5.2 BEEHAVE validation and resulting insights for the design of field studies with bees

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Abstract

Factors affecting honey bee health are manifold (including diseases, parasites, pesticides, environment and socioeconomic factors). A lack of standard procedures for higher tier risk assessment of plant protection products for bees makes coherent availability of data, their interpretation, and their use for higher tier risk assessment challenging. Focus has therefore been given to the development of modelling approaches which in the future could fill this gap. BEEHAVE is the first model attempting to link two of the processes vital for the assessment of bee mortality; the within-hive dynamics for honey bee colonies and bee foraging in heterogeneous and dynamic landscapes.

Here we show results of several BEEHAVE validation studies conducted. We specifically focus on insights gathered through these modelling exercises for the design and the usability of field studies for further development, testing and validation of the BEEHAVE model.

Overall the model validation shows that predictions of bee hive dynamics fit observations of the total number of adult bees, the total number of offspring in the hive, and the production of drones well. This result underpins the results of the EFSA evaluation of the BEEHAVE model, that the most important inhive dynamics are represented and correctly implemented in the model, with empirical evidence. Agreement between data and model predictions is particularly high for the initial experimental phase prior the generally conducted relocation of the bee hive from the actual experimental landscape to an overwintering site. Increased discrepancy following the relocation is an artefact of lack of information on the landscape characterisation of the overwintering site for model parameterisation; leading to increased inaccuracy of the model prediction for pollen and nectar resources in the hive, that in turn determines the abundance of bees and thus the overwintering survival probability of the colony.

It is vital to redistribute experimental efforts allocated to a field study to better assess the suitability of using BEEHAVE for the prediction of bee colony overwintering survival as an important endpoint for higher-tier risk assessment for bees. A more equal bee hive and landscape investigation throughout the entire field study, rather than a bias towards the actual exposure phase, is required to improve data availability for model validation.

5.3 Bee pollinator toxicogenomics: an interdisciplinary approach to unravel molecular determinants of insecticide selectivity

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Abstract

A favorable bee profile is one of the key requirements in the development and (re)registration of insecticides. While the toxicity of insecticides to bees is routinely assessed according to officially published guidelines and guidance documents, their interactions with bees on the molecular and biochemical level have not been intensively studied, yet.

Thus, Bayer AG, Crop Science Division, initiated the project “Bee Pollinator Toxicogenomics” with the particular aim to elucidate the molecular basis of selectivity of insecticides against bee pollinators with special reference to a comparative functional genomics approach covering different bee species in cooperation with external partners.

As a starting point, we performed toxicological studies with the *N*-cyano-substituted neonicotinoid insecticide thiacloprid and *N*-nitro-substituted compound imidacloprid to identify the reason(s) for the over 500-fold higher intrinsic toxicity of *N*-nitro-substituted compounds to the honey bee (*Apis mellifera*). Radioligandbinding assays revealed that both, thiacloprid and imidacloprid, display a similar nanomolar binding affinity to their target, the postsynaptic nicotinic acetylcholine receptor (nAChR). However, thiacloprid is significantly faster degraded by hydroxylation compared to imidacloprid providing evidence that cytochrome P450 monooxygenases (P450s) facilitate oxidative metabolism of this chemical class. Subsequently, a honey bee P450 expression library compromising all 27 clade 3 P450s was established and P450s belonging to CYP9Q-subfamily were identified to be involved in the rapid turnover of thiacloprid, mainly driven by CYP9Q3, but with a low turnover of imidacloprid. Beside the honey bee CYP9Q-family, we also identified in collaboration with external partners at Rothamsted Research and Exeter University the orthologous P450s CYP9Q4-6 in the bumblebee (*Bombus terrestris*) and CYP9BU1-2 in the red mason bee (*Osmia bicornis*) as key determinants of neonicotinoid selectivity. The knowledge obtained from this interdisciplinary approach is of high value to mechanistically understand the interaction of pesticides and bees beyond guideline studies and is further extended to gain insights in the molecular mechanism underlying bee-sensitivity in other pollinator species, i.e. the alfalfa leafcutter bee *Megachile rotundata*.

Moreover, the established molecular and biochemical tools are ready to be applied to address questions of fundamental research as well as in the targeted design of intrinsically bee-friendly insecticides.

5.4 Introducing the INSIGNIA project: Environmental monitoring of pesticide use through honey bees

Jozef J.M. van der Steen (on behalf of the Insignia consortium)

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Abstract

INSIGNIA aims to design and test an innovative, non-invasive, scientifically proven citizen science environmental monitoring protocol for the detection of pesticides by honey bees. It is a 30-month pilot project initiated and financed by the EC (PP-1-1-2018; EC SANTE). The study is being carried out by a consortium of specialists in honey bees, apiculture, statistics, analytics, modelling, extension, social science and citizen science from twelve countries. Honey bee colonies are excellent bio-samplers of biological material such as nectar, pollen and plant pathogens, as well as non-biological material such as pesticides or airborne contamination. Honey bee colonies forage over a circle of 1 km radius, increasing to several km if required, depending on the availability and attractiveness of food. All material collected is accumulated in the hive.

Keywords: honey bee, pollen, pesticides, citizen science, botanical origin, passive samplers