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Editorial

# The Pollinators in Agricultural Ecosystems

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The symbiosis of plants and animals is an evolutionary phenomenon that has been established for millions of years. Thanks to pollinators, the percentage of pollinated flowers significantly has increased, while reducing the costs associated with the production of generative cells by plants. As a result of this cooperation, pollinators gain easy access to a source of amino acids necessary for their development and to nectar, a source of energy for their everyday functioning.

The importance of pollinators is particularly important in the case of large-area crops, which are the basis of modern agriculture. In such crops, bees, including, primarily, the honeybee (*Apis mellifera*), dominate as pollinators, mainly due to the possibility of periodic isolation, ease of transport, large numbers, long flight range, flower fidelity, etc.

The effectiveness of crop pollination by pollinators depends on many factors, only a small part of which is discussed in this Special Issue: "The Pollinators in Agricultural Ecosystems".

The health of honeybees, environmental conditions, and exposure to harmful factors can be manifested in the sounds made by these insects. As well as other authors, this information is provided by Sharif et al. (2023) [1]. These authors investigated the bursting sounds emitted by experienced forager bees during the waggle dance at a specific angle on a vertical comb within the hive and assessed whether this information is suitable for predicting the spatial and temporal information of the available food sources. Based on the information provided by these authors, it can be concluded that sound analysis may be one of the potential methods of non-invasive control of the condition of a bee colony and the assessment of the location of the most preferred food sources of the bees.

Su et al. (2022) [2], in their research, conducted an experiment using two varieties of pears (*Pyrus bretschneideri*, native to the authors' country, and the exotic *P. communis*) and two pollinating species (*Apis cerana* and *A. mellifera*), in order to address the volatile compounds secreted by plants that induce a physiological response in the insects used in the research. Researchers have been able to identify a variety of compounds present in *P. bretschneideri*, such as methyl L-valine ester, benzaldehyde, 6-methyl-5-hepten-2-one, isophorone, 2-methyl acetate, longicyclene, longifolene, and caryophyllene, and in *P. communis*, such as ocimene, 4-oxoisophorone, and lilac alcohol D. The bees reacted to their presence in the volatile fraction of flowers. This type of research conducted in crop varieties that are economically important for humans, with the use of various pollinators, may in the future, contribute to an increase in the efficiency of the pollination process, either through the selection of selected pollinators sensitive to the smells emitted by a given plant or through the synthesis of such mixtures of attractants that in a mosaic-like space will attract more pollinators to areas where their presence will bring tangible benefits to humans.



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The appropriate compositions of essential compounds can also affect factors such as the total number of germs in the guts of worker bees, the number of brood cells and between the total number of germs and the honey yield. Such a study was conducted by Pătruică et al. (2023) [3] on bee colonies during the spring, involving the feeding of essential oils of basil (*Ocimum basilicum*), cinnamon (*Cinnamomum veruum*), clove (*Syzgium aromaticum*), juniper (*Juniperus communis* L.), oregano (*Oreganum vulgare*), mint (*Mentha piperita*), rosemary (*Rosmarius officinalis*), and thyme (*Thymus vulgaris* L.). The results obtained by these authors confirm that the adequate spring supplementation of bees can affect both the total number of brood in the colony and the honey yield in *A. mellifera* colonies.

Essential oils are just one of the ingredients that can be used for supplementing bee nourishment. Leska et al. (2022) [4] suggested that lactic acid bacteria found both in the nectar of plants that bees eat, in the digestive tracts of these insects, and in bee products, could potentially be probiotic for *A. mellifera*. In microorganisms, parameters such as the production of $CO_2$, lactic acid, or the ability to reduce selected sugars were assessed. The bacteria tested by the authors may be included in new protective preparations for bees in the future. As other studies indicate, micro-organisms can both decompose plant protection products that are dangerous to honeybees [5] and limit the development of *Paenibacillus larvae* [6], whose clinical symptoms of infection observed in hives lead to the complete liquidation of apiaries in many countries [7]. Thus, media with the right probiotics could potentially eliminate many of the risks to these beneficial pollinators.

Humans introduce various types of pollution into the agricultural environment, which can affect the health and life of bees. Such pollutants include heavy metals that can be taken up by *A. mellifera* worker bees along with pollen and nectar and then accumulated in honey—the only food used by bees during the overwintering period. The aim of the research by Tomczyk et al. (2023) [8] was to assess the level of harmful metals (Cd, Pd, Hg, Al, Ni, and Tl) in relation to essential macro- (K, Ca, and Mg) and microelements (Mn, Fe, Zn, Cu, and Se) in three melliferous plant species—rapeseed, dandelion, and goldenrod. The authors showed that heavy metals are present in trace amounts in bee honey, despite their significant presence in certain types of crops. This suggests that at least that part of the heavy metals accumulated by bees in honey will not significantly affect the health of future generations, including the overwintering generations.

Wintering is a unique challenge for bees. During this period, queen bees lay very few eggs, and the low temperature in the cluster significantly reduces the chance of their development, which means that the overwintering of the colony depends mainly on the health and lifespan of the worker bees that have entered their wintering state in autumn. A further factor responsible for the effectiveness of the wintering of a bee colony, in addition to the already mentioned chemical composition of honey, is the presence of appropriate amounts of glycogen accumulated in the bodies of bees. In their research, Grodzicki et al. (2023) [9] assessed the glycogen content and thermoregulatory phenomena in the three most frequently bred bee breeds in Poland—*Apis mellifera carnica*, *A. mellifera mellifera*, and *A. mellifera caucasica*. The authors found that in the Carniolan and Central European honeybees, the glycogen content in worker bodies was higher in autumn bees preparing for wintering than in summer bees. The Caucasian honeybee deviated from this pattern. The choice of ambient temperature by a given subspecies depended neither on the season nor the geographical race. This means that not only the amount of glycogen alone, but probably other factors, are responsible for the success of *A. mellifera* overwintering.

The already mentioned *P. larvae* is a pathogen that infects the young brood of *A. mellifera*, causing American foulbrood disease (AFB). The clinical symptoms of this disease observed in a bee colony in many countries are synonymous with the need to exterminate the infected colony or even the entire bee apiary [7]. In our study [10], using chromatographic techniques, we assessed the composition of the volatile fraction present in a healthy brood taken from control *A. mellifera* colonies and in those showing clinical signs of AFB. The obtained results allowed us, using statistical techniques, to qualitatively and quantitatively distinguish the tested samples of both types. The tests also allowed us to identify such combinations of volatile compounds that differentiated healthy from infected colonies. Such studies may potentially indicate directions in bee supplementation that will reduce the likelihood of the acute symptoms of *P. larvae* infection for this pollinator.

Editing this Special Issue has been a stimulating experience, as we received some very interesting research ideas (including those manuscripts rejected by reviewers) that have significantly increased our knowledge of pollinators. We would like to thank all the authors for the interesting and often very innovative research that they shared with us. We would also like to thank the editor, Bernice Xu, who often had to strongly motivate us to work, and all the reviewers who evaluated the research.

We hope that this Special Issue will provide researchers with a new perspective on old issues that affect farmers and beekeepers.

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