Alice Denis, the 20th of December 2008 Alnarp University

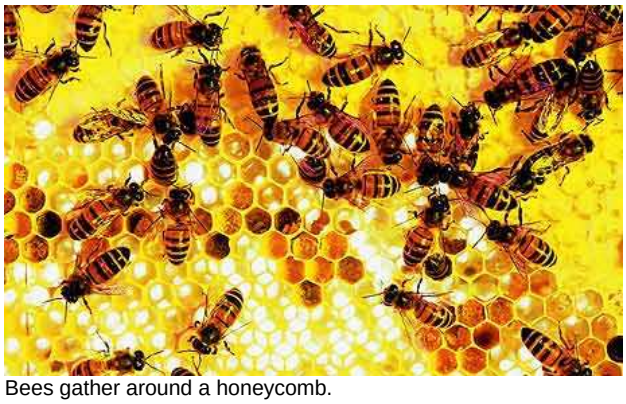
Research paper for the course: Environmental Issues in Crop production

Pesticide's impacts on bees (*Apis mellifera* L.)

"If the bee disappeared off the surface of the globe then man would only have four years of life left. No more bees, no more pollination, no more plants, no more animals, no more man." ***Albert Einstein***

ABSTRACT Pesticides are known to impact a lot on *Apis mellifera* L. (Hymenoptera: Apidae), a particularly important pollinator insect. As it is explained in that paper, several solutions can be done to act in a sustainable way for insect management in our landscapes. In fact, bees are currently endangered by our activities, especially because of the agricultural use of phyto-sanitary products. The impacts of those chemical substances are diverse and are studied here in two different parts. First the main visible troubles will be examined, before entering more discussed impacts which are sub lethal and behavioral effects on bee colonies. In fact, those social insects are living in group, so the individual effects are not the only problematic ones which can lead to a colony disparition.

Apis mellifera L., Photograph: Judi Bottoni/AP
(The guardian website, 29th of September 2008)



Bees gather around a honeycomb.
Photograph: Reso/Rex Features
(The guardian, 23rd of September 2008)

KEYWORDS

Apis mellifera L., bees, behavioral, lethal, pesticides, sub lethal, systemic.

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INTRODUCTION

Apis mellifera L. is a very important insect for different reasons, especially indispensable for agricultural and horticultural activities. But the agricultural landscape has evolved a lot those last decades, by specialization and intensification processes. The biodiversity has decreased; besides, bees can suffer serious effects from toxic chemicals in their environment. This includes various synthetic chemicals, such as insecticides and fertilizers, as well as a variety of naturally-occurring chemicals from plants, such as ethanol resulting from the fermentation of organic material (wikipédia).

Several impacts of pesticides can be noticed, and we will try to study broadly those effects. For example, contact insecticides which kill by touching the organism, affect the worker bee that is directly sprayed. But systemic insecticides that are incorporated by treated plants, can contaminate nectar or pollen, and kill bees in the hive. The actual damage to bee populations is a function of the compound's degree of toxicity, in combination with the mode of application.

First it is important to understand the interest of bees, to know why it is so essential to adopt a good management toward them. And some solutions will be discussed to find a better way to act, in order to permit the bees to survive more easily. Then the main pesticide effects on *Apis mellifera* L. will be explained, before studying more questionable impacts which are sub lethal and behavioral ones.

RESULTS AND DISCUSSION

1) Interest of Bees and good pesticide management toward them

In 2006, an investigator group concluded that 35% of the world food production is linked to the pollinator insects (Jachères apicoles). According to the US Department of Agriculture, these under-appreciated workers pollinate 80% of our flowering crops. One Cornell University study estimated that honeybees annually pollinate $14 billion worth of seeds and crops in the US (fourthbranchofamerica). The plant pollination accomplish by bees is grateful in two ways; it permits to increase the quality and the yield (for instance tree culture), and to obtain a more regular production for seed multiplication. While they spend their lives flying from one plant to the next collecting nectar, both pollination and revitalization through bees enhance the fertility and regenerative capacity of plants (the-importance-of-bees-in-organic-agriculture).

The troubles which can appear with the pesticide use are diverse, that is why a lot of precautions should be taken before applying such chemicals (depending on their kind of application and hazardous), especially on the most attractive flowers (ohioline.osu.edu):

1. Apply pesticides only when needed.
2. Use the recommended pesticide at the lowest effective rate.
3. Use the pesticide least hazardous to bees that will control the pest involved. If all recommended pesticides are equally hazardous to bees, use the one that has the shortest residual effect.
4. Use sprays or granules instead of dusts.
5. Use ground equipment instead of aerial application to apply pesticides near bee hives.
6. Apply pesticides in late afternoon or at night when bees are not working the blooms.

7. Avoid drift of pesticides onto plants that are attractive to bees. Unfortunately, no effective repellent has been developed that can be added to pesticides to keep bees away from treated areas.

Before being homologated, specific studies are done to know the pesticides's hazard on bees. The products are tested on different aged invidious to evaluate their toxicity, which allow determining their DL50 (50% of death). In consequence, a dangerous product cannot be homologated and commercialized today. In addition, the products which could endanger bees are forbidden during the blooming period. But the applying conditions are strict and need to be respected otherwise they can have real impacts on insects!

The farmers can also create beekeeping fallow land in order to increase the plant biodiversity for those pollen gatherers; in fact, really few plant are nowadays cultivated so do not provide a lot of diverse food for the bees (jachères-apicoles).

Bees can be intoxicated if they are in contact with a hazardous product. Two kind of intoxication can be noticed: The aïgue intoxication is a consequence of lethal doses of those products. In that case a short term important mortality is observed, both inside and outside the hive. The second is the chronic intoxication which occurs for sub lethal doses and causes, in a medium or long term, the colony's decline (jachères apicoles). In recent years beekeepers throughout Western Europe have reported experiencing 'Colony Collapse Disorder' (CCD) – a devastating phenomenon in which full strength honeybee colonies suddenly fail. Recent reports from France document mortality rates of up to 60%, while the UK farming minister has warned that British bee colonies could vanish in under a decade. "While the causes of Colony Collapse Disorder are still under investigation, the consensus scientific opinion is that CCD occurs due to a combination of factors –including exposure to pesticides toxic to bees. Pesticides most likely act as stressors making bees more susceptible to parasitic, microbial and viral attack" (PAN Europe, 2008). Between 15% and 20% of the 210 most important pesticide substances on the EU market are toxic to bees (HQ>50%), referring to the European Crop Protection Agency (ECPA)'s talks. This disorder influences the honey yield, but also the plant pollination, which led the pollination rental fees to increase particularly in France.

2) Main studied effects of pesticides on bees

Several ethnological factors, as a high rate of reproduction, a great mobility, a large flying range, and numerous flowers inspections per day permit to use *Apis mellifera* L. as an effective ecological detector. The insect is in fact in contact with its environment through the particles which are collected in his body, and makes it a good tool for monitoring environmental pollution (M-P. Chauzat & al., 2006). Apicultural matrix analysis such as honey, wax, bees themselves, or pollen can provide useful indications of the diffusion of pesticides within the environment; which explain why bees can be so affected by pesticides. Nowadays, pesticides are applied in fewer amounts, thanks to the innovative application methods; the new commercial preparations are responsible for these obvious decreases in pesticide residues contents in pollen loads. Modern pest management has to address the problem of maximizing insecticide efficiency while minimizing waste.

The following example of the United Kingdom will allow us to understand better the main pesticide's impacts on *Apis mellifera* L.. "There were 117 bee poisoning incidents in the UK during the 1994–2003 period, and in nearly half of these incidents bendiocarb or dimethoate were implicated. However, the potential impact of these incidents was different when the number of colonies affected was compared. Those with dimethoate involved nearly twice as many colonies as those with bendiocarb" (E. A. Barnett & al., 2007). The application methods are responsible for those differences, as Bendiocarb is used to treat nuisance/feral bees and is applied to a discrete area; whereas dimethoate is used to control insect pests in crops and so is applied over a wide area. "There were similar numbers of incidents with triazophos, carbaryl, permethrin and paraquat" (E. A. Barnett & al., 2007). The pyrethroid case is interesting, in fact, Pyrethroid compounds are acutely toxic to bees in laboratory conditions but they are not considered to be a poisoning risk to bees when applied to crops in the field thanks to their repellent effect. However, research has suggested there may be synergistic effects between pyrethroids and EBI fungicides which can reduce that repellency. It was also noticed that "Pesticide mixtures were found in 11 incidents during this period, and five of these incidents involved insecticide and fungicide mixtures. These incidents mainly involved pyrethroid insecticides" (E. A. Barnett & al., 2007). But it seems that there have been few incidents reported in the UK with multiple residues at toxicologically significant levels. It is possible that different sources, for example a feral bee treatment and a spray application, accounted for these incidents.

Pesticide accidents can be responsible for a lot of bees' death, especially the pesticides mentioned in the UK example. In consequence, the French government banned the possibility to use imidacloprid as a seed dressing on sunflowers in 1999, and then fipronil follows the same way (PAN Europe, 2008). Germany has also banned a family of pesticides that are blamed for the death of millions of honeybees. Indeed, reports from German beekeepers indicate that two thirds of their bees died earlier the month following the application of a pesticide called clothianidin. So the German Federal Office of Consumer Protection and Food Safety (BVL) has suspended the registration for eight pesticide seed treatments as imidacloprid, thiamethoxam, clothianidin, and methiocarb (the guardian, the 23 of May 2008). European regulations exist now, and some more will be discussed. But those deadly effects are not the only one existing; in fact, some studies show the effects of very small doses of pesticides on honey bee workers. One of the most enduring apicultural research problems will be the development of new techniques, to evaluate in the field how pesticide contamination can affect honey bee individuals (workers, males, and queens) and colonies. "The best way to evaluate such exposition would be to work on whole colonies, but this experimental solution is not yet available" (M-P. Chauzat & al., 2006). The next part will however try to give some answers.

3) Sub lethal & Behavioral effects

Honeybees are living in colony, and for the colony. Their social behavior relies on task distribution depending on their age, genetic background, and environmental conditions (M-H. Pham-Delègue & al., 2002). The young workers are always in the hive around the queen and make sure of keeping the colony's cohesion thanks to their pheromone emissions. The

forager bees gather the nectar for their sugar needs (which make honey), but also the pollen as their protein source (jachères apicoles). However, it is incredible to see how a colony of more than 50 000 invidious can be more considered as one individual alone. That is why behavioral changes can affect the colony's survival.

When bee losses are observed, and insecticide intoxication is suspected, there may be alteration of the flight pattern between a contaminated food source and the hive. It can be hypothesized that the homing flight of the exposed forager or of the information given by the dances of the returning forager may be impaired (wrong code information about the distance and the direction of the food source). They found that treated bees flew towards the sun light, and took significantly more time to fly back to the hive. And as the treated area is further away, the likelihood that the bees will return to the hive to die decreases (Minau.P & al., 2008), and the hive contamination can be avoided. The investigators suggested that the bees failed to include, or integrate the visual pattern of local landmarks like that of the sun's direction. This coding ability was affected by prior exposure to sub lethal doses of parathion, leading to changes in the angles of the dancing poisoned bees, or in the rhythm of the wagging dance so the information coded in the dances about distance and direction also were less precise (M-H. Pham-Delègue & al., 2002). "The examinations suggested that the pyrethroids affect learning too, rather than recall of memory" (H. M. Thompson, 2003). This can especially be a problem for their olfactory learning and the later foraging. Some pesticides as pyrethroids impair the insect's ability to find the way back to the hive. For instance, "Permethrin treatments resulted in 43% of foragers returning once to the colony and only 4% returned twice with none of the treated bees present the following morning (89% of the control bees were present)" (H. M. Thompson, 2003). The forager work was often really reduce because of spraying, and their ability to come back to the hive may greatly affect colony survival, as recruitment of nurse to forage may reduce brood production.

The honeybees are especially endangered by the effects of neurotic insecticides which impair either the reproduction, or the brood and new bees' survival. This is very dangerous for the future of the colony, much more than the forager's death because they can be quickly replaced if there are sufficient brood and new bees. Besides, the queen who is often the last individual to die can often see its status and ability to lay eggs reduce, this is also extremely threatening for the colony's becoming.

The studies determining mortality and the LD50 try to avoid those sub lethal impacts, however there is increasing evidence that mortality curves and possibly sub lethal effects may not be simple functions of dose. Additional observations should be done in laboratory, as the abdomen tucking, excessive cleaning, knockdown, aggressiveness and lack of coordination. But those studies are difficult, so should only be done is a validated methodology is available to give conclusions, and if they can be reasonably incorporated in justified ecotoxicological study systems, they can nevertheless be helpful as an optional test (H. M. Thompson & C. Maus, 2007).

It is also important to understand the difference between systemic and sprayed pesticides, because their impacts are not the same. A systemic product is taken by roots and transported through the vascular tissues in all the plant. Concern relating to exposure to non-sprayed products mainly relates to systemic products, and it occurs through the collection and consumption of plant materials such as nectar and pollen. "That means that

the exposure of insects in the case of a soil or seed applied systemic product is mainly a chronic and oral issue, while the exposure of insects in the case of a systemic product being sprayed is for the most part a short-term and contact issue, since exposure to the largest fraction of the dose applied occurs around the spray event, and exposure to the systemic part depends on factors such as blossom time relative to treatment" (A. Alix & C. Vergnet, 2007). The following scheme found in that publications explains how to test systemic products in order to determine their possible impacts to bees.

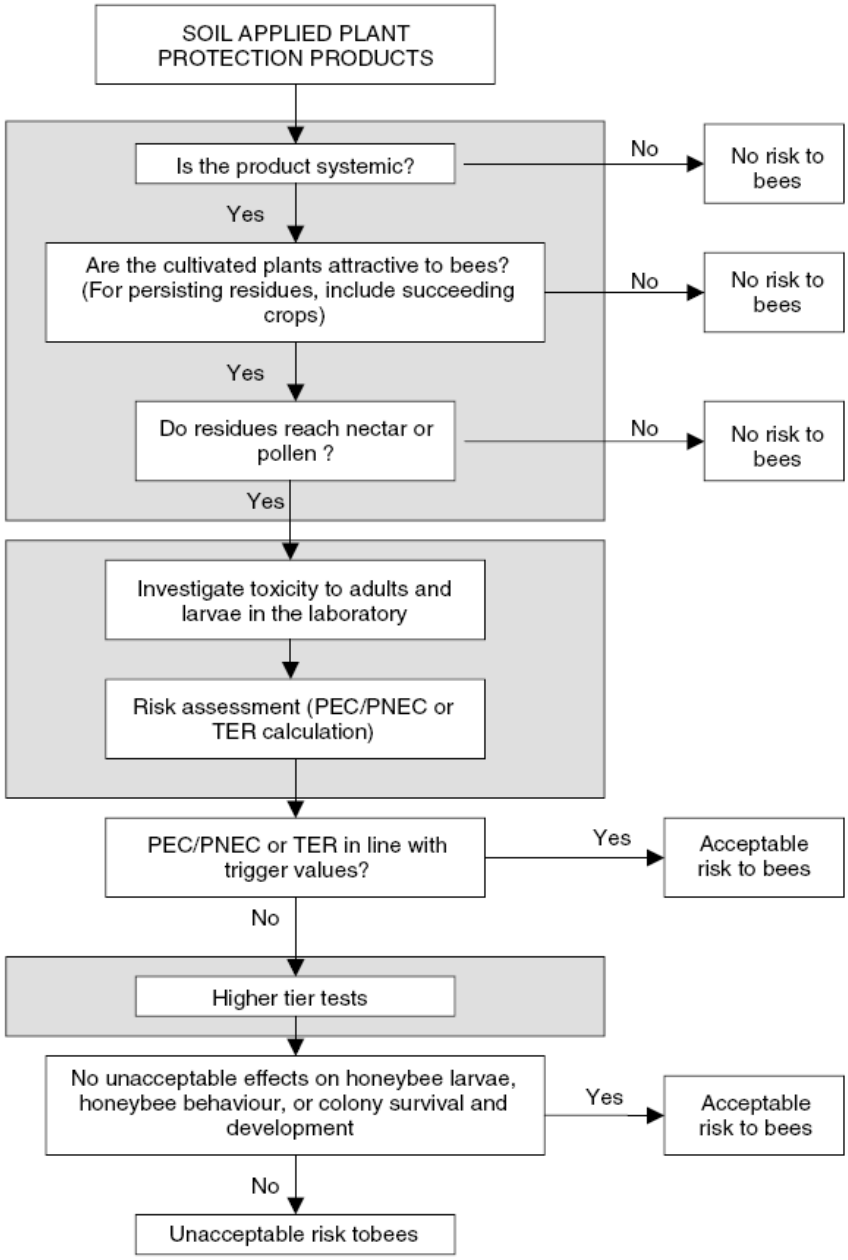

Figure 2. Draft risk assessment scheme for non-sprayed products as deduced from the current review.

CONCLUSION

As we could see, honeybee pollination increases the edible yield of 46 (40%) of the world's leading. In fact, they pollinate 115 food crop species – including apples, citrus, tomatoes, sunflowers, rapeseed and soy – and are also good for the diversity in general (PAN Europe, 2008). Honeybees play a key role in the successful production of over 80 million tones of EU food produce each year – which equates to 160 kilos of food per EU citizen.
But more than 140,000 tones of synthetic pesticides (active substances) are sprayed onto EU food crops each year. Many of these pesticides can contaminate pollen grains and therefore present a hazard to bees. Some precautions need to be taken, and the homologating system is already one important solution not to observe too many dead bees because of our pesticides. The UK example allow us to understand better that not only the substance toxicity is an important factor, but also its way of application.

Several problems are known and recognized by everyone, as the 'Colony Collapse Disorder' phenomenon, but all the impacts are not as visible and can be really hard to study. The concentration and duration of the exposure can vary: the quantity of chemicals, the persistence of residues, and the frequency of spraying on the crop are not the only information to take into account, since the product can be accumulated over long periods in the hive, and subjected to degradation/concentration processes. Therefore, it is especially important to estimate the actual risk, which results from the combination of the toxicity of the chemical and the exposure of bees to the product (M-H. Pham-Delègue & al., 2002). Moreover, it is necessary not only to consider the pesticides provoking acute toxicity but also those provoking slow and progressive poisoning, those exerting prolonged toxic action when stored in the hive, and those whose metabolites induce a gradual plant pollution (The Research Institute of Apiculture at Dol, 1990). And as we could learn, behavioral effects cannot be neglected in such colony specie that is why those aspects should still be studied.

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