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NOTES AND COMMENTS

Comments on: "*Varroa destructor*: research avenues towards sustainable control"

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A recent review in the *Journal of Apicultural Research* offers thoughts on research needed to achieve sustainable control of *Varroa destructor* (Dietemann *et al*., 2012). Discussion about such research is laudable because of the preeminent threat of the mite to honey bee health. However, while noting that identifying and breeding honey bee strains resistant to *V. destructor* would be ideal, the authors state that we are "not close to any such sustainable solutions". We disagree with this negative characterization of the status of honey bees with genetically based mite resistance. Resistance is usually defined as the ability of an organism to limit parasite burden, while tolerance is the ability of an organism to limit the harm caused by a given burden (see Råberg *et al*., 2009). Resistance thus is the preferred term to describe honey bees that keep *V. destructor* infestation at relatively low levels.

The review cites issues that are said to currently restrict the development and adoption of resistant bees. For example, there is a call for detailed knowledge of resistance mechanisms. While further knowledge of resistance traits certainly is desirable, it is clear that we have a good understanding of general hygiene against dead, diseased and injured brood, and of Varroa Sensitive Hygiene (VSH) against mite infested brood. Extensive research in North America (reviewed by Rinderer *et al*., 2010) has resulted in the development and use of bees having resistance based on these single traits: Minnesota Hygienic bees selected for general hygiene have moderate varroa resistance, while bees selected for VSH have high varroa resistance.

There is a criticism of selecting "blindly" for resistance, i.e., by using an approach that simply targets low mite infestations. This has already, however, been documented to be a viable breeding approach that has led to honey bees that now are used by both small-scale and commercial beekeepers with no or minimal acaricide input: Russian honey bees in the USA (Rinderer *et al*. 2010; de Guzman *et al*., 2007) and bees bred by John Kefuss in France (Büchler *et al*., 2010; Kefuss *et al*., 2004). Resistance in other untreated bees selected for survival may be functional but has not been documented with rigorous testing. Dietemann *et al*. (2012) offer two criticisms specifically about bees with hygiene-based varroa resistance. The first is a lack of general acceptance in the beekeeping community. However, there is documented acceptance of resistant bees in the USA. A 2005 survey showed that Russian honey bees were being used by 24% of US beekeepers (Kim *et al*., 2010). Other data collected in conjunction with this survey showed Minnesota Hygienic and VSH bees were being used at similar frequencies (J Westra, Louisiana State University, USA; pers. comm.). We expect that acceptance has increased after that survey. The average annual distribution of VSH breeder queens has more than doubled since 2008 (T Glenn, Glenn Apiaries, Fallbrook, CA, USA; pers. comm.), and a review of advertisements for honey bee queens in primary beekeeping magazines suggests that the VSH trait occurs in at least 25% of honey bees being produced in the USA. These metrics describe a desire for bees with hygiene-based varroa resistance and the willingness of beekeepers to pursue this option. In addition, members of the Russian Bee Breeders Association (RBBA) report that although production has increased, they cannot meet the demand for queens (S Coy, President, RBBA, Wiggins, MS, USA; pers. comm.). We recognize that there are circumstances where breeding for resistance may be restrained by cultural or economic factors, e.g., the need or desire to preserve native ecotypes in Europe.

A second criticism is that bees exhibiting hygiene do not represent a sustainable solution to varroa. Potential problems with sustainability over time may be thought to be of two sorts: maintenance of mite resistance itself, and decreasing genetic diversity. Regarding varroa resistance itself, there are beekeepers who have kept resistant bees (VSH and Russian) without the use of acaricides for up to a decade. And there are many instances of resistant bees being the centrepiece of an integrated pest management (IPM) approach that has employed fewer treatments and "softer" chemicals. These realities show clear progress toward eliminating or reducing reliance on chemical control of varroa. Regarding genetic sustainability, there are currently numerous

breeding efforts to enhance the level of hygiene in genetically diverse stocks. Notable among these is a coordinated selection for hygiene against dead (freeze-killed) brood by breeders of the large queen production industry in northern California, USA (Spivak, 2011). In addition, bees produced by outcrossing VSH breeding stock have been shown to be functional both in varroa resistance and in their beekeeping characteristics (Harbo and Harris, 2001; Danka *et al*., 2012). This process of outcrossing VSH seems well suited for introgressing resistance into genetically diverse types of desirable bees. Regarding Russian bees, commercial propagation began in 2001 and has been fully the responsibility of beekeepers since 2005; hence this resistant population has been used for about a decade with no evident loss of fitness. Finally, Dietemann *et al*. (2012) advocate the desirability of selection using genetic markers. Several efforts around the world currently are targeting varroa resistance traits to meet this goal (Behrens *et al*., 2011; Arechavaleta-Velasco *et al*., 2012; Parker *et al*., 2012; Tsuruda *et al*., 2012), and we agree that this approach should improve opportunities for selection in diverse populations of honey bees. However, while genetic markers are expected to be useful, they clearly were not essential for the development of the current varroa resistant stocks now being used.

We agree with Dietemann *et al*. (2012) that the effectiveness of IPM programmes (presumably including genetically resistant bees) for varroa control, depends on the dedication and proficiency of individual beekeepers. Our experience is that small-scale beekeepers are further ahead than large-scale beekeepers in acceptance of resistant bees. This is understandable, because commercial beekeepers are necessarily more averse to risks and the technology is new. However, the rate of adoption of agricultural technology tends to follow a logarithmic trend. Thus the adoption of resistant strains can be expected to accelerate, in part because of recent advances in basic IPM of varroa (e.g. improved sampling techniques for large-scale beekeeping; Lee *et al*., 2010) and in knowledge about the negative effects of acaricides on bees (e.g. Johnson *et al*., 2009).

Honey bee strains that are resistant to varroa are a valuable resource that beekeepers are using successfully. Although these bees have not completely solved the problem, we are in fact moving toward the ideal of sustainable varroa control described by Dietemann *et al.* (2012). Further research to determine the best IPM procedures to support the full expression of resistant phenotypes would move us more quickly toward ending reliance on acaricides.

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