What Have Pesticides Got to Do with It?

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There is agreement among beekeepers and scientists that the health of honey bees has been in decline for years, and the rate of decline appears to be accelerating. A 2007 survey estimated a loss of about 1/3 of US honey bee colonies during the winter of '06-'07 (vanEngelsdorp et al. 2007). It is generally agreed that varroa mites are playing a key role in the demise of honey bee health; additionally, the interaction between diseases and varroa and the newly identified Israeli acute paralysis virus (IAPV) are likely important contributing factors (Cox-Foster et al., 2007). However, the past year's research into the newest malady, Colony Collapse Disorder (CCD), supports an emerging hypothesis that no one factor alone is responsible for the dramatic losses of honey bees in general or CCD specifically.

A 2007 publication by the National Academy of Sciences documents a decline in many North American pollinators (Committee on the Status of Pollinators in North America, 2007). Another study published in the journal *Science* documented a loss not only of pollinators in Great Britain and the Netherlands, but also in the plants that are dependent on them for pollination (Biesmeijer et al. 2006). Clearly the phenomenon of pollinator decline is not limited to honey bees or to the US and the consequences are far reaching for agriculture and our food supply.

Are pesticides a contributing factor?
Honey bee exposure to chemical pesticides has long been a concern for beekeepers and growers alike. A large portion of our 2.4 million colonies is utilized for crop pollination and typically employed on several different crops per season. These colonies are at risk of exposure to the pesticides used by growers to control pest insects, diseases and weeds. Also, our own use of miticides within the hive to control varroa mites has long been a concern due to their potential impacts on developing bees (especially queens) and contamination of hive products. In the past, pesticide poisoning of honey bees has been associated with lethal exposure and the obvious symptom of a pile of dead bees in front of the hive. We are becoming increasingly concerned that pesticides may affect bees at sublethal levels, not killing them outright, but rather impairing their behaviors or their ability to fight off infections. For example, pesticides at sublethal levels have been shown to impair the learning abilities of honey bees or to suppress their immune systems (Desneuz et al. 2007). For these reasons we believe that pesticide exposure may be one of the factors contributing to pollinator decline and CCD.

The prevalence of pesticides
In 2007 we analyzed pollen (bee bread and trapped pollen) and wax for pesticide residues. A significant number of samples analyzed were from operations impacted by CCD and control operations (not impacted by CCD) that were collected by members of the CCD working group as a part of a larger CCD study (the results of which will be published at a later date). Additional samples were from honey bee colonies placed in Pennsylvania apple orchards where pesticide applications over the past 7 years have been well documented. The third source was from beekeepers, who trapped pollen while their bees were in specific cropping situations or who were concerned about the declining health of their colonies. Samples were mainly from migratory

operations but also included smaller, non-migratory operations and the PSU research apiaries, with operations represented from across the country. The USDA Agricultural Marketing Service, National Science Laboratory in Gastonia, NC, conducted the pesticide residue analysis under the direction of chemist Roger Simonds, who is also a beekeeper. The pollen samples were analyzed for 171 chemicals, and some metabolites. Metabolites are the breakdown products of pesticides, and some can be more toxic than their parent compound. Wax samples were similarly analyzed.

In a total of 108 pollen samples analyzed, 46 different pesticides including six of their metabolites were identified. Figure 1 summarizes the pesticide classes found and the number of different pesticides identified within each class. Up to 17 different pesticides were found in a single sample. Samples contained an average of 5 different pesticide residues each. Only three of the 108 pollen samples had no detectable pesticides. Figure 2 shows the 14 most frequently detected pesticide residues in pollen and the percentage of samples containing them.

Figure 1. Pesticide class and types of compounds detected in 108 pollen samples in 2007.

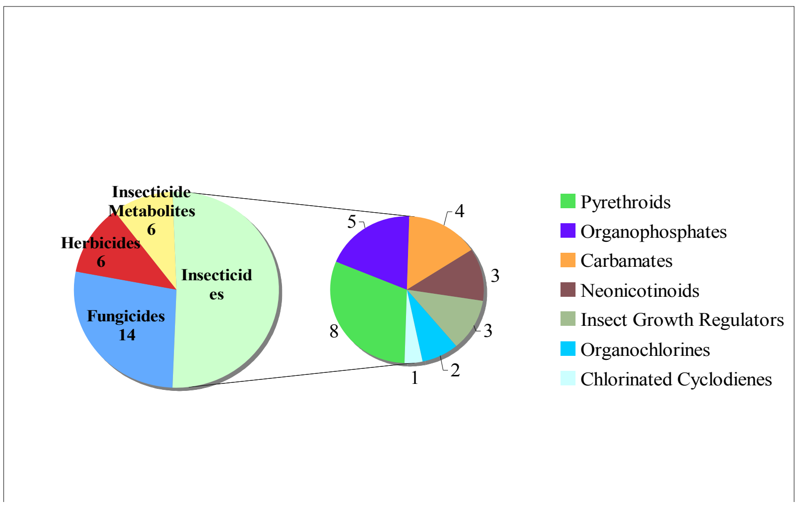
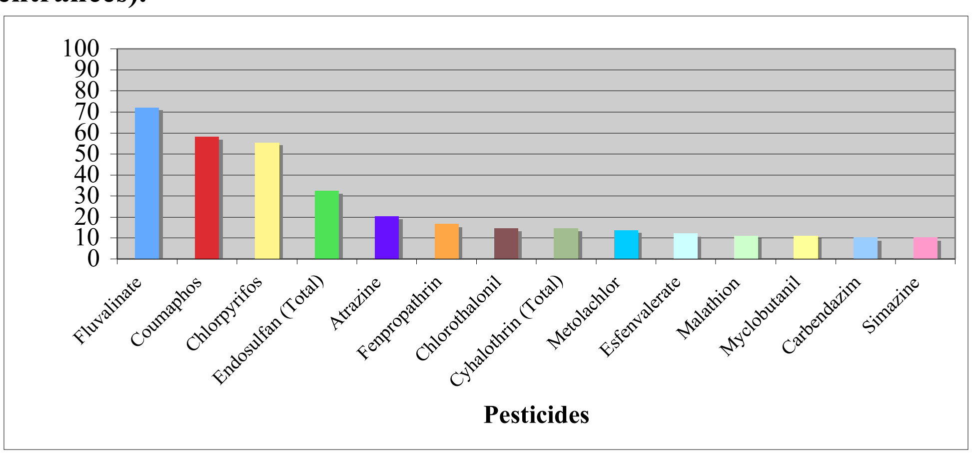


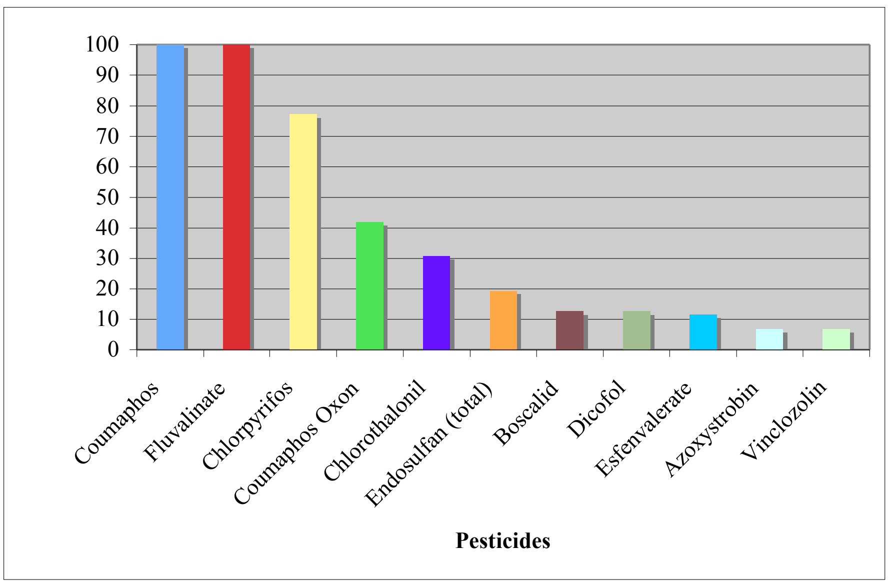
Figure 2. Most frequently detected pesticides in honey bee pollen (bee bread and trapped at entrances).



Some samples had multiple pesticide residues including insecticides from several chemical classes in combination with fungicides and less commonly with herbicides. These findings raise serious concerns about the possible combined effects these chemicals may have on honey bee health from acute as well as chronic exposures. We are currently investigating the impacts of these pesticides individually and in combinations on honeybee behavior and survival.

Wax from a broad sampling of brood nests from CCD and other US colonies was also analyzed. In a total of 88 wax samples analyzed, 20 different pesticides including two of their metabolites were identified. Figure 3 depicts the 11 most frequently detected pesticide residues in wax and the percentage of samples found to have the residue. As found in pollen, fluvalinate, coumaphos and chlorpyrifos were the most commonly detected pesticides with fluvalinate and coumaphos were detected in 100% of the samples. Amitraz, a compound that breaks down quickly, has not been detected in any of the samples represented here; however amitraz metabolites have recently been added to the chemical residues being screened for and have been detected.

Figure 3. Most frequently detected pesticides in brood nest wax of honey bees.



The problem with fluvalinate

We have always considered fluvalinate a relatively “safe” material for honey bees; however its history is unclear with potentially significant implications for honey bee health. The original formulation of fluvalinate (racemic or having multiple forms) had an established lethal dose that killed 50% of the tested population (LD50) at 65.85 µg/bee for honey bees, which is considered relatively non-toxic (Atkins et al. 1981). However in the early 1990’s racemic fluvalinate was replaced with tau-fluvalinate (having a single form) resulting in a 2-fold increase in toxicity of this material to honey bees. The amended LD50 was then 8.78 µg/bee, a level considered moderately toxic to honey bees. In addition, US registration of this material changed hands several times over the past 20 years with potential changes being made in the formulation of fluvalinate Due in part to the high cost of bringing a pesticide to market, pesticide companies may make existing pesticides more effective or overcome resistance by changing their chemistry or reformulating them. Surprisingly, in 1995 EPA reported the LD50 of fluvalinate as 0.2

µg/bee, a level that is considered to be highly toxic (EPA-OPP 2005) to honey bees. In addition, Piperonyl butoxide (PBO) (a pesticide synergist often added to formulations of pyrethroids to increase their potency) can be found in frequent use around urban apiaries. With or without the addition of PBO or other adjuvants, fluvalinate is now considered to be a highly toxic material to honey bees. Based on its prevalence in wax, wide-spread resistance in varroa and its toxicity to honey bees, fluvalinate appears to have outlived is usefulness.

Conclusions

Unprecedented amounts of fluvalinate (up to 204 ppm) at high frequencies have been detected in brood nest wax, and pollen (bee bread). Changes in the formulation of fluvalinate resulting in a significant increase in toxicity to honey bees, makes this a serious concern. In addition, coumaphos, and numerous environmental insecticides along with fungicides and herbicides have also been widely detected in hive matrices. The large numbers and multiple kinds of pesticides that have been found could result in potentially toxic interactions for which there are no scientific studies to date. Europe researchers have found similar pesticides and frequencies in hive matrices and express similar concerns (Martel et al. 2007). These chronic levels of pesticides in pollen and wax at potentially acute levels needs to be further investigated with regard to their potential interactions with other stressors (e.g. IAPV) and their role in CCD. It is anticipated that additional pesticide analyses of brood, adult bees and nectar samples will provide valuable insights into recent declines in honey bee health. Figure 4 summarizes our findings and highlights our major concerns regarding the unknown consequences for honey bee health. A more detailed report on this work is currently being prepared for publication in a peer-reviewed scientific journal.

Recommendations

There is growing evidence that a number of factors, including IAPV, pesticides, varroa mites and other stress factors such as poor nutrition are most likely involved in the overall declining health of honey bee colonies in the US. However at this time, members of the CCD working team agree that there are steps that can be taken to help minimize stress on honey bee colonies and to improve their chances for survival.

1. Monitor and control varroa mite populations using "soft" chemicals. These soft chemicals include formic acid (Mite-Away II®), Apiguard ®, and Apilife var®.
2. Reduce pathogen and pesticide build-up in combs by regularly culling old comb, recycling comb and/or irradiation of old comb. This is particularly recommended for dead-out colonies.
3. Fluvalinate should only be used as a material of last resort. Use of off-label products should NOT be considered.
4. If coumaphos must be used, only the registered product, CheckMite+® should be considered.
5. Communicate with growers where bees are used for pollination to minimize colony exposure to agricultural-use pesticides. Some pesticide labels permit application during blooming periods, but this is definitely not the best procedure for honey bee safety, so work with your grower.
6. Monitor and control Nosema disease using fumagillin.

Acknowledgements

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