Bee health: what can farmers and the industry do to help?

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A third of the plants eaten by human beings benefit to some extent from pollination by bees or other insects. The estimated value of pollination to agriculture is over €150 billion ($165 billion) a year. At the same time, the health of pollinators, and particularly bees, is claimed to be under severe threat from agricultural practices worldwide. What is the true situation and what can farmers and the crop protection industry do to further improve bee health?

Although pollinators include honey bees, bumble bees, solitary bees and other wild bees, butterflies, wasps, flies, beetles, birds and bats, most scientific research, academic publications and activist rhetoric has tended to focus on honey bees. That is understandable. For many millennia, humans have been emotionally attached to honey bees as the most important source of sweetener and wax, and have valued them economically as pollinators and suppliers of honey. Consequently, concerns about bee health are by no means a modern-day phenomenon.

Bee mortality – past and present

The close relationship between honey bees and human beings goes back at least 7,000 years. Evidence unearthed by archaeologists indicates that bees were kept in human dwellings in Mesopotamia around that time. Columella (4-70 AD), the Roman Empire's most important agricultural author, wrote a practice-oriented treatise on beekeeping in which an average loss of hives of 10-15% per year is described as normal.

The first recorded incident of bee mortality was in Ireland in 950 AD. Historical records throughout the Middle Ages repeatedly refer to large-scale colony losses and by the end of the 17th century, scientists in Europe were beginning to analyse the reasons for repeated incidents of mass bee mortality. The most frequently identified issue was adverse weather conditions, although factors such as pathogens or parasites may also have played a role.

Ever since the earliest recorded shipment of the Western (or European) honey bee (*Apis mellifera*) to the Americas in 1621, bee mortality incidents in North America have been the subject of both observation and scientific research. Colony Collapse Disorder (CCD), for example, first came to light in the US in 2006. In recent years, there have been substantial losses of honey bee colonies in certain regions, particularly in Europe and North America, during or directly after the winter months. These incidents have turned the attention of apian scientists and NGO activists to the emotionally charged issue of bee health.

Pressures on pollinators

There is a huge discrepancy between our knowledge of wild bees and of honey bees, especially in terms of their numbers, distribution and ecology. This is largely because of

the economic and emotional significance of honey bees. Yet there are around 30,000 other bee species worldwide, including solitary bees and bumble bees. Some of these species have undoubtedly declined over time, mainly due to changes in land use and a reduction in the habitat they rely on for food or nesting. But the question of whether the situation is still deteriorating is a matter of conjecture as there are few historical records of the abundance and range of many solitary bee species.

One thing, however, is clear. Most pollinating insects face numerous pressures in much of the modern world. The need to produce more food and fodder to feed the growing global population has led to more intensive agriculture, and this has contributed to a reduction in the abundance and diversity of flowers in agricultural areas. The impact of weather, parasites and diseases, a lack of suitable nesting sites, agricultural and apicultural practices, and exposure to wrongly applied environmental chemicals, including pesticides, have also been implicated in poor pollinator health.

Are honey bees in decline?

Overall, the number of managed honey bee colonies has remained either relatively stable or shown positive increases over the past ten years across North America. Meanwhile in Europe, colony numbers have been relatively stable at approximately 15-16 million hives. However, the total number of managed honey bee colonies worldwide increased by some 45% between the 1960s and 2010. In other words, there is no statistical evidence that honey bees are in general decline. But bee health is indeed a complex issue that is affected by many different factors.

Multiple causes of bee mortality

Two acclaimed bee scientists, Dennis van Engelsdorp and Marina Meixner, come down firmly on the side of multi-causality in explaining bee mortality. In their study of managed honey bee populations in Europe and the US published in 2009, they concluded that "*Varroa* mites, together with the virus complex associated with mite parasitism, are likely (to be) one of the major causes for considerable overwintering losses documented by many northern nations over the last several years (…). Modern pesticides with reduced acute toxicity may have sub-lethal effects that are more difficult to quantify. Additional factors, such as reduced bee forage, climate, narrowing of the gene pool, poor queens, and socio-economic factors all have measurable effects on managed honey bee populations."

The deadly Varroa mite

If bee health experts are asked to name the greatest threat to apiculture, the consensus of opinion points to the honeybee mite, *Varroa destructor*. Having appeared in Europe in the 1970s and in North America in the 1980s, the Varroa mite is a relatively new parasite affecting the European honey bee. But since then, it has spread rapidly to the rest of the world, leaving Australia as the only significant land mass where there are currently no mite infestations thanks to high biosafety protocols designed to prevent mites entering the country.

Varroosis, the Varroa-induced disease, affects both adult bees and the brood. Moreover,

this parasite also affects bee health by spreading a variety of viruses that result in dead pupae, swollen and shortened abdomens, lack of pigmentation and deformed bees with legs or wings missing. Untreated infestations of Varroa mites can kill entire honey bee colonies.

Since the 1980s, the pesticide industry has been researching effective solutions for treating infested honey bee colonies. Bayer's first product was registered as early as 1986, a second one followed in 1991 and a third in 2001. Currently, Bayer researchers and bee experts from universities in several countries are working on Varroa Gate, a solution to effectively combat the Varroa mite at the entrance to the hive, thus preventing renewed infestation or stopping the mites from spreading from the outset. If registration of the Varroa Gate goes well, the product could be on the market in 2017.

Self-defence brood cannibalism

Asian honey bees are not totally defenceless against this parasite. Their self-defence mechanism involves removing the Varroa parasite from a hive by means of selective brood cannibalism. Worker bees bite off the cover of brood cells, pull out the Varroa-infested pupa and devour it. Bee experts refer to this behaviour as Varroa Sensitive Hygiene (VSH). The non-profit Arista Bee Research Foundation is working to strengthen this protective behaviour among European honey bee colonies through breeding bees with highly effective VSH habits. Bayer is supporting the Fo*undation's* highly promising work.

Invasive threats to bee health

Unfortunately, the Varroa mite is just one of the invasive species endangering honey bee health. The Asian hornet (*Vespa velutina*) was first reported in western France in 2004 and has since spread across the European mainland. This pest hunts and feeds on other insects, including worker honey bees, and also enters the hive, feeds on the honey and removes the brood. Although Asian honey bees have developed strategies to defend themselves against these hornets, the European honey bees have not. Research into the hornets' behaviour, partly funded by Bayer, will be useful in helping develop effective solutions to control this predator.

Natural detoxification by bees

Another self-defence mechanism comes from the honey bee's genome in that it encodes detoxification enzymes to protect itself from insecticides. Bayer and Rothamsted Research are running a bee toxicogenomics project that aims to understand the molecular basis of insecticide selectivity in different bee pollinator species (honey bees, bumble bees and solitary wild bees) using a functional genomics-driven approach. That includes the development of tools to assess insecticide selectivity in biochemical screenings in order to identify chemical scaffolds in insecticides that inherently provide bee safety.

Neonicotinoids in the spotlight

Neonicotinoids are an important class of insecticides of low toxicity to mammals and humans. They help farmers worldwide to manage harmful pests that would otherwise limit crop production and quality. Another advantage of neonicotinoids is their systemic distribution in the plant, which enables them to be applied as seed treatments to protect

the entire plant in its early growth stages. Applying the pesticide at seed level radically reduces environmental exposure and does away with the need for multiple spray applications in the early growth stages of the crop. Hence, neonicotinoids have been extensively used to replace older, less environmentally friendly insecticides.

In the past decade, there has been a marked increase in the number of scientific publications dealing with the potential effects of neonicotinoids on bees. Discussions within the scientific community have focused on colony mortality issues, the sub-lethal and acute lethal effects of neonicotinoids, the dust that may be released while sowing neonicotinoid-treated seeds, and residues from neonicotinoid seed treatment products. Although no conclusive scientific evidence was produced that neonicotinoids were a relevant cause of widespread bee mortality, highly emotional yet effective lobbying of the EU bodies by NGOs and environmental activists led the European Commission to restrict the use of three neonicotinoid seed treatment products on bee-attractive crops from December 2013.

The fatal effects of false agricultural policy

What happens when agricultural policy decisions are based not on sound scientific evidence but on activists' arguments has been evident in the past year at oilseed rape (OSR) farms in the UK, Germany and Poland, for example. By autumn 2014, numerous OSR crops in the UK had been decimated by cabbage stem flea beetles (*Psylliodes chrysocephala*), a pest previously controlled most effectively by neonicotinoid seed treatments. Losses were estimated at around 20-50% in what, climatically speaking, should have been a good growing year.

To assuage the farmers' plight, some EU governments gave a number of OSR, maize, and sunflower growers exceptional permission to use neonicotinoid seed treatments on their crops in 2015. Farmers who were not able to benefit from such derogations were left with no option other than to control the pests that would otherwise destroy their crop with multiple spray applications of broad-spectrum insecticides. Even then, nearly 30,000 ha of OSR were lost to insect damage.

The situation in Germany's OSR stronghold, Mecklenburg-West Pomerania, is no better than in the UK. Here, huge beetle-induced OSR losses led to a decline in OSR acreage in 2015. That put additional pressure on bees and other pollinators since nectar- and pollen-rich OSR is one of the most important sources of early-season forage. In south-west Poland, Stanislaw Szpara, an experienced agricultural adviser, spoke of the severe impact on OSR crops: "The ban means our farmers are having to spray several times during the season. This is not only more expensive than buying treated seed, it is also worse for beneficials and the environment."

The EU's "save the bees" restrictions seem to have been counterproductive.

Field studies on neonicotinoid impacts

Much of the scientific evidence that pointed to the intrinsic bee toxicity of neonicotinoids came from model experiments in which levels and conditions of neonicotinoid exposure greatly exceeded real-world exposure. Field trials, in contrast, provide a more realistic test of the true impact on bee colonies of neonicotinoid use. Such trials have to be conducted

on a large scale. They require significant resources and crop protection companies such as Bayer have been involved.

One such large-scale study in Ontario, Canada, led by Professor Chris Cutler and Professor Cynthia Scott-Dupree involved ten fields of canola seed treated with clothianidin, one of the three EU-restricted neonicotinoids. The five control fields and five test fields were at least 2 ha in size and at least 10 km apart. No adverse effects were observed on honey bee colonies.

In Mecklenburg-West Pomerania, Bayer commissioned one of the most extensive landscape-level studies ever on clothianidin-treated winter OSR in 2014. The study, parts of which were conducted by scientists from the German Universities of Frankfurt and Cologne, covered 17-18 OSR fields totalling 600-800 ha in each 6,500-ha control and treatment area. Once again, no adverse treatment-related effects were found on honey bees, bumble bees (*Bombus terrestris*) and a solitary bee species (*Osmia rufa*).

Bee health evidence from overseas

Neonicotinoid insecticides are in widespread use in Australia. In February 2014, an overview report on “Neonicotinoids and the Health of Honeybees in Australia” published by the Australian Pesticides and Veterinary Medicines Authority (APVMA) concluded that “… the introduction of neonicotinoids has led to an overall reduction in the risk to the agricultural environment from the application of insecticides … Australian honey bee populations are not in decline despite the increased use of this group of insecticides in agricultural and horticulture since the mid-1990s”. Significantly, the Varroa mite is not present in Australia. In New Zealand, a report on bee health published by a Parliamentary Committee in July 2014 said of neonicotinoids: “… although these pesticides are commonly used as a seed dressing (and) as foliar sprays, there is no evidence that these pesticides, when used correctly, are affecting bees’ health in New Zealand …”

Industry initiatives to reduce impacts

FITBEE, a Germany-wide collaborative project involving 14 research institutions and companies from a range of affected industries (including Bayer), is working to gain a better understanding of the interactions between bees and their environment.

The Dropleg project, which is part of FITBEE, has developed a new way of spraying crop protection products to further minimise pollinators’ exposure to them: hook extensions hanging from the spraying machine enable the product to be applied to the green parts of the plant instead of being sprayed onto the blossoms. Tests have shown that Dropleg significantly reduces residue levels in the pollen and nectar.

To minimise the risk of dust drift when sowing treated seeds, Bayer is proactively promoting stewardship measures, including the innovative SweepAir technology. Here, the exhaust air from a sowing machine, which may contain abraded seed treatment dust, is sucked into a cyclonic device that removes the dust from the air and deposits it in the soil.

These are just a few examples of how industry initiatives are working to better bee health.

Fruitful collaboration and smart apps

Due to the intensification of agriculture, most agricultural land now offers little long-term food or shelter for beneficial insects such as bees. However, a multi-year field experiment on two farms in the Upper Rhine Valley of Germany where 10% of the farmland has been sown with flowering plant strips is demonstrating that these measures can greatly increase pollinator species and insect numbers.

Bayer is also co-operating with farmers in south-west Germany, Brazil, Chile and other South American countries in crop attractiveness studies to discover which insects pollinate which crops and how or when. The Feed a Bee initiative launched in March 2015 by Bayer's North American Bee Care Program called on bee supporters to plant bee-attractive flowers. More than 200,000 individuals responded and the goal of 50 million flowers was reached in just 11 weeks.

Smartphones can also be used to promote bee health. In Australia, the BeeConnected app enables collaboration between beekeepers, farmers and spray contractors to facilitate best-practice pollinator protection. In Canada, the DriftWatch app tells a beekeeper if it is safe to place his hives next to a field of crops.

Bee Care at Bayer

Bayer's intrinsic interest in bee health and safety is largely based on the important pollination role played by bees and its relevance for agriculture, global food sup-plies and the honey production industry. As a life science company, Bayer knows full well how commercially significant pollina-tion is for hybrid canola (a variety of oilseed rape that produces edible oil) and vegetable seed breeding. In Canada, Bayer is one of the major users of bee pollination services for its canola seed production opera-tions and Bayer's high-yielding canola hybrid, InVigor, would not be successfully bred without pollination by honey bees.

Bayer has been researching and developing products specifically designed to promote bee health for 30 years. Its dedicated Bee Care Program established in 2011 is proving to be an excellent central platform to promote bee health, support research and corresponding product development, and facilitate discussion and collaboration on bee health topics across all stakeholders. The Program also enables Bayer to combine and better utilise its in-depth expertise and experience in the fields of animal health and crop protection for the benefit of bees' health. The two Bee Care Centres, one in Germany and one in the US, serve as a platform for scientific exchange and communication, inviting discussions and joint projects with external partners. By proactively reaching out to stakeholders, Bayer strives to increase the transparency of its activities and generate open discussions and partnerships.

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