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Editorial

Special Issue: "Frontier Research in Apiculture (Diagnosis and Control of Bee Diseases, Bee Products, Environmental Monitoring)"

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In recent years, the attention paid to farmed honeybees has considerably increased based on new and different threats posed to this sector, i.e., colony depopulation and colony losses, exotic pathogens, invasive alien species, residues in bee products, and antimicrobial resistance. This Special Issue reflects the complexity of this sector and of the animal species, the honeybees (*Apis mellifera*), at its core. This sector views the farming of honeybees; the control, prevention, and management of their diseases, pests, and pathogens; and the production of honey, pollen, propolis, royal jelly, beeswax, and venom as indissolubly linked. Furthermore, honeybees share an environment with human activities, and can be affected by them. In particular, agrochemicals, if not properly applied and regulated, can severely affect farmed honeybee colonies with acute, subacute, and long-lasting effects on their health and development. In addition, farmed honeybees are a recognized biomarker of agriculture and environmental pollution based on their biological characteristics and behaviour, which can be exploited to collect information regarding the health status of the territory. Twenty full articles, two review articles, and two miscellaneous articles have been collected for this Special Issue, "Frontier Research in Apiculture (Diagnosis and Control of Bee Diseases, Bee Products, Environmental Monitoring)".

Formato et al. [1] provided basic information on nosemosis and reviewed the majority of the diagnostic methods, highlighting advantages and disadvantages in order to provide a source of knowledge for veterinarians and researchers. Both *Vairimorpha apis* and *Vairimorpha ceranae* can lead to the weakening or death of *A. mellifera* colonies. Mazur and Gajda [2] reviewed the currently known techniques for the prevention and control of nosemosis, including good beekeeping practices (GBPs) and biosecurity measures (BMBs that appear to be optimal approaches to combat this infection via an "integrated pest management strategy", as a sustainable solution alternative to the use of antibiotics). Prouty et al. [3] tested the efficacy against *V. ceranae* of some commercially available products in one lab-based and three field experiments. The obtained findings raise questions regarding the efficacy of the products currently being used by beekeepers to control *Vairimorpha* spp., since the observed reduction in *Vairimorpha* spp. is more likely relevant to the phenology of spore prevalence and intensity in honeybee colonies than to therapeutic treatment.

Using a metataxonomic approach, Georgi et al. [4] revealed an overall decrease in the microbial diversity of both bacteria and fungi in honeybee and beebread samples of colonies showing severe *V. ceranae* infections (>2.5 M spores per bee) as compared with colonies exhibiting very low spore counts. They hypothesised that the overall reduced microbial diversity and relative abundance of certain microbial groups could serve as biomarkers of colony collapse. Cilia et al. [5] investigated two different methods of real-time PCR (qPCR), relying on the 16S rRNA and Hsp70 genes, respectively, for the quantification of *Vairimorpha* spp. infection. The polymorphic nature of 16S rRNA was shown to be a limit during the infection quantification, while the abundance of *V. ceranae* was assessed in honeybee samples using methods based on the single-copy gene Hsp70.

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Kleckner et al. [6] reported a detailed method for an acute toxicity bioassay that delivers active substances via pollen in traps made from modified compact disc cases to control the small hive beetle (SHB), *Aethina tumida*. Acetamiprid showed promising results. Di Ruggiero et al. [7] tested the "mobile divider"-based method in the field to facilitate the detection of *A. tumida* and save time during hive inspection. Formato et al. [8] described the protocol adopted in the Calabria region (southern Italy) to manage SHB-positive sentinel honeybee colonies under the supervision and management of the local official veterinary service to find a more effective and less time-consuming approach to SHB surveillance.

De Carolis et al. [9] presented the results of an international survey regarding the risk assessment of honeybee (*A. mellifera*) health for Varroa infestation management. They took into consideration the adoption of good beekeeping practices and proper biosecurity measures, revealing a significant interest of beekeepers in additional bee health training and connecting with veterinary experts who specialize in bees. Mezher et al. [10] reported a worldwide survey performed in 2015–2017 to gather information on beekeepers' perceptions concerning good beekeeping practices, the main honeybee diseases, and the technical assistance which they receive. Cournoyer et al. [11] demonstrated that continued and severe exposure to varroa leads to increased viral charges and decreased sugar concentrations in haemolymphs, with possible alterations in immunity, metabolism, and reserve mobilization. Porporato et al. [12] developed the Bee Ethic system to apply hyperthermia in order to control *V. destructor,* using an integrated pest management (IPM) approach without chemicals. Smodiš Škerl et al. [13] recorded the efficacy of VarroMed® against *V. destructor* in different climatic conditions, ranging from 71.2 to 89.3% in the summer/autumn and from 71.8 to 95.6% in the winter. According to Pietropaoli et al. [14], the powdered sugar roll method may be suggested to beekeepers as a suitable IPM tool for estimating the level of varroa infestation, while natural mite fall represents a more accurate method that could be adopted for selection/research purposes.

Carra et al. [15] presented a new, quantitative TaqMan® probe-based real-time PCR (qPCR) assay, targeting the 16S rRNA gene of *P. larvae*. They used this for the quantification of *P. larvae* spores in powdered sugar samples collected from hives, and compared them to the culture. A close concordance with the clinical–epidemiological statuses of the hives was observed using both methods, with higher infection levels detected by qPCR. Pietropaoli et al. [16] investigated the efficacy of one strain of *Lactobacillus plantarum* that was orally administered to honeybees for American and European foulbrood prevention.

Martinello et al. [17], based on archive specimens of dead honeybees, pollen, honey, and vegetables, revealed the presence of many active substances, several belonging to hazard classes I and II, thus representing a potential risk for human health. Competent authorities could exploit the information provided by a One Health approach. Papa et al. [18] detected inorganic particulate matter (PM) in pollen grains collected by forager bees in an industrial area of the Po Valley (Northern Italy), demonstrating the potential risk of PM entering the food chain and the exposure of bees to it via ingestion.

Bordin et al. [19] investigated the health statuses of apiaries in different areas of the Veneto region (northeast of Italy) for two consecutive years (2020 and 2021) in the spring, during the resumption of honeybee activity. The viruses BQCV, SBV, and CBPV, followed by *V. ceranae* and *L. passim,* were the most prevalent pathogens, and many of the investigated hives, despite being asymptomatic, had different degrees of co-infection. By means of an end-point PCR, which was confirmed by Sanger sequencing, Pietropaoli et al. [20] detected the presence of *A. woodi* in samples of honeybees and hive debris collected from apiaries in the Latium region (Central Italy). A potential underestimation of the occurrence of *A. woodi* in Italian apiaries is hypothesized. Boncristiani et al. [21] carried out a screening of natural products in laboratory cages, demonstrating their potential to reduce the levels of deformed wing virus (DWV-A and-B). This would positively impact the gut microbiome and stimulate immune responses in honeybees.

The Italian national beekeeping registry (BDNA) was deemed a suitable tool with which to explore and identify the availability of areas that could be used as controlled mating stations for queen honeybees by Mutinelli et al. [22].

Abdollahi et al. [23] reviewed the existing literature on bee acoustics analysis between January 2012 and December 2021, providing a set of recommendations. Abdollahi et al. [24] investigated three different environmental noise factors, then developed a system based on these features and a convolutional neural network to predict beehive strength.

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