SUMMARY

The growing demand for food and the desire to maximize crop profits, driven by human population growth, negatively affect the biodiversity of insects, including pollinators, whose role in agricultural production cannot be overestimated. The strong decline in the number of pollinating insects observed in recent years, mainly in agricultural landscapes, not only negatively affects biodiversity but can also harm the agricultural economy and lead to higher food prices. Therefore, it is important to maintain a sufficiently large population of pollinating insects in agricultural areas. This, in turn, requires maintaining the necessary habitat conditions to prevent the extinction of pollinators. The intensification of agriculture through increasing crop acreage and the use of pesticides, especially insecticides, threatens pollinators. Many crops, such as cereals, especially in large monocultures that lack baulks, trees, and other refuges for pollinators, are unattractive to pollinators and even without pesticides can significantly affect their biodiversity. On the other hand, mass-flowering plants, such as oilseed rape, can provide nectar and pollen to wild pollinators. However, even crops attractive to pollinators, which offer abundant food supply, are treated with pesticides. Therefore, research on the combined effects of landscape structure and pesticides on bees, with the red mason bee (*Osmia bicornis*) as a representative, is essential to fully understand their effects on future generations of these bees and to implement adequate conservation strategies for pollinators. Pressure from agricultural intensification can manifest itself as direct effects visible in the survival rate of parental individuals, but unfavourable living conditions of parents can affect the development of their offspring (*carry-over effect*) or reveal themselves in the next generation as maternal effects. Therefore, one of the main objectives of this dissertation was to investigate whether agricultural intensification, expressed in the structure of agricultural landscape with a gradient of the share of oilseed rape around the nest, and thus increasing pressure from agriculture, negatively affects population parameters of the solitary bee *O. bicornis* and its sensitivity to the representatives of the major groups of insecticides currently in use, and whether the consequences of the development of individuals in the landscape dominated by oilseed rape are visible only at subsequent developmental stages in the given generation, or also in the next generation developing under conditions without agricultural pressure (article I). Additionally, it was examined whether pollen diversity decreases and pollen pesticide contamination increases with the increase in the proportion of oilseed rape around the nests of *O. bicornis* bees (article II).

It is common practice in agriculture to use mixtures of two or more different pesticides, usually belonging to different groups. The effects of pesticides in a mixture may be much more harmful than the sum of the effects of individual substances, due to possible synergistic effects of two (or more) substances on the organism. However, the effect of several substances can also be antagonistic, i.e., weaker than expected from a simple summation of the effects of these substances used independently. In addition, pollinators are often exposed to sublethal doses of chemicals, i.e., doses that do not cause immediate and unambiguous toxic effects. Studying effects of a mixture of insecticides belonging to different groups on survival (article III) and on selected biochemical parameters, i.e., the activity of three enzymes (acetylcholinesterase (AChE), S-glutathione transferase (GST), and esterase (EST)), and the level of ATP (article IV), were other goals of this dissertation.

The study showed that larval development in areas dominated by oilseed rape monoculture (i.e., with the elevated share of oilseed rape around the nest of the parental generation (P)) negatively affected some population parameters of offspring (F1), namely decreased the emergence success of bees from cocoons and increased the sensitivity of females to the insecticide Dursban 480 EC, but these effects have mostly disappeared in the next generation (F2). In the F2 generation that developed in an area without agricultural pressure (mid-forest meadows), the effect of the share of oilseed rape and the landscape structure around the nest established by the females of the P generation was evident only in the distorted sex ratio, i.e., the higher proportion of females. In addition, the presence of natural and semi-natural landscape elements was shown to be important for the development of bees in agricultural landscapes. The share of oilseed rape around the bees' nests did not affect the floral diversity, energy value or contamination level of pollen collected by P generation females for their F1 offspring, but the diversity and energy value of this pollen depended on the presence of landscape elements other than oilseed rape. Moreover, pollen diversity decreased, and energy value increased with landscape diversity. In the studied agricultural landscape, bees collected pollen from 28 plant taxa, among which *Brassica napus*, *Quercus* sp., *Ranunculus* sp., Poaceae, and *Acer* sp. were predominant. Residues of 12 pesticides were detected in the pollen, with acetamiprid, azoxystrobin, boscalid, and dimethoate being the most frequently detected. Pollen contamination with pesticides decreased with increasing floral diversity.

Contrary to expectations, laboratory tests on adult females showed either no interaction (in the Sherpa 100 EC × Dursban 480 EC mixture) or antagonistic effects of the tested insecticide mixtures on the *O. bicornis* survival. Antagonistic interactions occurred in mixtures in which one insecticide belonged to pyrethroids (Sherpa 100 EC or Karate Zeon 050 CS), and the other was a neonicotinoid (Mospilan 20 SP) or a sulfoxymine (Closer). The pyrethroid Sherpa 100 EC affected all biomarkers tested (AChE, GST, EST, ATP), and organophosphate Dursban 480 EC affected AChE and EST activity and ATP levels. The complex interactions between these insecticides and the neonicotinoid (Mospilan 20 SP) affected ATP levels, giving results that could not be predicted by testing each insecticide separately.

The results show that larval development under conditions of oilseed rape dominance negatively affects some life history parameters of bees, but these effects mostly disappear in the next generation. This gives hope for the rapid recovery of wild bee populations, as long as favourable conditions are provided. The presence of landscape elements such as water bodies and vegetation close to water, meadows, forests, and a landscape structure with long boundaries between fields and natural habitats should be considered in the protection of beneficial insects in agricultural landscapes, as well as the provision of a diverse food base. It has been shown that using a pyrethroid in a mixture with a neonicotinoid or sulfoximine may be safer for *O. bicornis* than using these insecticides alone. Further, results of ATP level analyses suggest that organophosphate insecticides should not be mixed with neonicotinoids and/or pyrethroids, as such insecticide combinations negatively affect bee metabolism.