bee brood have a shortened development time, meaning that varroa either doesn't have enough time to produce viable offspring, or produces fewer viable offspring. The mite non reproduction (MNR) includes VSH, REC and HYB, and other traits that we have not yet found a way to select for, it includes any trait that prevents Varroa from reproducing; selecting for low infestation rates (LMP) or low mite population growth (MPG) will select for all of the above traits, and any that we have not yet identified.

Breeding

Breeding should focus on traits that result in decreased mite load, increased colony survival, and reduced chemical use. Proof of low infestation levels without treatment or with minimal treatment should be provided when calling stock 'resistant'.

Single action traits

HYB, REC, VSH, MB, and SDT are single action traits. They can be effective against varroa, though it varies based on the population. These traits are not always linked with decreased mite load and increased colony survival. This doesn't mean that these traits aren't useful, but why give your bees one weapon when you can give them an arsenal?

MNR

MNR is responsible for reducing the ability of mites to produce viable offspring. Some traits can be selected individually: VSH, REC, and HYB. However, by focussing on singular traits, we fail to recognise and promote all the mechanisms that honey bees have to keep mites from reproducing their colonies. MNR is quantified by removing purple-eyed pupae and determining the number of infested cells with and without viable offspring. A minimum of 35 infested cells should be inspected.

VSH vs SMR: A brief history lesson

The USDA were selecting for low mite population growth, and then found that this was associated with suppressed mite reproduction (SMR). They developed a test for SMR which examined whether or not mites produced viable progeny in mite-infest, purple-eyed pupae. A breeding program began selecting for this trait. Further research showed that the mechanism behind the trait was varroa sensitive hygiene (VSH), which is specifically the detection and removal of varroa-infested brood. The trait and the population were termed VSH. VSH is the main contributor to SMR, but not the only bee trait involved. There are also factors related to the mites themselves that impact on their ability to reproduce, such as age. The scientific community is moving toward using the term MNR to described reduced mite reproduction, and the use of VSH only when the removal of mites from brood cells is considered. A common definition and language for these traits will reduce confusion and make it clear to beekeepers which trait has been selected for. The USDA population has been selected for MPG, VSH and MNR, these traits being intrinsically linked.

Low mite populations and population growth

Selecting colonies with low mite populations (LMP) or reduced population growth (MPG) to breed from will result in decreased mite loads. LMP and MP have been strongly linked with increased colony survival. Measurement is quick and simple to perform and will be part of every beekeepers' toolkit: alcohol or soapy water washes. LMP refers to a single assessment of mite populations, while MPG involves measuring it over time; MPG will give you more accurate results and more effective breeding. Selecting for LMP and MPG will promote all traits that keep varroa populations low, even those that we do not know about.

Natural resistance

Honey bee populations have become naturally resistant to varroa when left to their own devices without treatment and with little management. Generally, this involves massive population losses before the bees start to recover, and the populations tend to stay small. These populations also tend to have less desirable traits for beekeeping, such as small colonies that swarm frequently and low honey production. Natural resistance is difficult to achieve without everyone in the area being on board with the objectives. It would be worthwhile setting aside an area with a wide mix of genetics to help us to identify potentially resistant stock.

There have been a number of reports of previously resistant populations succumbing to varroa when they are moved, and thus a push for keeping populations locally (30 km). Others report they have no problem moving their bees around. This phenomenon could be due to a variety of reasons:

- The bees are not actually resistant.
- Exposure to new/different viruses, viral strains, more virulent mites, or other pathogens overwhelms them.
- Exposure to untreated collapsing colonies with massive mite loads can overwhelm resistant breeding colonies with mites. While they may have a level of resistance, they cannot cope with an influx of hundreds or thousands of mites at once.

Keeping colonies within a 30km zone is not feasible for most Australian beekeepers. The aim of any varroa resistance breeding program should be that they can be moved anywhere and survive and thrive.

Successful breeding

There are few proven varroa resistant stocks that are currently commercially available. This is due to various reasons, including the quality of the starting stock, focusing on single traits that cannot confer high enough resistance on their own, release of stock before it had enough resistance or appropriate commercial traits, breeding programs that don't select for resistance in both queens and drones which means that the trait doesn't reach high levels in the population, or the sheer volume of work involved in reaching the commercial stage. We can learn from what is working well overseas.

Bee breeder collaboration

Utilising two bee breeding strategies are recommended either together or in isolatio: MPG and MNR. Both strategies that confer lower mite loads resulting in reduced or no chemical treatments, and increased colony survival. A hygienic behaviour program based on unhealthy brood odours has already been initiated in Australia. Traits breeding groups choose to select for should be supported by a breeding focused extension and education program with dedicated staff that will assist the groups in setting up selection and breeding structures and assist with selection assays, evaluation, data collection, and data interpretation.

Partnering with other breeders will enable exchange of genetics, technology, expertise, collaboration to quantify traits, and a sense of community. Such communities may be able to develop designated mating stations to control mating and increase the presence of the trait in the population. Breeder collaboration is a proven key to success in the international breeding program led by the Arista Foundation.

Produce quality stock

Start with commercial stock and continue to select for commercially relevant traits. Releasing poor stock, or calling stock resistant before the trait is fixed in the population will result in distrust and low uptake.

Control mating and keep pedigrees

Selection for resistance traits must occur in both drone and queen mothers, otherwise the rate of selection will be slow. The best way to fix traits in a population is through the use of artificial insemination. The fastest way is via single drone insemination of breeder queens, or insemination of queens with drones from a single colony. This can result in poor performing colonies, however it is important to note that these colonies are not for production - they are for selecting the varroa resistance trait that can then be passed on into the wider population. With careful pedigree records or genetic testing, inbreeding can be avoided. These methods are powerful and will fast-track the selective breeding process, but are time consuming and require significant technical expertise.

Production queens can be produced with open mating. The mating yards should be flooded with high quality genetics - drones should carry genes for commercial traits and varroa resistant traits.

It is possible to determine if isolated mating yards are truly isolated using sugar feeders, taking some test queens to see if they mate successfully without drones being provided, or using queen pheromone to attract drones to potential drone congregation areas.

Treatment

Breeding for varroa resistance is next to impossible when regularly using treatments. Use of treatments means that colonies with non-resistant genetics continue to survive and prosper in the population. Limited chemical treatment may be appropriate but must be supported by monitoring/ infestation data. For example, if surrounding beekeepers are choosing not to treat their colonies then this can result in heavy infestation of breeding populations if/when these colonies collapse. This can result in the loss of breeding lines that have been the product of years of work. The timely and considered application of miticites should be considered.

Key takeaways

- The aim is to produce bees that are desirable for beekeepers, keep mite populations low, require no or reduced chemical treatment, and have increased survival.
- This is best achieved by selecting for MPG and MNR.
- It will take a lot of work and at least five years to produce stock that can be called resistant.
- Bee breeder networks and input from beekeepers will be essential.
- Evidence must be provided that the stock is resistant; simply surviving is not enough to be called resistant.
- Record keeping will be essential - pedigrees and trait quantification.
- Selection must be performed on both drones and queens, and mating controlled to fix the traits in the population.

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Varroa support

This fact sheet is the fourth of a series to support beekeepers to manage varroa. Other tools will also be made available, including webinars and podcasts. You can find all these tools online at AHBIC and AgriFutures Honey Bee & Pollination Program. AgriFutures Australia is working to support beekeepers in conjunction with industry.

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