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STATUS AND PERSPECTIVE OF DISEASE RESISTANCE BREEDING IN THE HONEY BEE

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Abstract

Breeding for disease/Varroa resistance is much more complex than for production traits. Hygienic behaviour against diseased brood is the most important factor of disease resistance and but likely to be controlled by a limited number of loci, which affect a bee's sensitivity to the stimulus of diseased brood. Disease resistance traits are likely to exceedingly benefit from markers-based models for genetic evaluation.

Keywords: Honey bee, Disease resistance, Breeding

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1. Introduction

Approximately 70% of plant species cultivated for human consumption are at least partly dependent on insect pollination, and Apis mellifera is arguably the single most important pollinator species (Klein et al., 2007). Although the worldwide honey bee population increase (FAOSTAT(http://faostat.fao.org), honey bee colony numbers have reportedly declined in some areas with the most likely explanation being a combination of stressors, including synergistic interactions between parasites, pathogens, toxins including pesticides, and other stressors. However, the most serious cause for the periodic colony winter losses of 30% and more are honeybee diseases, especially the ectoparasitc mite Varroa destructor and associated viruses (Genersch et al. 2010). A promi¬sing approach to prevent its spread is to breed for Varroa tolerant honey bees. A trait which has been shown to provide significant resistance against the Varroa mite is hygienic behaviour, a behavioural response of honey bee workers to brood diseases in general. Hygienic behaviour is defined as the ability of honeybee workers to detect and remove pupae that are infected with brood diseases before the causative organism reaches the infectious stage, thereby limiting the spread of infection. Considering these facts, the hygienic behaviour presents a useful mechanism of disease resistance, since almost all serious illnesses of honey bee result from brood diseases. Therefore, hygienic behaviour can be effective not only against Varroa, but also against other brood diseases, which provide a significantly stronger olfactory stimulus by causing more obvious damage to the brood.

2. Results and Discussion

2.1. Practical Breeding Programs

In the past honey bee breeding programs focussed on traits of direct apicultural interest such as honey productivity, gentle temper and low swarming tendency. However, since Varroa destructor began spreading throughout Europe research on mite resistance of honeybees and later breeding program carried out by bee breeder bees started. Starting about 30 years ago, much research focused on the identification of suitable selection characters and a measurement of the within colony Varroa population growth and the hygienic behaviour against freeze-killed or pin-killed brood are now most commonly used as selection traits to breed for Varroa resistance (Büchler et al., 2010). Significant progress has been achieved by the use of BLUP genetic evaluation (Bienefeld et al., 2007) for these traits.

2.2. Experimental Breeding Programs

Uncapping and removing of infested brood are assumed to be important traits within Varroa resistance. Traditionally, selection in honey bee breeding programs is carried out on the basis of colony performance with respect to group traits such as honey production and colony defense. Hygienic behavior of colonies with respect to artificially killed, ill or parasitized brood has a moderate genetic basis but colony level selection may not be very efficient for Varroa resistance breeding because of significant intracolonial variations, caused by the multiple mating of the queen and consequently the composition of several patrilines within colonies. Consequently, we started selecting a Varroa resistance line based on the hygienic behavior towards Varroa parasitize brood cells of individual worker bees (Figure 1) during a 6 d infrared video observation (Bienefeld et al., 2016). Individual, hygienic worker bees, normally infertile, were induced to lay eggs. Unfertilized eggs of worker bees develop in the honeybee into drones, whose sperm can be used for insemination. Consequently, worker bees were use as fathers for the next generation. In those cases in which this procedure was not possible, we used the within sister frequency of hygienic worker bees daughters as a selection objective for the breeding queens. We found that uncapping behaviour towards Varroa infested cells is extremely rare in A. mellifera, but varies (0% to 5%) significantly between colonies. This most promising, direct Varroa resistance trait was found to be genetically determined and we observed a significant genetic progress within our selection line.

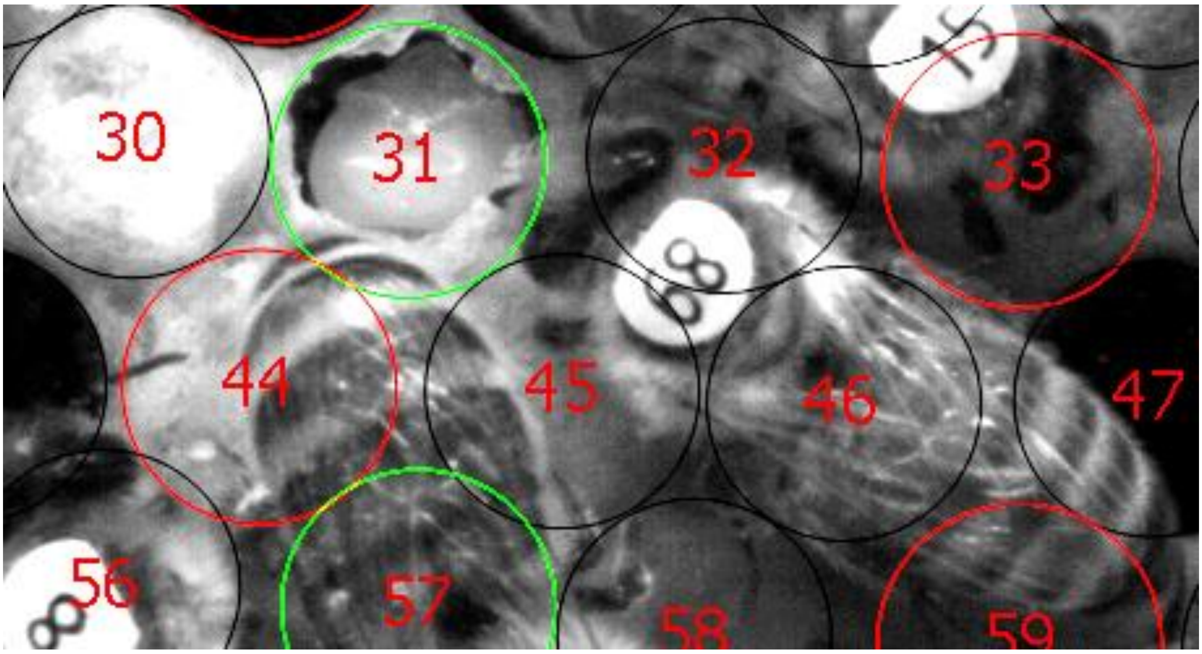

Figure 1. Pair Video screenshot showing a worker bee, which uncapped a Varroa-infested brood cell (marked green). Brood cells marked red are Varroa-free controls.

2.3. Genetic markers for Varroa resistance

Genome-wide association studies (GWAS) have evolved into a powerful tool for investigating the genetic architecture of traits in different species. However this approach needs well-defined phenotype of interest and an appropriate control. Our selection line and our long term infrared observation technique provided the conditions for this approach. 22000 worker bees from crossings between our selection line and unselected colonies were monitored with the infrared camera technology and we subjected the 122 top performing hygienic bees and 122 negative controls to a SNP genotyping assay (44K SNP chip), which was specifically developed for the analysis of Varroa resistance traits (Spötter et al., 2012) . After false discovery rate correction of the p-values, six SNP markers had highly significant associations with the trait investigated. Inspection of the genomic regions around these SNPs led to the discovery of putative candidate genes involved in odour reception neuronal sensitivity to external stimuli (Spötter et al., 2016). Further proteomic studies have confirmed these findings (Hu et al. 2016).

2.4. Future trends in honey bee breeding: Genomic selection

Traditional breeding programs rely mainly on phenotypes, plus pedigree information. Genomic selection is a new approach for improving quantitative traits that use whole-genome molecular markers. Genomic prediction combines marker data with phenotypic and pedigree data in an attempt to increase the accuracy of breeding and genotypic value prediction. Using next generation sequencing of drones from different A.m. carnica populations, a new 100 000 SNP chip was developed, aiming to initiate genomic selection for traits of Varroa resistance, productivity, and gentleness in honey bees. Due to the lower heritabilities and the time consuming recording of disease resistance, these traits are likely to benefit significantly from genomic selection.

Conflict of interest

The authors declare that there is no conflict of interest.

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