



BEENOW

2016

The Bee Health Magazine

Bees, Beans and Blossoms

Improving knowledge in Colombia

Working Towards a Better Harvest

The Fraunhofer Chile Research Foundation is monitoring bee health

Spotlight on Pollinators

Bee research in Brazil



EDITORIAL

In South America, many insects, including a wide variety of bee species, contribute to providing essential pollination services for agriculture. As the lead exporter of coffee, citrus and cane sugar, the region has a vocation for agriculture which it is committed to maintain. Pollinators help produce apple, cherry, tomato, watermelon amongst others, so ensuring they remain healthy is a key concern for agricultural productivity and local economies.

The region is also a major honey-producing area. For many years, the number of honey bee colonies has been increasing as honey production expanded.

Healthy bees are also important for the specific role they play in maintaining the diverse and unique regional ecosystems of South America.

Bee health can be impacted by various factors. While *Varroa* may be an issue in some countries, Chile for example, it does not seem the most important threat to honey bee health in all parts of the region. In countries particularly where Africanized honey bees prevail, which are more resistant to *Varroa* problems, other diverse factors can affect pollinator health and these need to be understood. Especially, as available evidence suggests South American native bee species, which often have very specific habitat requirements, play a particularly important role as pollinators.

Pollinator health is a shared responsibility which must be collectively tackled. To thoroughly explore the specific situation and challenges faced by pollinators in the region, Bayer is working with external partners in many South American countries.

In 2015, Bayer initiated collaborations with the Fraunhofer Foundation in Chile for bee health. In addition and with Bayer's support, field studies in Brazil, Peru, Colombia and Chile have been done or are underway by bee researchers, to determine which pollinators are found in which specific crops.

In Brazil, dedicated Bayer functions are working with our global experts to facilitate discussions with eminent Brazilian researchers, triggering specific collaborations on joint bee health projects, which are ongoing. Articles on several of these projects can be found in this edition of BEENOW.

Bayer has been committed to bee health and to identifying solutions to further improve bee health and safety for nearly 30 years. As such, we will continue to play an active and visible role in bee health – for sustainable agriculture and honey production in South America and around the world.



A stylized, handwritten signature in black ink, appearing to read 'Eduardo Estrada'.

Eduardo Estrada
Head of Bayer CropScience
Brazil & Latin America

CONTENT



As the world population grows, modern agriculture and pollinators will need to work in harmony to produce more food than ever. Pollinators and agriculture are inherently linked and farmers in South America and around the world depend as much on sustainable pollination services provided by, for example, bees as they do on new technological crop protection solutions to maintain their market competitiveness. As such, we are working with many dedicated stakeholders who are taking a keen interest in bee health in their own regions of the world.

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beehappy

STRONGER COLONIES

Keeping Bees Fit in Belgium

What makes bees happy and healthy? The Belgian project 'Bee Happy,' supported by Bayer and other agricultural enterprises, intends to find out. Scientists are researching the factors that caused many bee colonies in various parts of Belgium to die unexpectedly over the last few winters. It combines spatial information on different factors such as air pollution, weather events, biodiversity and plant protection product use with the local beehives and beekeeping practices. Phytofar, the Belgian plant protection industry association that initiated the study, wants to get to the root of the problem and develop solutions with support from companies in order to prevent further bee colony losses.

BEEKEEPER TRAINING IN INDIA

Beginning with the Basics



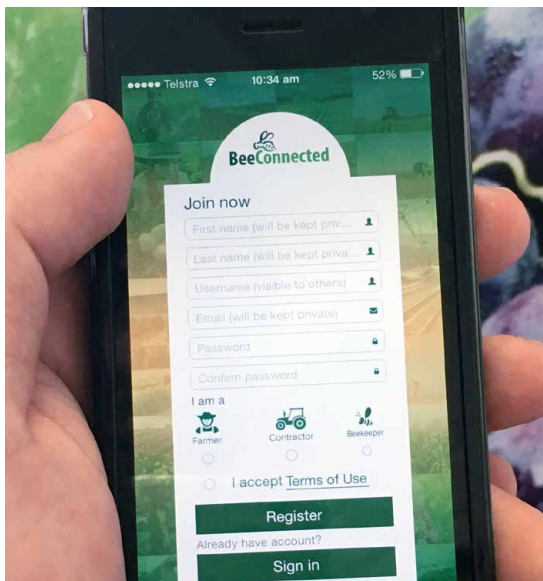
New beekeepers in India learn how to best care for their bees. Here, the need for cooperation between beekeepers and farmers was explained.

A beekeeper's job is to properly look after tens of thousands of bees. In order to master the job, beekeepers need to know how to fight pests in beehives. Eighty-six new beekeepers learned how to do precisely that in a workshop organized by the Vidya Pratishthan's School of Biotechnology in Baramati, in the Indian state of Maharashtra. Bayer experts took part in the workshop as consultants and explained how beekeepers and farmers can work together to protect bees from potential adverse effects of plant protection products.

BEECONNECTED: THE BEE PROTECTION APP

Keeping Each Other App to Date

CropLife Australia and the Australian Honey Bee Industry Council have developed an app with the support of Bayer. The "BeeConnected" app facilitates communication between farmers and beekeepers: Registered farmers receive notifications when beekeepers set up beehives near their fields, for example, and beekeepers can find out when crop protection products are being used. The two parties can also keep in contact by sending each other direct messages via the app. "In Australia, we have the healthiest honey bee colonies in the world, and it's important for us to do everything we can to keep it that way," says Matthew Cossey, CEO of CropLife Australia. The BeeConnected app was created as part of CropLife Australia's Pollinator Protection Initiative and has been granted the Agrow Award for Best Stewardship Program in 2015.



Mobile network: The app enables beekeepers and farmers to connect and share information.

APIMONDIA IN SOUTH KOREA

News on Bees in Asia

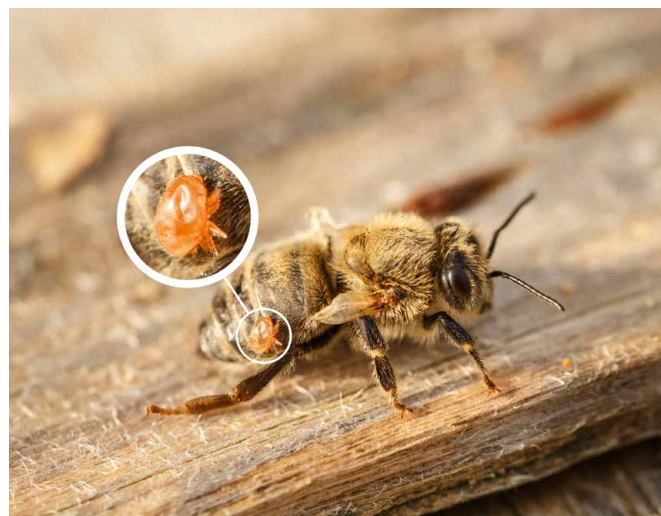


The president of Apimondia, Gilles Ratie, welcomes several thousand attendees to the event in Korea.

The 44th Apimondia Congress, organized by Apimondia – the International Federation of Beekeepers' Associations – took place in South Korea in September 2015. Thousands of researchers and beekeepers gathered to discuss beekeeping and bee health. "Apimondia gives us the opportunity to exchange current scientific results with international scientists," says Dr Christian Maus, Pollinator Safety Manager at Bayer. Among other issues, the use of neonicotinoids, which is particularly controversial in Europe, was debated among Congress participants, which included representatives from Bayer and Syngenta, European stakeholders and local authorities. Monitoring studies by Korean authorities in 2014 had shown no harmful effect on honey bee colonies when neonicotinoids were used in apple and chili crops. However, the debate about the bee safety of some compounds of this class of insecticides is still ongoing.

FIGHTING RESISTANT VARROA MITES

Know Your Enemy



A dangerous pest: The *Varroa* mite is the biggest threat to the European honey bee.

Varroa mites can become resistant to the substances intended to control them, if products from the same compound class are constantly used. For beekeepers, it is especially important to know which products they can use to effectively control *Varroa* mites in their bee colonies. Therefore, Bayer researchers are cooperating with scientists from Germany, England, Spain and the USA to analyze the parasites' resistance mechanisms and the spread of the relevant genes. The basis of resistance is incidental mutations in the mite's genome. If a mite is able to survive a treatment and reproduce afterwards, the genetic mutation will spread. Thus, new types of resistance develop in the mite population. This resistance is dynamic; it can also disappear if the products are temporarily not used. Currently, researchers in Monheim, Germany, are analyzing thousands of *Varroa* mites from all over the world using Polymerase Chain Reaction (PCR) technology to quantify the presence of resistance mutations. In this way, the researchers intend to develop new treatment recommendations for beekeepers.

BASIC RESEARCH IN BRAZIL

Almost Beeless Rice Fields

Rice, one of our staple foods, is wind pollinated and so has not specifically adapted to attract pollinators such as bees. This was confirmed in a study, funded by Bayer, in Brazil. Scientists at Eurofins, a contract research organization, conducted research into the main bee species found in rice fields. The study was conducted across a total of 16 fields in two regions of Brazil. The researchers found that, compared with other crops, rice fields attract very few bees. The bee species discovered in the two regions differed, but the Apidae family, which includes the common honey bee, was dominant.



FACTS & FIGURES

Remarkable facts about bees, food and pollination

MEASURING HONEYCOMBS

The honeycombs in beehives are around 10 to 12 millimeters deep with a diameter of about 5.4 millimeters. The cells in which the drones grow are 14 millimeters deep and have a diameter of 6.9 millimeters.

60,000

Honey bees have around 60,000 olfactory receptors on their two antennae. This allows them to not only determine what the scent is but also which direction it is coming from.

BEE DIVERSITY

Alongside the familiar honey bees, some 30,000 other bee species, including solitary bees and bumble bees, exist worldwide and many also help pollinate crops and wild plants.

HIGH FLYERS

Some bees can fly at heights of 4,550 meters: One such adapted is the bee species of the *Lasioglossum* genus, for example, which lives on the vegetation line of Kilimanjaro in Tanzania.



POLLINATOR SPECIALISMS

Not every bee can collect nectar from every plant. Some flowers, such as carrot blossoms, are so small that only tiny insects can reach the nectar. Sometimes, pollinators even have to shake the blossoms of plants like tomato and blueberry so that the pollen falls out. Powerful insects like bumble bees manage this best.





Bombus dahlbomii

FOCUS ON SOUTH AMERICA

South America has a wide variety of different habitats – from the Amazon rainforest in Brazil to the Atacama desert in Chile. For this reason, it is home to a hugely diverse range of bee species and other pollinators. Some of them are record breakers.



GIANTS IN THE SKY

South America is said to be home to the largest bumble bee in the world: *Bombus dahlbomii*. The queens of this particular species can measure up to four centimeters in length – locals even call them “flying mice.”

Brazil is home to an estimated **3,000** different bee species.

MAKING LIKE THE MAYA

It's not just honey bees that produce honey; it is also produced by the large group of stingless bees. The Maya kept these bees for thousands of years. Increasingly, amateur beekeepers today, for example in Mexico and Brazil, are recognizing the potential of these insects. The so-called *Meliponini* bees live in colonies of a few hundred individuals, and a swarm produces just a few liters of honey a year. By way of comparison, a honey bee colony produces 20 to 30 liters.



Meliponini

5 million

A total of 5 million beehives are managed by beekeepers in Brazil.

A BEE CAN FLY
AT ROUGHLY

25 KM/H



SEDUCTIVE SCENTS

Euglossini bees, also known as orchid bees, live only in South and Central America. The males of this species do not collect the blossoms' nectar but the scent of flowers on their hind legs and use it to attract females.



BEE RESEARCH IN CHILEAN AGRICULTURE



BUZZ ON THE GRAPEVINE

All over the world, pollinating insects such as bees, butterflies and flies play an important role in cultivation of many crops, especially fruit, vegetables and nuts. In other crops, for instance corn, bees may collect pollen without contributing to pollination. Researchers investigated which of these scenarios applied to grape production in Chile. Together with another industry partner, the local Bayer Bee Care Team in Chile commissioned a study with Ceapimayor as academic partner to see whether grape crops and vineyards are attractive to pollinators.



When fruits ripen, they develop more sugar. For wine production, Chilean farmers must harvest the grapes in early fall, so the grapes are not overly sweet.

Chile's agricultural sector relies heavily on the fruit of the vine: Table and wine grapes make up around half of all food crop yields in this South American country. With a cultivation area of 193,000 hectares, Chile is one of the largest wine producers in the world and table grapes are among its main exports. To ensure success on the international market, farmers protect their precious vines from diseases and pests by using crop protection products. This could, in some cases, harm pollinators such as wild bees if they are foraging in the plantations.

In order to minimize any risk for pollinators, it is important for growers to know when the bees are present. "Until the 1970s, it was generally assumed that bees were not attracted to grape flowers," explains Dr Christian Maus, Global Pollinator Safety Manager at the Bayer Bee Care Center in Monheim. However, it was later observed in southern Germany that bees do in fact fly around in vineyards. "Still, that doesn't mean that it's necessarily the same in Chile," says Dr Maus. Attractiveness of crops to bees can vary greatly depending on climate and landscape, which is why the situation is likely to differ from region to region.

That said, studies can help broaden our knowledge generally and are indicative of similar areas elsewhere. Bayer, therefore, investigated the activities of the bees in Chile, in collaboration with industry partner Syngenta, who co-funded the study. Researchers of Ceapimayor, the Bee Center of the Universidad Mayor in Santiago de Chile, carried out the field studies in Chile from September 2014 to February 2015 to find out which and how many pollinators were present in the grape farms and vineyards during the flowering period. The researchers carried out part of the study on table grape farms in Linderos, a village in the fertile center of the country. They also examined the situation in the vineyards located in Molina, in Chile's central south. "There are many more forests in Molina. And in these natural forest areas, wild bees, for example, can find more places to nest than in the other test area further north," explains Alan Lürer, responsible for Public & Government Affairs and Stewardship at Bayer and Head of the Bayer Bee Care team in the Cono Sur region.

"We had expected to find only a few bees in the fields," he explains. "From October to December, we studied vineyards in two areas of Chile with different climates – at various times of day, and also from the early flowering stages to later ones," adds Lürer.



AT A GLANCE

- // Table and wine grapes are among the most important crops in Chile.
- // The local Chilean team and their partners investigated whether pollinators in Chile fly around in vineyards.
- // The study was done to see if the use of crop protection products could impact pollinators. They are not affected by this because they are apparently not significantly attracted to the vineyards in Chile.

Vineyards cover some 193,000 hectares of the Chilean landscape (below). Researchers have studied the number of pollinating insects in the vineyards and in flower meadows alongside the vineyards (right).



The researchers took part in the studies at the plantations, counting every wild bee they saw in the space of ten minutes at eight defined points at each test area. They did the same for other insects, too, including wasps, beetles, flies and butterflies, and collected samples of the insects. That way, the scientists were able to estimate how many different pollinator species were found in the middle and on the outer edges of the wine-growing areas. In addition, they also examined the situation outside of the study areas. Both plantations were surrounded by uncropped land covered in wildflowers such as dandelions and wild radish. The experts then identified the insect samples in the lab and recorded the numbers and species of the animals.

The results of the study: “There are virtually no pollinators in the plantations,” summarizes Lüer. “We found a significantly higher number of them outside of the vineyards, and in greater variety, too.” The researchers observed and sampled a total of 718 insects of 705 different species, demonstrating an enormous level of diversity. On the outer edges of the plantations, there were on average just eight individual pollinators, and only five among the grapevines.



Bees and other pollinators do not find grape flowers particularly attractive when the grape plantations are surrounded by sufficient pollen-rich grasses, flowers and forests.

This means that if Chilean farmers have the right conditions in their fields, they can, for example, use crop protection products on their grapevines even during the flowering period without much risk of exposing bees.

Together with its partner Syngenta, Bayer would like to extend its two-year research partnership with the Universidad Mayor in Santiago de Chile into the future. “For the coming years, we are planning other studies on different crops, such as corn surrounded by stone or pome fruits,” explains Lüer. “Together, we want to learn even more about the bee situation in Chile and in other South American countries and so make an important contribution to the safety of bees in agriculture.”

Interview with Rafael Rodríguez

Rafael Rodríguez is a veterinarian at Ceapimayor, the Center for Beekeeping Entrepreneurship at Universidad Mayor in Santiago, Chile. There, he leads the unit for diagnosis of bee diseases.



What are the most serious risks to honey bees in Chile?

*The main problem in Chile is **Varroosis**. *Varroa destructor* is a wide-spread mite in Chile that transfers viruses to honey bees, resulting in colony losses and decreased honey production. Another major problem is the lack of nearby food resources. Finally, climate change is resulting in bigger honey bee colony losses.*

How did the cooperation work between the researchers of the field study on grape crops and the staff from Bayer company?

The study successfully confirmed and documented that bee pollinators usually do not visit grapes during Chile's flowering season. Bayer scientists supported the choice of vineyards for the study and provided standardized test protocols. The Universidad Mayor adapted the protocol for grape crops; we carried out field trials, lab identification of pollinators, and data analysis. Both groups analyzed the project's process and progress. The study's results are representative of our local situation but may be just as important for other countries.

In general: What are the future responsibilities of research on bees?

Short-term, finding strategies to avoid spreading diseases and pests between bee colonies. The long-term focus should be discovering new types of disease control and integrated pest management. It's also necessary to investigate the impact of agrochemicals and climate change. But all research must be communicated effectively; the focus should be research with a practical touch.



The scientists documented all of the insects they found, such as the butterfly called "Western Painted Lady", ladybugs and beetles known as "pololo común" or "common boyfriend" (top to bottom).

OUTLOOK

The study has shown that very few bees fly around in vineyards if the plantations are surrounded by other richer food sources. Together with industry partner Syngenta, Bayer is planning other research projects in this region in the coming years, to investigate insect populations in other crops.

BLOSSOM BOOM FOR BEES

Honey bee colonies require a sufficient and balanced diet in order to thrive. However, in some landscapes, such as ‘green deserts’, expanding acres of row crops, or large expanses of concrete urban sprawl, worker bees are unable to find enough flowers to give them a varied diet. This can weaken their colonies and make them more susceptible to disease. In response to this situation, the North American Bee Care Program has called on organizations and individuals to help feed honey bees and provide the pollinators with new forage sources.

A bee colony needs about 70 kilograms of honey to feed itself throughout the year. For each kilogram of honey they produce, the honey bees have to gather around three times as much nectar, visiting up to six million flowers in the process. Yet some landscapes are lacking a diversity of flowering plants. As a result the worker bees are unable to find enough diverse supplies of food, causing a lack of nectar and pollen that weakens the entire colony. “We are often asked what individuals can do to help honey bees,” says Dr Becky Langer, director of the North American Bayer Bee Care Program. “This prompted us to launch the ‘Feed a Bee’ initiative in March 2015.” The goal was to plant 50 million bee-attractive flowers within a year and thus provide additional forage acreage for the insects.

Everyone had the opportunity to lend a helping hand: American bee supporters could request one of thousands of free packets of wildflower seeds online and grow their own pollinator patch – or ask the Bayer Bee Care team to plant flower beds on their behalf. Additionally, “Feed a Bee” partners committed to planting acres of pollinator habitat on their company’s grounds. The initiative reached its goal in only eleven weeks through the participation of more than 200,000 individuals. “We were overwhelmed by the enormous response,” says Dr Langer. “The campaign exceeded all our expectations.” The result is indeed impressive: Pollinating insects now have large areas of flowering habitat to provide nutrition – some 65 million flowers through wildflower seed packets planted by individuals and more than 1,300 hectares through large company partners. The project shows what can be accomplished when people work together. “We can now set our sights on larger goals,” says a pleased Dr Langer. “In 2016, the basic goal of ‘Feed a Bee’ will remain the planting of flowers but we will introduce national partnerships to reach broad audiences, augment the education portion of the program and work to connect existing partners to further expertise and resources. For instance, North Carolina State University students will use the North Carolina Department of Transportation Roadside plots for pollinator field studies.”



Feed a Bee



Dr Becky Langer
Director of the North American
Bayer Bee Care Program

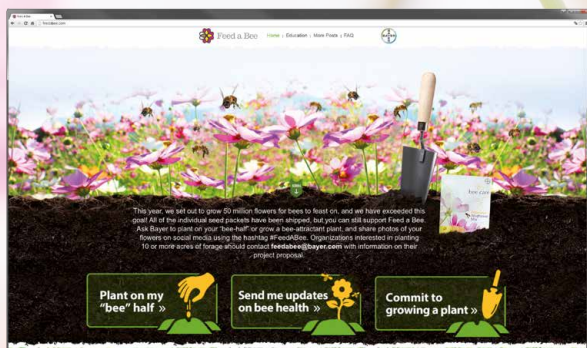
“The campaign exceeded
all expectations.”





CONCLUSION

Through the support of some 200,000 people and numerous industrial partners who helped plant bee forage, large areas of additional flowering habitat have been created. This improves honey bees' food resources and, thus, their health.

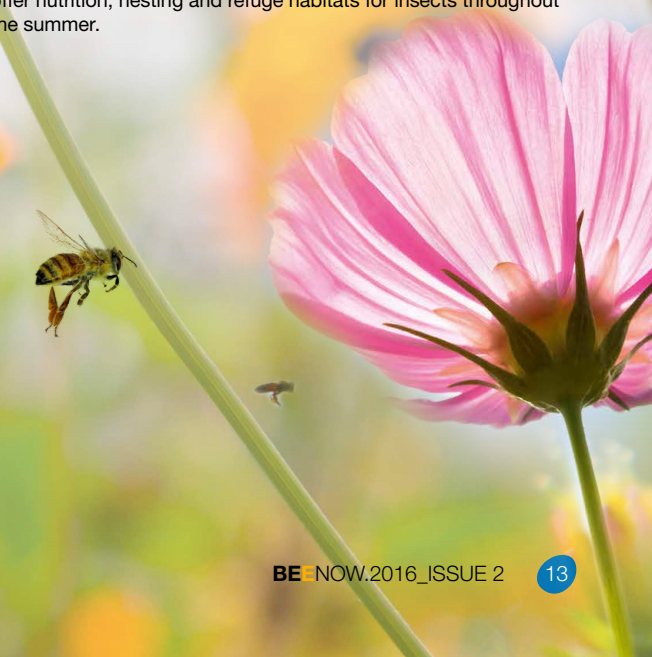


www.feedabee.com – this website explains which flowers are particularly nutritious.

The **BEE FRIENDLY** campaign provides the opportunity for other countries, such as Germany, to enrich the bees' menu. These schemes help people plant their own pollinator patches, which then attract pollinators and beneficial insects to the garden. They offer nutrition, nesting and refuge habitats for insects throughout the summer.

Keep feeding them

Flowering meadows are more than an eye-catcher: They provide bees with important forage. The US team will continue distributing packets of wildflower seeds at some Bee Care events.





AT A GLANCE

- // Honey bees have metabolic mechanisms that can effectively break down certain insecticides.
- // Bayer researchers have now discovered how enzymes in bees break down certain insecticides particularly quickly.
- // This knowledge can be used to facilitate the development of new, bee-friendly insecticides.

Teamwork in the lab: Denise Steinbach, Dr Ralf Nauen, Harald Köhler and Marion Zaworra (from left) not only work with bees; they also analyze how some pests can become resistant to crop protection products.

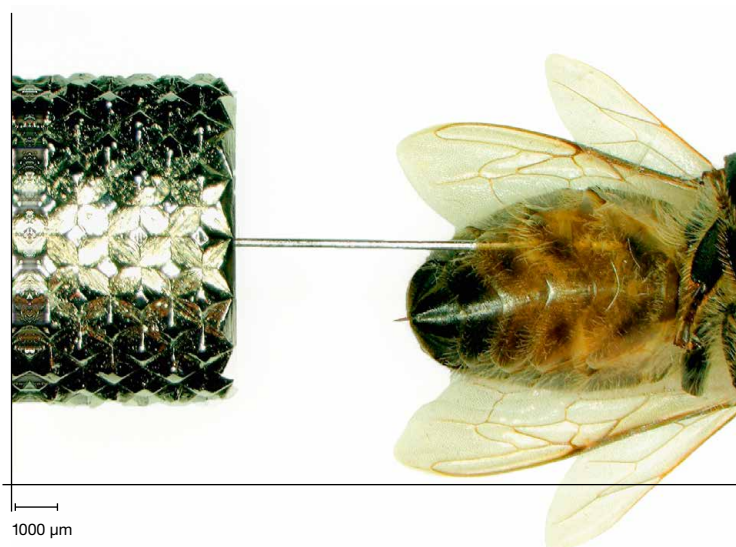
IN PURSUIT OF THE KEY ENZYMES

Honey bees have metabolic mechanisms that can effectively break down certain insecticides quickly, allowing the applied dose to remain toxic to the target pest insects, yet not to bees. Due to this, it is possible to use certain insecticides on flowering crops which are attractive to bees. Bayer researchers are currently investigating which enzymes are involved in this metabolically driven detoxification process. Armed with this knowledge, they hope to become even more targeted in their development of plant protection products that are effective against pests while remaining low-toxic for honey bees.

The molecular mechanisms and tools which honey bees use to break down certain plant protection products lead to some remarkable differences. While a certain amount of one insecticide can kill a honey bee, another may have no effect on their health. "Honey bees seem to have very effective metabolic processes for coping with certain insecticides," explains Dr Ralf Nauen, Head of the Bee Toxicogenomics project for insect research at Bayer. Dr Nauen and his team intend to document which metabolic processes are involved in bee detoxification mechanisms.

In order to achieve this, the researchers expose bees to different kinds of insecticides. "We've tested several products containing insecticides that are used against pests such as aphids and leaf-eating beetles. While certain compounds such as thiacloprid had no impact on bee health at a certain dose, others from the same chemical class were acutely toxic to the bees at comparable exposure rates," explains Dr Nauen. Even though some of the molecules are only slightly different in their structure and react with the same receptors in an insect's body. "The findings also show that you can't make generalizations about the effects of insecticides of a chemical class such as neonicotinoids," says Dr Nauen. He and his team wanted to get to the bottom of why that is – and indeed there are natural resistance or self-defense mechanisms involved to protect honey bees from active ingredients which have, as a consequence, a low acute toxicity to bees, such as thiacloprid.

The researchers therefore analyzed the honey bee genome which was published in 2006. They examined almost 10,000 genes in an effort to find those involved



Precision work

The intra-abdominal microinjection apparatus administers an antisense RNA to an anesthetized honey bee.

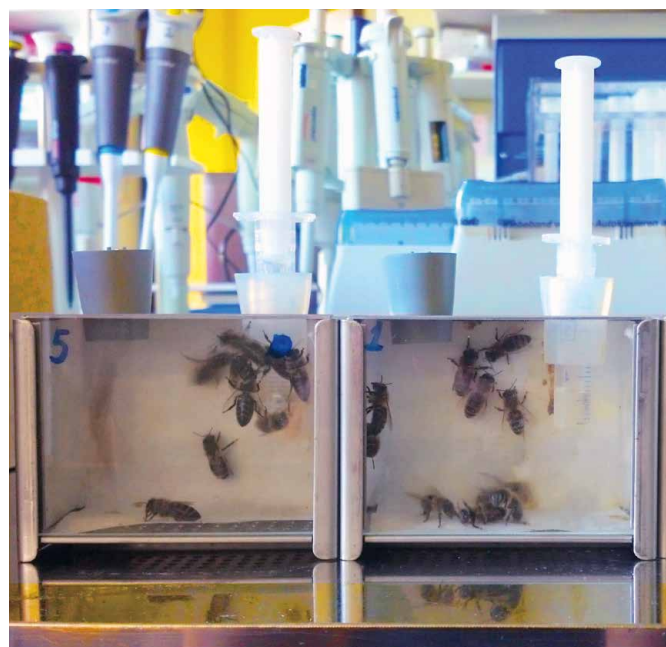
in detoxification of certain insecticides. They cloned and expressed many of them to investigate their detoxification capacity in insect cell lines. However, that is not all: "In order to determine the function of a gene, we have to shut it down," explains Dr Cristina Manjon, a postdoctoral researcher in Dr Nauen's laboratory. To do this, you anesthetize a honey bee and carefully administer an "antisense RNA". This type of Ribonucleic Acid (RNA) targets an intermediate product of a particular gene called messenger RNA, by binding to it and blocking it.

The gene can then no longer perform its normal function. The bees which have this silenced gene are then exposed to an insecticide they would normally resist. A control group of untreated bees is also exposed to the same substance. “We then examine how the bees react to the practically non-toxic insecticide – whether it affects their well-being or triggers symptoms of poisoning,” she explains.

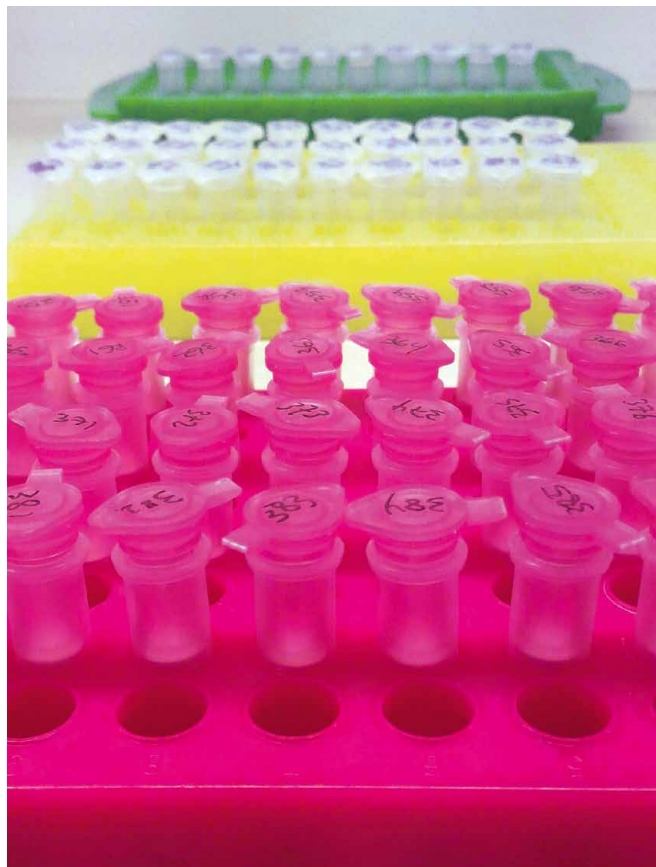
Very recently the researchers identified such a gene which protects honey bees from the effects of certain insecticides: Bees with an inactive copy of that gene did not survive contact with the applied insecticide but the control group did. “This means that this gene is important for the bee’s detoxification process,” explains Dr Manjon.

The gene encodes a particular enzyme, a protein molecule catalyzing specific metabolic reactions. This protein molecule helps the honey bee to break down the insecticide within minutes – so rapidly that there is not time for the insecticide to take effect.

Dr Manjon was even able to identify where the enzyme acts: “Surprisingly, several insecticides are not broken down in the midgut as in most insects. Instead, they are metabolized and broken down in the nerve cells of the brain and the Malpighian tubules – the insects’ kidneys.”



The researchers applied certain insecticides under controlled conditions, to compare untreated insects with ones containing an inactive copy of a particular gene.



During extensive test series, the Bayer researchers have discovered how enzymes in bees break down certain insecticides particularly quickly.

These findings from Dr Nauen’s lab could revolutionize the development of plant protection products: “If we learn and understand more about the detoxification mechanisms and about which enzymes and mechanisms are involved, we can develop more targeted plant protection products,” explains Dr Nauen. The researchers could then test and select active ingredients that are practically non-toxic for honey bees much more easily and earlier in the development process. This would make the development of bee-friendly plant protection products a great deal more efficient.

The scientists are also researching other molecular mechanisms and tools that honey bees use to break down plant protection products. They hope to find out, for example, whether such enzymes can also reduce the effects of certain insecticides. As the researchers want to avoid that their study ‘goes into hibernation’ alongside the honey bees that they are studying, they conduct tests using another insect during the fall and winter: “We transfer the bee genes of interest to fruit flies, which then also produce the enzyme. In this way, we can carry out tests all year round,” explains Dr Manjon. She and the rest of the team are also looking for other enzymes that can quickly break down insecticides. Dr Nauen notes, “We want to learn about all natural resistance and the metabolic defense mechanisms in honey bees. The more we know about what distinguishes them from other insects, the better we can protect them in agriculture.”

WAY FORWARD

Plant protection products must also be safe for bee species other than the honey bee. Dr Nauen's team is, therefore, working with scientists at Rothamsted Research in the UK. They are investigating the same biochemical and genetic mechanisms in two other important bee pollinator species: the red mason bee, a solitary wild bee species, and the buff-tailed bumble bee often used for pollination in greenhouses. The team also has plans to research other types of bee in the future, such as stingless bees, which play an important role for pollination in Brazil.

INTERVIEW



Chris Bass is Head of the Bee Toxicogenomics project at Rothamsted Research in the UK. Since June 2014, he and his team have been studying the resistance mechanisms of two wild bee species. Specifically, they are looking at how insecticides such as neonicotinoids affect them.

What is your focus in the Bee Toxicogenomics project?

*The primary focus of the group at Rothamsted is to expand on the work of Bayer on honey bees by exploring the molecular basis of insecticide selectivity in additional bee species, principally the social bumble bee *Bombus terrestris* and the solitary bee *Osmia bicornis*. Our specific objectives are to generate new genomic and transcriptomic (which means the complete set of messenger RNA transcripts produced by the genome) information and to compare the toxicological profile of these wild bees with that of honey bees. The final aim is to identify and characterize the gene(s) involved in bee detoxification of insecticides.*

Spotlight on Wild Bees

How do your research results differ from the results with honey bees?

*The results have revealed interesting similarities, but we have also observed some differences: It is clear that, as shown for honey bees, profound differences exist in the sensitivity of these bee species to different insecticides within the same class. This finding suggests an understanding of the molecular basis of this observed selectivity could be harnessed to develop pest-specific insecticides that are not harmful to these bee species. We also find similarities across the bee species in the type of specific detoxification enzyme family that is metabolizing the less toxic compounds, but there are differences at the level of the specific genes involved. We are excited with the results generated to date. In the case of *Osmia bicornis*, the speed with which the results have been obtained is a reflection of the powerful next-generation sequencing technologies that have become available over the last few years. These technologies allow unprecedented power to rapidly characterize whole insect transcriptomes, produce draft genomes in non-model organisms that are typically not well-studied, and identify whole super-families of genes involved in insect detoxification.*

What are the next steps for the project?

A huge amount of data and novel information has been generated so far. Our priority is to see this initial data published as swiftly as possible. Beyond this, we will start to explore the molecular basis of selectivity observed in other insecticide classes. We also want to focus on translation of the knowledge generated into rapid and user-friendly test methods that can be used as a future screening tool to develop next-generation, bee-friendly insecticides.



AT A GLANCE

- // There are still some knowledge gaps concerning which insect species are attracted to different crops.
- // A study in Colombia is therefore investigating the insect community foraging on blossoms in bean fields.

In many parts of the world, beans rank among staple foods. Scientists in Colombia are now examining just how popular the plant is with pollinating insects.



COLOMBIA:
IMPROVING FUNDAMENTAL KNOWLEDGE OF POLLINATOR COMMUNITIES IN CROPS

BEEES, BEANS AND BLOSSOMS

In the heart of Colombia, researchers from the Universidad Nacional de Colombia are combing through bean fields. They hope this study, funded by Bayer, will help identify which bee species pollinate bean crops and which are simply visiting the flowers.

The bean is the king of legumes, which are vegetables contained within a pod. It is one of the staple foods in many South and Central American countries and a plant which is also valued by farmers. In Latin America, they cultivate beans alongside corn and coffee because the legume enriches the soil with nitrogen, thanks to the special bacteria found in its roots, thereby fertilizing the other crops. In addition to this, the broad bean is usually self-pollinating, meaning it doesn't need to rely on insects. Nonetheless, honey and bumble bees can help: It is currently thought that, in general, only two percent of plants at most are totally dependent on insects for pollination but scientists suspect that a higher percentage of plants could benefit through increased yields.

In order to investigate this possibility, researchers first need to gather some basic information, such as finding out if bean plants and their flowers are in any way an attractant to honey bees and other insects. For this reason, scientists at the Universidad Nacional de Colombia have developed a study with funding from Bayer. Dr Roberto Ramírez Caro, responsible for public and governmental affairs and stewardship in northern Latin America, and his colleague Beatriz Arrieta locally managed and coordinated the research project on the Bayer side. "If we're talking about pollinating cultivated plants, the honey bee *Apis mellifera* is normally dominant in Colombia. It can be found in most crops," explains Dr Ramírez Caro. "However, until now, it was not clear whether the honey bee is also prevalent in the bean fields."



Dr Roberto Ramírez Caro coordinated the study in Colombia from Bayer's side.

At the beginning of the study, the university's researchers selected five commercial bean farms near Bogotá, the country's capital in the heart of Colombia. Many varieties of the common bean are grown there, including the cargamanto bean, also known as the cranberry bean, which was first bred in the country. The researchers, supported by Bayer experts, studied two to five hectares of land on each of the farms to discover how many and what kind of pollinators were found in the bean fields. The scientists observed the insects' activity at different times of day and also collected samples. Back in the laboratory they then identified which insect species they had found.

Honey bees struggle with the structure of bean flowers.

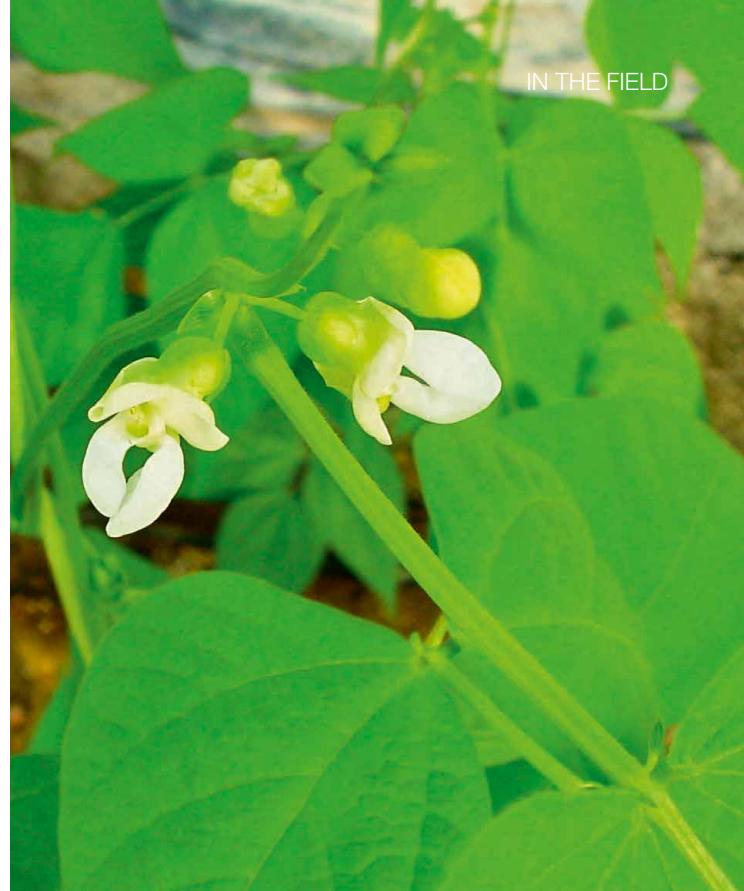
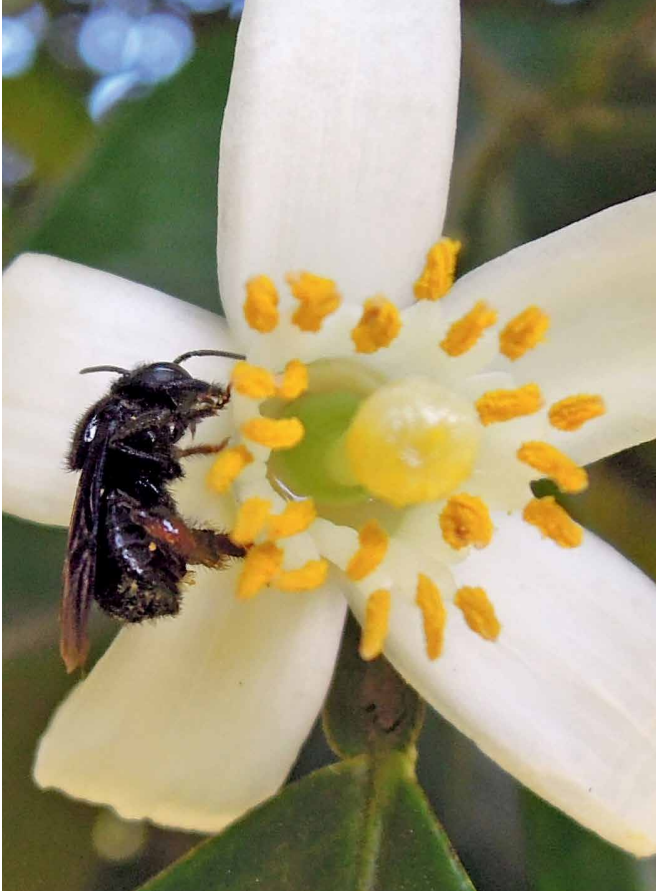
"The latest results show that honey bees do not find the common bean particularly attractive," says Professor Dr Augusto Ramírez Godoy, who was in charge of the study at University together with Professor Rodolfo Ospina, who adds: "That's due to the structure of the flower. It is almost closed and this makes it difficult for the honey bees to reach the nectar and pollen." The researchers did find, however, that other types of bee were able to open the flower to reach the sweet food source inside. Stingless bees, for example, particularly members of the *Trigona* genus, can open the flowers with their mandibles and access the nectar.

Beans for science

Legumes have already made history in the realm of research. In the early 20th century, for example, the Danish botanist Wilhelm Johannsen used bean plants to find out to what extent genes affect specific plant characteristics, such as the weight of a seed or the height of a shrub. In 1865, Gregor Mendel also conducted experiments on pea plants and established some of the fundamental genetic laws of inheritance.

By forcing their way in, these bees often pierce the base of the bean flower but that does not prevent it from developing into a bean. As such, the *Trigona* bees' forced entry does not have a negative effect on crop yield. In fact, other insects even benefit from it: Honey bees, which tend to struggle with the shape of the flower, can take advantage of the opening made by others and access the food with ease. "The frequency of this phenomenon – *Trigona* bees making flowers accessible to honey bees – varies a great deal," says Professor Ospina. In the initial evaluation, this only happened on seven percent of the bean flowers in one test area. The figure was five times higher in another field. "We suspect that this level of variation is linked to the fact that food resources for insects vary from place to place," explains Professor Ramírez Godoy. *Trigona* bees live socially and in colonies, much like honey bees. So, depending on the farming methods used on the bean field and the kind of landscape that surrounds it, the bees have more or less of an opportunity to nest near the field.

As well as honey bees and *Trigona* bees, bumble bees and spider wasps also foraged in the bean fields. Bean flowers are presumably an important source of food for them all. Since these insects are comparatively large in size, strong, and have long tongues, they can reach the nectar more easily than the smaller species, such as the honey bee.



IN THE FIELD

Stingless bees such as *Trigona* (left) force their way into the almost closed structure of bean flowers (right). Other insects can benefit from the opening that is made.

In addition to observing the bees' activities in the test fields, the researchers also examined the insect populations in the surrounding areas. The land around the bean fields was covered in either grass or other cultivated plants, such as vegetables, potatoes or corn. The predominant species found was honey bees but various wild bee species, including members of *Halictidae* and *Megachilidae* families were also present. The researchers still need to work out exactly how many bee species come into contact with the bean plants and nearby crops but they are already planning other projects. "We want to conduct similar studies in other regions of Colombia," explains Professor Ramírez Godoy. The professors also want to study the pollen collected by the insects, as well as the pollen taken straight from the bean flowers and nearby crops. "By analyzing the pollen, we can see which bees actually collect it – compared to those just flying through the field. We also want to know which and how many other plants in the area the insects are attracted to." The study will therefore fill a gap in our knowledge of insect pollinators – especially when it comes to bees that forage on bean blossoms.

CONCLUSION

In some cases, it is not known which bee pollinators are found in particular agricultural fields. The study conducted in Colombia fills the knowledge gap for bean crops. As pollinator populations can vary from country to country, depending on climate and geography, Bayer is providing funding for other, similar projects to better understand pollinator-crop interactions in Colombia and other South American countries.



Professor Dr Rodolfo Ospina (2nd from right) and his team studied the pollinators that were found in the bean fields.



Working for Brazilian Pollinators

INTERVIEW WITH CLAUDIA QUAGLIERINI ON BEE CARE ACTIVITIES IN BRAZIL



Claudia Quaglierini has been an agronomist for almost 20 years. She holds a Master's Degree in Agribusiness Marketing and specializes in dialog with external collaboration partners and other stakeholders. Her professional skills, large network and experience are now contributing to bee health in Brazil.

You are the first person specifically appointed to coordinate the bee health topic for Bayer in Brazil – what is your key role in doing this?

When Bayer invited me to work with the Bee Care Center I could really visualize it as a big opportunity for everyone involved. My first task was to produce a key stakeholder map for Brazil. The goal was to build better relationships to them and implement ideas already set into motion at the Bee Care Centers in Germany and the USA. In the end, it is all about increasing communication and engagement throughout the bee community. Here in Brazil, many beekeepers and researchers are still very skeptical towards agrochemical companies and see them as the main problem in bee health.

How did you go about tackling bee health in Brazil?

At first many researchers were strongly opposed to anything that came from the agro-industrial side. So we really started at the beginning, establishing contact with beekeeping associations and sector organizations. We also participated in beekeeping events and worked on developing a close relationship with all the parties involved and steering the discussion toward a more scientific common ground.

What are your greatest challenges for this topic?

Brazil is a very large country with an amazing diversity in different regions – not only from a biological point of view but also culturally. Because of that, it was necessary to gather all of the stakeholders from the different parts of Brazil to join the same discussion. It was really challenging to get everyone in the same room at the same time but in the end we managed to do it!

How are you working with others – global or local – to promote bee health?

Locally we have been developing new scientific studies about bee health together with top Brazilian researchers. Globally, we count on the support and experience of the Bee Care Centers and promote actions and discussions about the bee health topic. Remember, Bayer is one of the few companies in the industry with many people dedicated exclusively to bee health.

What kind of research is being done in bee health in Brazil?

The areas we are working on now are bee nutrition, an online pollen catalog, an investigation on bees in melon crops and a study of pollination in canola crops. Many more projects are starting in 2016.

What is your favorite thing about working with bees?

After having worked in the area for the past two years I am totally in love with the bee health topic and everything related to it. Bees are fascinating insects with complex social interactions and they are immensely important for agriculture in general. In Brazil, not many people know a lot about bees. Since we have Africanized bees in Brazil, the insects also have a very bad reputation for being aggressive. So it is an even greater task – but also very rewarding – to convince the public that bees play an important role.

What do you see as the most important achievement that Bayer Bee Care has made in Brazil so far?

We consider our most important achievement to be the forming of a discussion group. Now, every participant can suggest, express and discuss his opinion about bee health. For the first time, we have all 13 of the most important Brazilian experts in the field working together with Bayer to find possible actions and solutions. This achievement recently culminated in the group's visit to the Bee Care Center in Germany in April, 2015. There, they had the opportunity to present their collaborations in front of an even broader international audience.

If you could sum up the bee health topic in a few words – what would they be?

What I really learned from bees and their hives is the importance of teamwork and living in a large, productive community. I now truly understand the saying “Coming together is a beginning, staying together is progress, and working together is success”.



Brazil is the largest country in South America with a diverse landscape.



One of the important crops grown is sugarcane.



Bayer's sales representative, Antonio Duarte (middle) helps growers appreciate how insect pollination improves the quality and quantity of their melons.



An Africanized bee resting on a leaf. Researchers in Brazil want to find out which other crops are attractive to bees.

RAPESEED: A SAFE SOURCE OF FOOD?

Large rapeseed fields are an important source of food for bees. Unfortunately, pests which weaken the plants and diminish flowering potential, consequently, also threaten this important resource for bees. Available crop protection products for controlling some rapeseed pests are limited. The registration for a highly effective product was withdrawn due to concerns that rapeseed grown from seed treated with the product might harm bees. In order to generate additional real-field evidence, Bayer investigated the safety of these products to pollinators using rapeseed grown from clothianidin-treated seed.

Rapeseed is particularly attractive to bees, because the crop produces abundant amounts of nectar. Additionally, its pollen supplies essential amino acids and proteins which the bees need to raise their brood. However, when worker bees forage on crops that have been seed-treated with systemic pesticides, there is a chance that they collect small amounts of these substances with the nectar and pollen from the flowers. Small amounts of these substances are harmless to bee colonies. In recent years, however, there has been growing concern by some stakeholders that even traces of crop protection products known as neonicotinoids could be harmful to the health of honey bees and other pollinators. In 2013, the European Commission responded to these concerns by asking the European Food Safety Authority (EFSA) to carry out a review of the safety of neonicotinoid seed treatment products. EFSA analyzed the results of previously submitted registration trials,

using new and extremely conservative criteria. As a precautionary measure, the EC restricted the use of three neonicotinoid substances in certain crops deemed attractive to bees.

This restriction has had consequences for farming: Pests destroy crops and need to be controlled. Jörg Thieß, the manager of Agrargenossenschaft Groß Niendorf e.G. in Germany, has experienced this situation firsthand. At first glance, his rapeseed field appears to be growing well – but a closer look reveals holes chewed through the leaves and eroded stems. Even the roots, well below the soil, are damaged. Pests – such as the pollen beetle, cabbage stem flea beetle and the cabbage root fly – weaken the plants and ultimately destroy large areas of the crops. “At this point, all we can do is accept the loss of yields within the rapeseed farming community,” Thieß says. A few years back, Thieß as well as other farmers had been

AT A GLANCE

- // There is intensive scientific discussion as to whether or not neonicotinoids harm bees.
- // Bayer commissioned one of the largest field studies of rapeseed in the world. In total, some 1,400 hectares of agricultural land, equivalent to roughly 4 times New York Central Park, was sown.
- // The company and agricultural experts of other institutions jointly investigated whether plants grown from seeds treated with clothianidin had an effect on wild bees and honey bees.
- // For the three bee species observed, experts did not find any evidence of harmful effects from the seed treatment.





In the midst of activities: Dr Fred Heimbach (above) coordinated the study and brought all participants together.

Environmental safety is the highest priority for Dr Richard Schmuck (below). His department evaluates Bayer's plant protection products.



Sebastian Wiegand (left) and Daniel Rolke (right), project leaders from the German Bee Research Institute in Oberursel, analyzed the health of the honey bee colonies being studied.



During the study, honey bees (right) carry rapeseed pollen into their hive. The bumble bees (left) also bring their food into the bumble bee box.



able to control the pests. However, with the new EU regulations, farmers are no longer permitted to use seed treatment products containing clothianidin, and effective alternatives are scarce.

This leaves farmers in a predicament. Due to the restrictions, some now cultivate less rapeseed than before. "We have already reduced rapeseed yields by a third," Thieß states. This not only decreases the production of rapeseed oil, animal feed and bio-diesel but it also eradicates valuable sources of forage for bees. "The question as to whether these restrictions make farming any safer for bees has been ignored," says Dr Richard Schmuck, the director of Environmental Safety at Bayer. Dr Holger Kersten, an agricultural consultant for crop protection products, adds: "Only scientifically sound data will allow for objectivity within the debate on controversially discussed products."

Therefore, Bayer initiated one of the world's largest bee monitoring studies in rapeseed fields. The study's participants included bee and crop protection experts as well as beekeepers and farmers in Mecklenburg-Western Pomerania (northeastern Germany). Their goal: To make a

large-scale test on landscape level of the crop protection product Elado® – which contains the active substance clothianidin – under realistic agricultural conditions. Several farmers provided their agricultural land. They sowed rapeseed that had been pre-treated with clothianidin in 2013, the last year when the usage of the restricted neonicotinoids was allowed in winter rapeseed. This seed treatment process covers seeds with a thin multi-layer containing the crop protection product. It is through the roots, then, that the plant absorbs the substance that offers protection against destructive pests during germination and early growth. The farmers sowed these treated winter rapeseeds throughout a total of 800 hectares of agricultural land. On similarly large control fields, untreated rapeseed was cultivated. "The farmers were left to cultivate their fields using their own normal farming practices," explains Dr Fred Heimbach, Senior Expert Ecotoxicology at tier3 solutions and coordinator of the study. "This allowed the researchers to conduct their field studies directly on typical locally cultivated fields, avoiding a simulated test design that would have limited practical relevance. The conditions were completely realistic," states the ecotoxicologist.

The bee health monitoring activities began in spring 2014, during the flowering period: Experts from the Bee Research Institute in Oberursel, Germany, positioned 96 honey bee hives alongside rapeseed fields. In addition, two types of wild bee species were released: the buff-tailed bumble bee and the solitary red mason bee. Under these realistic conditions, the researchers wanted to determine any effect that the crop protection product might have on the different bee species. To provide the most accurate data, the trial and control fields were set far apart from each other, which would prevent the bees from moving between treated and untreated fields. To limit alternative sources of forage, the fields were carefully selected to ensure there were no other bee-attractive crops in the surroundings.

“The researchers did not observe any signs of harmful effects to the three bee species from the clothianidin-treated crop,” Dr Schmuck says. To assure that the bees did, in fact, forage on the treated rapeseed plants, the team of researchers monitored the pollen brought back to the beehives: “The foraging honey bees mainly collected food on the rapeseed fields,” Dr Heimbach recaps. The red mason bee and the buff-tailed bumble bee are known to collect pollen from different types of wild plants. In this study, the bumble bee also collected significant amounts of pollen from rapeseed plants on several occasions when measurements were being made. The researchers also examined the amount of residues from substances in pollen samples. The results: Clothianidin was only found in small amounts, at levels typical for winter rapeseed and below levels deemed harmful for bee colonies.

“Many field trials from different groups of scientists have proven that crops which have been seed-treated with neonicotinoids do not harm the health of honey bees under realistic conditions,” says Dr Christian Maus, Global Pollinator Safety Manager at Bayer. The study confirms this; honey bees showed stable colony development and delivered good honey yields. Similar findings were observed for the other two bee species: The strength of the bumble bee colonies and the number of queens, drones and female workers were well comparable between control and treatment groups. The red mason bee also showed normal nesting and reproductive behavior. “It has become clear that seed treatment of rapeseed is not harmful to bees,” Dr Heimbach concludes.



Precise observation: Martina Flörchinger, employee at tier3 solutions, counts the number of red mason bees in the nesting site.

While the honey bees near the treated rapeseed fields developed perfectly, a different stress factor caused trouble during the winter period: Large numbers of the tested colonies died due to the *Varroa* mite. “Unfortunately, the infestation levels of honey bee colonies was too high to finish the wintering analysis and continue the investigations the next spring,” explains Professor Dr Bernd Grünewald, who leads the Bee Research Institute in Oberursel, Germany. *Varroa destructor* is a parasite that transmits viruses and diseases that can be deadly for honey bees. Colonies from both the treatment and the control fields were affected. “This study clearly shows the complexity of honey bee health, which is dependent on several factors. The study was designed to observe the influence of agriculture on bees but the real danger was a parasite,” says Dr Maus.

Beyond the scientific results, the study helped considerably to raise awareness of bee health for many participants: “During this study, I learned how critical and profoundly essential bee health is. Many other farmers became more aware of the subject as well,” says Thieß. Bayer plans to continue building the collaboration between beekeepers and farmers – bringing together the protection of plants with the welfare of bees.

CONCLUSION

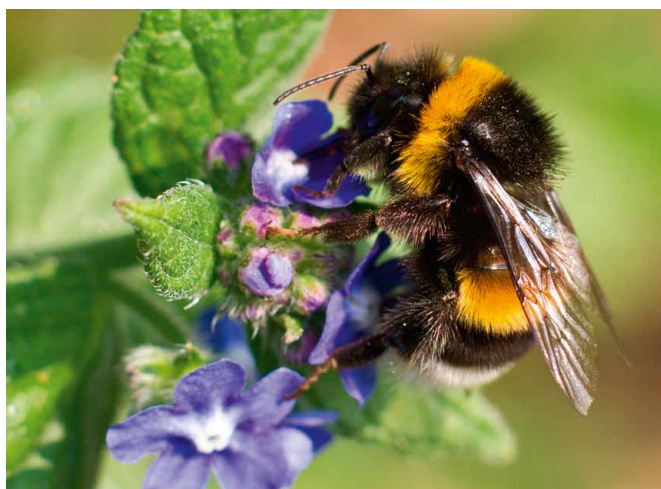
Through this large-scale study conducted in winter rapeseed fields, it has been proven that growing this crop from seed treated with clothianidin is safe for all the tested bee species. Currently, Bayer is supporting additional testing for bee safety with neonicotinoids that is being carried out under realistic field conditions in Germany, Hungary and the United Kingdom. The company will continue to ensure that its agricultural crop protection products can be used safely near bees.



Bee species with different lifestyles

The **honey bee** (*Apis mellifera*) is the most popular type of bee and has been domesticated. A honey bee colony during summer season typically consists of a single queen, several hundred drones and up to 60,000 female worker bees.

- The **queen** is predominantly responsible for reproduction. She will lay up to 2,000 eggs per day and lives for up to 4 years.
- **Worker bees**, which typically live for 4 to 6 weeks, keep the beehive going. They are, for instance, responsible for nursing the brood but they also collect nectar and pollen. The nectar is processed and stored by the bees as honey.
- **Drones** are male bees which live for around 3 months. During summer, they mate with the young queens – mostly from other colonies. Afterwards, they will not be fed any longer and eventually are banished from the hive.



The **buff-tailed bumble bee** (*Bombus terrestris*) builds its colony during spring and summer – this is similar to honey bee colonies but there are less complex social structures. Nonetheless, the colony can comprise over 500 bumble bees and does adhere to a division of labor between the queens, the drones and the female workers. However, only one queen survives the winter and has to reproduce to build a new colony in spring.



The **red mason bee** (*Osmia bicornis*) is a solitary bee species. It adapts well to its surroundings and uses hollow spaces for nesting, such as holes and insect tunnels in wood. Typically, the red mason bee's nests are tubular with compartments made of clay. The red mason bee spends the winter in a natural cocoon.

You could hear a pin drop – and yet, the scene on the screen is a literal hive of activity. It is peak season for the virtual bee colony living inside the computer. The landscape of bits and bytes offers an abundance of nectar and pollen, honey production is on point and there are no *Varroa* mites to affect the health of the pollinators. That is the scenario Dr Thomas Preuss planned when he set the parameters for his virtual bee world. The biologist works in Environmental Modelling at Bayer's division Crop Science and has already created, observed and analyzed thousands of virtual colonies or, in other words, the digital models of beehives.

“Just like in a computer game, we can set different starting conditions. The BEEHAVE¹ simulation model then uses a series of scientific processes to work out how those conditions affect the colony,” explains Dr Preuss.

The background: In the context of pesticide regulations, the European Food Safety Authority, EFSA for short, formulated specific protection goals for honey bees and recommended that they be translated into testing requirements. When these goals were established, the model from which they were derived was still rather basic. Now, a much more refined and realistic model is available as the result of collaboration between scientists from research institutes such as Exeter University in England and the Helmholtz Centre for Environmental Research in Germany and other industry experts. Bayer is very interested in this development and is committed to investigating the potential effects of plant protection products under realistic field conditions by means of monitoring studies and the BEEHAVE¹ model.

Some simulations last a few days, depending on the complexity and starting conditions. However, Dr Preuss can often tell after only ten minutes how his virtual beehive is going to develop over the following years. BEEHAVE¹ knows exactly how many drone bees there are in the colony, how many eggs the virtual queen lays in a day and what percentage of worker bees is looking after the brood.

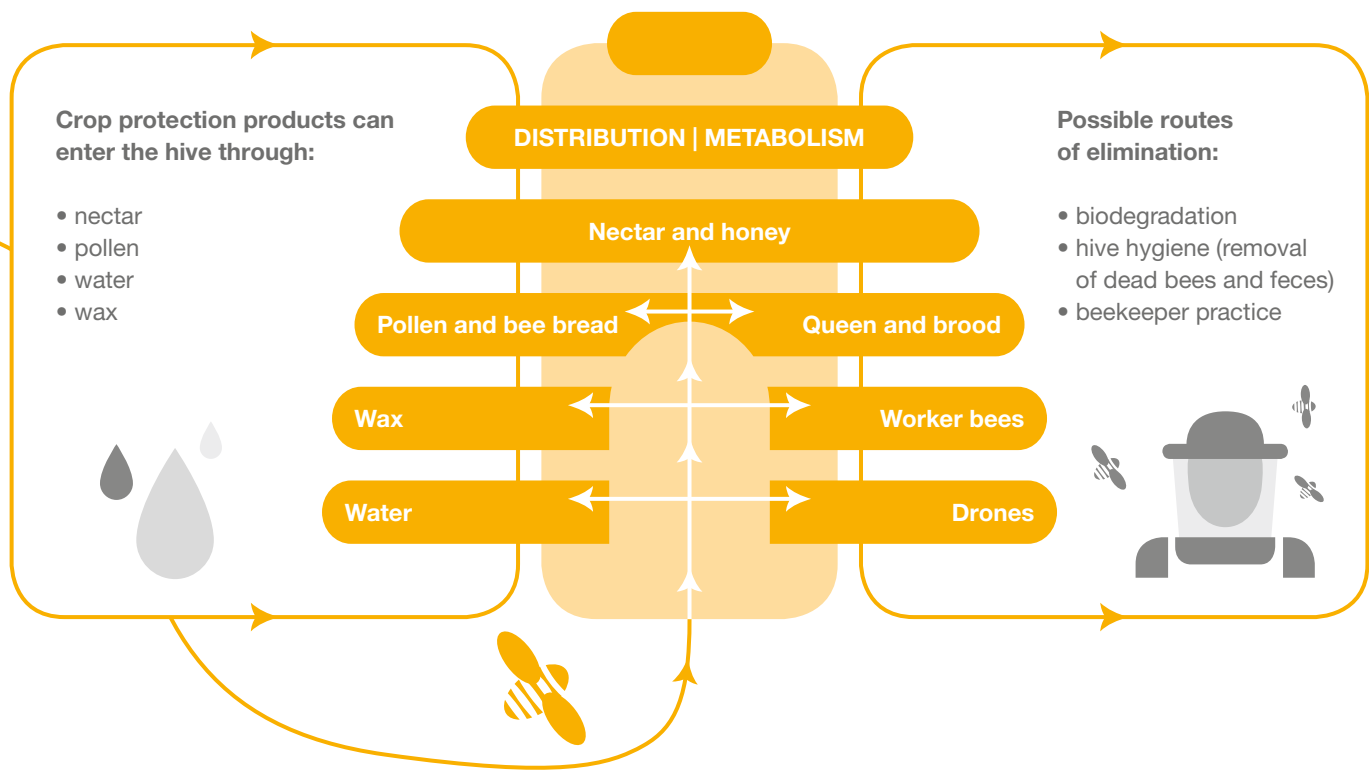


Dr Thomas Preuss can simulate different scenarios in the BEEHAVE¹ program and thus calculate how a bee colony will develop in future.

The biologist can even predict the lifespan of worker bees and how far they fly, how much pollen is in the hive and how much nectar is consumed in a day. “At the end, we also work out how much honey was produced, how many *Varroa* mites there were in the beehive and how many of the parasites were transmitters of a virus,” says Dr Preuss. Many of the calculated parameters, such as how the *Varroa* mites are distributed in the beehive and how they affect the colony, have already been validated in initial experimental tests. The model also considers the role of the beekeeper. “This is because they actively intervene with the colony, collect the honey, give the bees sugar water, fight pests and disease vectors, and thus ensure the colony’s survival,” says Dr Preuss.

AT A GLANCE

- // The European Food Safety Authority has formulated specific protection goals for honey bees and wants to make the impact assessment procedure for plant protection products more extensive.
- // However, many experts believe that the protection goals – and particularly their translation into regulatory testing requirements – need to be revised.
- // Mathematical models can help to establish more realistic goals. Virtual bee colonies can be created by using simulation software such as BEEHAVE¹.
- // The model observes the impact of various factors, including *Varroa* mite infestation, the role of the beekeeper and environmental factors.
- // On the basis of the findings, researchers want to make more realistic predictions of the potential impact of plant protection products on honey bee colonies.



The mixture and the amount of nutrients influence the strength and welfare of the bee colony. Some residues of crop protection products can also enter the beehive in food the bees gather. These products will be excreted through different mechanisms.

The BEEHAVE¹ program (<http://beehave-model.netw>) is available free of charge and is constantly being developed further by bee researchers around the world. Kerstin Horig, a PhD student in Dr Preuss's former team at the German RWTH Aachen University, is making the virtual bee world more and more realistic as part of her doctoral thesis. She focuses on the ways in which crop protection products affect the colony. "We have to include feedback mechanisms that play an important role in biological systems such as bee colonies," explains Dr Preuss.

"Many factors mutually affect each other – such as food availability and the beehive's susceptibility to disease – and can be represented best using computer models."

There can also be a few surprises along the way: During a simulation study, Dr Preuss did not let any of the forager bees return to the virtual hive for five consecutive days. Yet the negative effects on the colony were minimal: "This is only possible in an extremely favorable environment, with plenty of nectar and pollen available," says the biologist. "This keeps the colony healthy and resilient. It can build up stocks, which helps make up for losses."

The researchers are currently assessing the data collected from monitoring studies and experiments with a view to better understanding the biology of bees and offering them even more protection in future. They have to filter out the relevant information from the findings, evaluate it and develop a set of measures. "We want to understand the impact of environmental factors and make recommendations on how to prevent potential negative effects of plant protection products under realistic conditions," says Dr Preuss.

CONCLUSION

Simulation programs, such as BEEHAVE¹, analyze and evaluate the risks to bee populations posed by a variety of different factors in different scenarios. On this basis, the complexity of the factors at play and their combined effects can be better understood and, thus, environmental risk assessment can be amended and optimized. There are comparable mathematical models that simulate the effects of plant protection products and environmental factors on organisms such as water fleas and mice.

FOOD IN NUMBERS



30 MILLIGRAMS OF NECTAR
PER BEE / TRIP

NECTAR is a source of carbohydrates and energy for bees. Its availability depends on time of year and weather. On each trip, foraging bees transport some 30 milligrams of nectar in their “honey stomachs”. Every year, a colony gathers about 120 kilos of nectar in the hive and turns it into around 25 kilos of honey.

120
KILOS OF NECTAR
PER COLONY / YEAR

20 TO 25 KILOS OF POLLEN
PER COLONY / YEAR

POLLEN is a source of protein. Bees transport it in the pollen baskets on their hind legs. Every year, the worker bees transport between 20 and 25 kilos of pollen and use it to make “bee bread” which is fed to the brood. Over the season, collection and consumption of pollen roughly balance out, so stocks are usually stable at about one kilogram.

¹ Becher MA, Grimm V, Thorbek P, Horn J, Kennedy PJ, and Osborne JL, BEEHAVE: a systems model of honeybee colony dynamics and foraging to explore multifactorial causes of colony failure. J. Appl. Ecol., 51(2): 470-482 (2014).

SPOTLIGHT ON POLLINATORS

Three thousand bee species are found in Brazil owing to the country's hugely diverse climatic zones and landscapes – and the variety of potential pollinators is therefore large. Bees can help many agricultural crops to bear more and better-quality fruit, for example in melon plants and cashew trees. However, research is still needed to understand which pollinators are important for which crops. That is why Bayer is working with South American bee researchers to fill in the gaps in our knowledge.



Professor Dr Breno Magalhães Freitas, agronomist at the Federal University of Ceará in Brazil, documents the number of solitary bees in the nesting sites.

“We need to investigate the conditions under which different pollinators best thrive.”

The climate in Brazil varies considerably from the tropical north, near to the equator, to more temperate climates in the south and from the semi-arid northeastern region to the humid Amazonian rainforest. The variety of habitats is reflected also in the diversity and abundance of its flora and fauna: Brazil is one of the most species-rich countries in the world. The number of insect species, alone, is estimated at more than 70,000 and among them are many important pollinators. However, there is still much to learn about plant and pollinator interaction and what this means for agriculture. Bayer researchers are working with Brazilian bee experts like Professor Dr Breno Magalhães Freitas to fill in these knowledge gaps.

Professor Freitas, an agronomist at the Federal University of Ceará in the coastal city of Fortaleza, is investigating pollinators for agriculture: “I want to know which bee species seek out which plants and what cultivation methods enable them to do so.” Professor Freitas is investigating which insects act as

pollinators with the potential to improve harvest yields – and which are just visitors on the field or could even cause damage. “Once we know which pollinators are important for agriculture, we need to investigate the conditions under which they thrive best and which agricultural methods can help attract them safely,” he explains. “In the tropics, particularly, there is still a great need for research in this area.”

Around 3,000 different bee species are found in Brazil – making it a research paradise for bee experts like Professor Freitas. Many of his investigations have provided impressive evidence showing how pollinators, such as bees, can make an important contribution to food security. He has, for example, investigated the influence of insect pollination on one of Brazil's top crops, soybean. Even though soy plants can also self-pollinate, the harvest in the test fields visited by wild pollinators and honey bees was almost 20 percent higher than in control fields.



“Insects can help us increase yields on existing fields without having to farm new areas,” explains Professor Freitas.

Many of Brazil’s other crops also benefit from pollinating insects. Flies, moths and bees help cashew trees bear higher yields, for example. Similarly, many types of watermelon depend entirely on insects.

In addition, Professor Freitas is developing artificial nesting options for solitary bees that will help ensure especially bountiful harvests in, for example, Acerola (also known as Barbados Cherry) plantations. He is also trying to find out which native pollinators in Brazil thrive in greenhouses and can thus be used to increase yields there, too. “A stingless bee, for example, could be particularly suitable for pollinating peppers in greenhouses,” he explains. Professor Freitas already has the next research step in mind and is optimizing bee breeding methods to release the greatest possible number of suitable pollinators into fields, plantations and greenhouses.



3,000

About 3,000 bee species are found in Brazil.

AT A GLANCE

- // There is considerable insect species diversity in Brazil, but their potential as pollinators in agriculture has not yet been extensively explored.
- // Bayer is working with bee experts in Brazil to improve bee health and increase yields through insect pollination.



Professor David de Jong is analyzing samples of honeycombs to find out more about the correlation between honey bee health and their nutrition.

These options can only be put into practice, however, if farmers are also involved in pollinator research. In South America, in particular, collaboration among beekeepers, scientists and farmers can help move research forward. Consequently, Bayer supports exchange and direct interaction among all interest groups. In spring 2015, over a dozen bee experts such as university researchers and representatives from beekeeping and agricultural organizations met for a workshop, but not in South America – instead, they were the guests of the Bee Care Center in Monheim, Germany.

Bayer bee experts and their guests, including Professor Freitas, shared information about the current situation and discussed possible future strategies, measures and cooperative projects. “I can well imagine working with Bayer in the future to gain new insights and give farmers effective management recommendations,” said Professor Freitas. Conversations about possible cooperation opportunities are currently underway.

Farmers harvest a better quality of melons if the melon plants were pollinated by insects.



Among the other workshop participants was Professor Dr David de Jong from the University of São Paulo in Brazil. Professor de Jong has already cooperated with Bayer in various studies. One of his research areas is honey bee nutrition. In predominantly agricultural areas, there are often not enough natural food sources available throughout the season. Beekeepers then have to supplement their colonies’ diet. “But not all supplemental nutrition is equally suitable for bees,” explains the entomologist. Professor de Jong’s team has, therefore, developed a rapid laboratory test that shows how well bees are utilizing pollen substitution products. “That allows us to test many different compositions in a very short time and to understand why certain mixtures work well in some regions of Brazil but can even be harmful for bees elsewhere,” he says.

He is also interested in the conditions under which bees will accept the artificial food sources. Bayer researchers have already supported several of his field studies, such as in a joint project with melon farmers. “With Bayer’s support, we carried out tests in one of Brazil’s harshest regions for bees: Mossoró, in northeastern Brazil,” reports Professor de Jong. “It is so dry there that bees sometimes lack natural food all year round.” Bayer is currently funding a visit to Brazil by US bee expert Dr Gordon Wardell, who developed a marketable pollen substitution product. “We will definitely benefit from Dr Wardell’s experience,” says Professor de Jong.

Further joint projects with Bayer are also planned: “We still want to test newly developed bee food that is supposed to be particularly nutritious. And we are thinking about how to implement a simple, mechanical solution for transporting beehives,” he says. It is hoped that the results of such joint efforts will benefit both beekeepers and farmers – not only in Brazil. “Our insights and developments can contribute to bee protection in other countries, too, especially in other regions of Latin America,” concludes Professor de Jong.



STATEMENT BY ROBERTA NOCELLI

Roberta Nocelli is a professor at the Center of Agricultural Sciences at the Federal University in São Carlos. She investigates bee biology as well as the bees' role as pollinators and how they are influenced by agriculture.

"Brazil has the greatest bee species diversity in the world – as well as a strong agricultural sector. To preserve both, existing ecosystems must be protected and pesticide manufacturers, researchers, farmers and beekeepers need to communicate. This has already led to some initial positive results. For example, at the Bee Care Center workshop, it became clear what still needs to be investigated in order to effectively protect bees in predominantly agricultural surroundings."



STATEMENT BY DECIO GAZZONI

Scientist Decio Gazzoni leads the Agriculture and Pollination Service research program at the Brazilian research foundation EMBRAPA.

"There is still a great need for research into many pollinator topics. At EMBRAPA, for example, we are investigating the regional frequency of various pollinator species, feeding and reproductive sites, economic and ecological aspects, and the influence of management methods in agriculture. We work with many partners, and now have also teamed up with Bayer. At the workshop in Monheim, we agreed on a five-year collaboration. Soybean farming in Brazil is one focus of our joint research activities."



STATEMENT BY STEPHAN CARVALHO

Stephan Carvalho is a beekeeper, entomologist and professor at Brazil's Federal University of Uberlândia. He researches the effects of plant protection products and beekeeping methods on bee health.

"Brazil is a very agricultural country. Protecting species diversity and the different environments in which they live is an important challenge for everyone. We will make progress only if we have environmentally friendly management methods and training programs for beekeepers and farmers that raise awareness of the problems."

CONCLUSION

Research thrives on the exchange of ideas. That's why Bayer continues to work closely with universities and partners on bee research and protection projects.

Bayer is conducting joint studies with Brazilian researchers to optimize honey bee nutrition.

The golden age of oil and honey

Spain is an important producer of honey: Its honey bees produce around 33,000 tons of honey each year – roughly 15 percent of Europe’s total output. Sunflowers are an important crop in Spain due to the valuable oil that can be extracted from their seeds. Balancing the protection of pollinators, like the honey bee, with productive agriculture is another example of Bayer’s commitment to “Science For A Better Life”.



AT A GLANCE

- // The use of the crop protection products clothianidin and thiamethoxam in bee-attractive crops has been restricted in the European Union since 2013.
- // Bayer and industry partners are supporting bee researchers who are carrying out tests in Spanish sunflower fields to determine if these crop protection products have any impact on honey bee colony health.

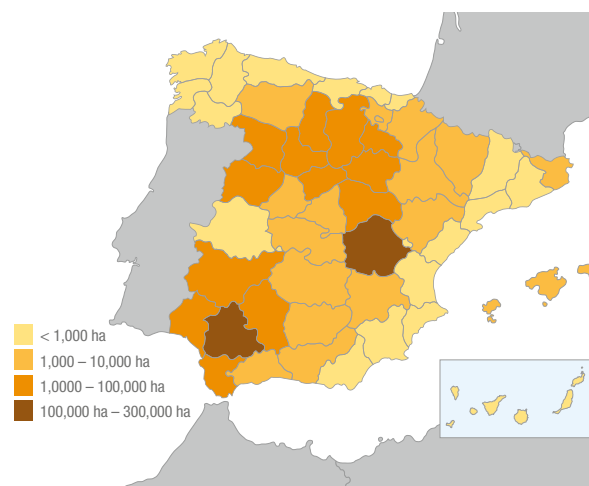
A STUDY INTO THE SAFETY OF NEONICOTINOIDS IS BEING CARRIED OUT IN SPAIN

UNDER THE SPANISH SUN

A multi-year honey bee monitoring study in sunflower has been launched in Spain in 2015, aiming to investigate the relationships between bee health and advanced plant protection technologies in order to ensure the co-existence of agriculture and apiculture. Both activities entail remarkable socio-economic impacts in Spain. Bayer is fully committed to sustainable agriculture and, therefore, is contributing to this study.

Researchers dressed in white protective clothing and surrounded by thousands of honey bees are at work in the middle of a huge sunflower field. They are removing honeycombs from the beehives lined up across the field and recording the number of bees and brood combs they find. Small samples are taken from the individual combs, which are then packed up ready for detailed analysis back at the laboratory. The researchers are carrying out this work to determine the honey bees' level of exposure to the plant protection products used on the crops in the field. Bayer has teamed up with bee researchers from the University of Córdoba, Spain's Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA), and industry partner Syngenta for this large-scale study – the first of its kind to be carried out in Spanish sunflower fields. The aim is to investigate if there is any effect of seed treated with the substances clothianidin and thiamethoxam on the health of bee colonies. “We are carrying out an in-depth study of these bee colonies over a period of three years. Assessments are made twice before the beehives are installed in the fields, twice during the crop pre-flowering season, twice more when the flowers are in bloom and then three times after bloom – the last when the beehives have overwintered,” says Dr María Dolores Hernando of the Departamento de Medio Ambiente at the INIA. “We are looking at wax, honey, pollen, bee larvae and adult bees.”

The motivation behind the study was the EU-wide restriction in certain crops of the use of these two neonicotinoids back in 2013, due to suspicions they could be harmful to honey bees and other pollinators. The evaluation on the basis of which the restrictions were implemented is still being intensively debated, however, and the restriction is having negative consequences for farmers, who now lack highly effective means of protecting their crops against destructive pests.

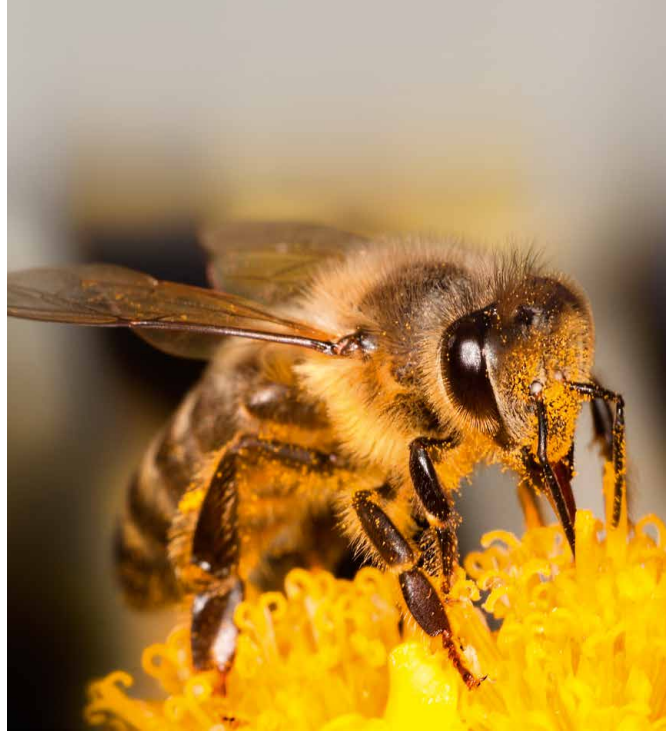


Sunflower cultivation in Spain
Source: MAGRAMA, 2015

Sunflowers are important for both farmers and beekeepers in Spain. In recent years, farmers have cultivated roughly 800,000 hectares for sunflower production – bringing in around 350 billion Euros in 2013. This is mainly a dry land crop – only ten percent of the cultivated surface is irrigated. Owing to its ability to develop taproots the crop is capable of penetrating soil to a depth of four metres. Sunflowers bloom during summer, when high temperatures and water scarcity limit the development of wild flora, resulting in depleted sources of food for honey bees. Therefore, beekeepers consider this crop a valuable source of nectar for their hives, which are often sited in the vicinity of sunflower fields during the hot and long summers of central and southern Spain.



Agustí Soler, Food Safety and Good Agricultural Practice Manager at Bayer, coordinates the input of Bayer to the Spanish sunflower field study.



Spain is home to the most beehives in Europe: Some 2.5 million colonies are found here – 18 percent of the continent’s honey bee population.

“Sunflower seeds treated with insecticide allow for early sowing, which in turn boosts yields and farmer’s income,” says Agustí Soler, Food Safety & Good Agricultural Practice Manager at Bayer Iberia. Previous research conducted in Spain has shown the absence of a correlation between small residue concentrations of insecticides in stored pollen in beehives and colony failure. “Nevertheless, large-scale field trials in treated crops, addressing potential effects of neonicotinoid seed treatments on honey bee colony vitality and survival, have never been conducted in Spain,” says Soler.

That is why Bayer and Syngenta decided to finance the current field study, which began in February 2015. Both companies provided sunflower seeds that had been treated with the substances in question.

“We chose sunflowers as the test crop because bees collect a particularly high quantity of pollen and nectar from these plants in comparison to other field crops, such as corn,” says Germán Canomanuel, Corporate Relations Manager at Syngenta in Spain.

“To avoid compromising the results, we had to ensure there were no other sunflower fields within a two-kilometer radius. This was no easy task,” explains Canomanuel. The research partners chose fields in the southern province of Cádiz in Andalusia and in the south of the regions of Extremadura, Ciudad Real and Madrid. The combined area of all fields equates to some 24 hectares.

“We positioned the beehives in the fields,” says Professor Dr José Manuel Flores of the Departamento de Zoología at the University of Córdoba. “A total of six bee experts from the university are responsible for assessing the bee colonies. The project partner INIA analyzes and evaluates the honey bees’ state of health.” The data gathered in Spain should help to complete the data bases available for the assessment of potential risk of neonicotinoids to bees. Farmers in many European countries have a keen interest in the results: If the substances are shown to have a safe use, the results can feed into the ongoing regulatory process, perhaps to the point where these products can once again be used to protect crops such as sunflowers against pests and thus help provide a more sustainable future for agriculture.



Yellow splendor: 24 hectares of sunflowers are used by researchers to test potential side effects of crop protection products on honey bee colonies.

INTERVIEW

Pooling Knowledge in Research

The cooperation between industry partners and the various project partners is critical for the overall success of the field study.

Dr María Dolores Hernando of the INIA, Germán Canomanuel of Syngenta, and Professor Dr José Manuel Flores of the University of Córdoba bring together many years of invaluable experience and knowledge, complementing one another's expertise perfectly.

What is the basic situation regarding bee health in Spain?

Dr Hernando: Various factors have been identified in causing an increased mortality of pollinators. The current challenge is to consolidate research on the issue using risk weighting, and the evaluation of potential convergence between the key factors that affect the abundance of bee populations.

What is the main goal of the study?

Professor Dr Flores: We as scientists hope to get reliable field data on honey bees exposed to treated sunflower under realistic conditions. Our team of six researchers is keeping and assessing the honey bee colonies that collect pollen and nectar from sunflower blooms grown from seeds treated with neonicotinoid insecticides.

What is your role in the project?

Dr Hernando: The INIA research group is in charge of evaluating residue levels of plant protection products to develop a robust and science-based understanding of the implications of the use of these products. This ongoing research aims to gain additional monitoring data and assess whether there are unacceptable risks for honey bee colonies.

What are the prospects for the future?

Germán Canomanuel: This project will last for three years and is part of a European initiative supported by Bayer and Syngenta that includes studies in oil seed rape and sunflower. I am sure that both companies will continue providing their support with their high standards of technology, expertise and know-how to help deliver the necessary knowledge to take decisions based on science and real facts.

CONCLUSION

The large-scale field study in Spain is running until spring 2018, after which researchers will analyze the gathered data.

The results of the joint Bayer/Syngenta-supported study will provide additional data about potential side effects of neonicotinoids, clothianidin and thiamethoxam, on honey bee colonies foraging in sunflower fields. It will make an important contribution to the bee health debate in Europe.



Dr María Dolores Hernando



Germán Canomanuel



Professor Dr José Manuel Flores



Farmers can benefit from increased yield and quality for their cherry harvest if the flowers are pollinated by insects such as honey and wild bees.



The varied landscape of Chile

Chile is more than 4,000 kilometers long and the land ranges from sea level to a height of 6,000 meters. The western edge runs along the Pacific Ocean, the Andes Mountains tower from the east, in-between are the central valley plains. There are more than 2,000 volcanoes and the country has seen at least 48 eruptions in the past century.

THE FRAUNHOFER CHILE RESEARCH FOUNDATION IS MONITORING BEE HEALTH

WORKING TOWARDS A BETTER HARVEST

Pollination of crops can sometimes be a bit hit and miss, if left to happen naturally. However, where managed pollination with honey bees is practiced, pollination levels can be greatly improved. Therefore, the Fraunhofer Chile Research Foundation, supported by Bayer, is compiling comprehensive scientific data about the bee health situation in Central Chile and how this relates to the pollination of crops.



Across Chile, the degree of pollination achieved can be as diverse as the climate and terrain. As the human population worldwide continues to grow, improving agricultural yields everywhere is essential to guarantee food security. In 2014, the Fraunhofer Chile Research Foundation began a study of pollination and sustainable agriculture with the ultimate goal of professionalizing pollination management in crops like avocados, almonds and cherries. “70 to 90 percent of Chile’s fruit production is pollinated with bees. They are a farmer’s ‘best workers’, responsible for year-round productivity,” says Marnix Doorn, the study’s project manager. In order to ensure the bees provide effective pollination services, they need to be kept healthy.

However, there is a lack of some scientific data about the health of the honey bee, a major pollinator in the country. “The study aims to get complete data, in order to generate a scientifically sound base for focused decision-making in how to create quality agriculture and beekeeping practices that will benefit both farmers and beekeepers,” states Doorn. He and his team want to understand the productivity differences of crops seen in Central Chile: “We want to know if some farms are productive and others, even ones nearby, are less so due to the influence of bee health on the level of pollination services provided. The project was created with the goal of accurately measuring bee health, so conclusions reached will have a scientific foundation.” As part of this overall study, Bayer is providing funding and research support for a detailed analysis of the influence of factors such as apiary management, pests and pesticides on bee health.

During the study, 70 apiaries are being monitored throughout the season. The Fraunhofer researchers are assessing beekeeping practices, colony strengths, pathogen levels in the hives and the amounts of pesticide residues found in bee bread of the colonies. At each of the 70 apiaries, three honey bee colonies were selected at random for detailed investigations. Beekeepers are being regularly interviewed to discuss the conditions of their hives, their own observations, and their apicultural practices. The colony strength is determined by



Botanically speaking, avocados are actually berries that grow on trees in countries such as Chile, Peru and Spain.

Almond trees originate from Central Asia and are grown in warm climates. The blooming period of almond trees in the Northern hemisphere is usually from January to April.

AT A GLANCE

- // The Fraunhofer Chile Research Foundation and Bayer are cooperating in a large-scale study about bee health in Central Chile.
- // The study is making a detailed investigation of the influence of factors, such as apiary management, pests and pesticides, on bee health.
- // Chilean farmers grow diverse crops, from almonds to avocados, many of which depend on insect pollination.
- // By analyzing the bee health situation, researchers can look at how this relates to the pollination of crops.



Marnix Doorn (left) and his team at Fraunhofer want to make a difference: By monitoring honey bee health in Central Chile, they want to obtain data that may help to improve pollination provided by bees and thus the productivity of crops.

“This lack of skills does not contribute to the problem, it is the problem.”

Another challenge for his team will be to transform scientific findings into concrete action. “The big question that arises now is how to educate everyone on the correct practices,” Doorn notes.

estimating the number of bees per hive. The amount of honey, brood and pollen in each frame is also measured. This data creates numeric values that can be compared between apiaries.

Strong apiaries require basic bee care: providing abundant, clean water, a varied and healthy diet, and fostering and maintaining the diversity of forage plants that bees need. At the same time, responsible farm management is essential. “If you know that your almonds depend almost 100 percent on insect pollination, your bees are one of the most important tools on the farm. It’s like knowing you need a combine harvester to reap your field but the harvester doesn’t work unless you look after it well,” says Doorn, adding, “Bees are the ‘combine harvesters’ of these farms. When they aren’t looked after, the farm is less productive.” He concludes that farmers need to understand that there are many ways they can help the bees to stay healthy.



Marnix Doorn’s team has already generated some initial results. In this first round of monitoring, general trends can be seen which are not yet fully conclusive, mainly related to apicultural and agricultural management practices: “For example, we see poor colony strengths due to malnutrition and lack of cleanliness,” says Doorn. The research team has also found reasons to be optimistic: Levels of *Varroa* infestation, for example, were considered acceptable for most apiaries in the area. And some of the apiaries being studied are extremely well-managed by knowledgeable beekeepers.



Bee experts regularly observe and document the health of 210 honey beehives overall (below). The hives are positioned close to different crops such as plum trees (above).

Even so, as Doorn notes: “Although there is a high level of goodwill among the beekeepers, some are still lacking apicultural management skills.” After this first round of monitoring, their research already supports what has been noted in previous, short-term investigations. The Bayer-sponsored data feeds into the current, overall study of pollination and sustainable agriculture in Chile that shows there is a knowledge gap related to the link between good beekeeping practices and the pollination of crops. This is a crucial point, says Doorn:

The conditions of this study are specific to Chilean agricultural practices, its landscape and diverse crop cultures. With this detailed analysis, combined with professional educational outreach, the study is creating a map of bee health in Central Chile. For Doorn, there is a fundamental principle behind this study: “It is not just about making a company, industry or economy better. We need good science in order to assist good decision-making that can help to make agriculture even more sustainable and guarantee stable yields.”

CONCLUSION

This current, overarching study of pollination and sustainable agriculture in Chile shows that there is a knowledge gap related to the link between good beekeeping practices and the pollination of crops. The monitoring study by the Fraunhofer Chile Research Foundation, with the support of Bayer, is creating a paradigm for how to analyze bee health to optimize pollination, and thus agricultural yields, not just in Chile, but perhaps also on a broader geographical level.

INTERVIEW

Creating Useful and Meaningful Data



Marnix Doorn, the study's project manager, is originally from the Netherlands. In 2004, he came to Chile for business reasons; one of his projects led him to work with beekeepers, which was his introduction to the bee world. Doorn is currently the Head of the Agriculture Division of the Center for Systems Biotechnology at the Fraunhofer Chile Research Foundation.

“With its diverse landscape, Chile provides habitat for more than 400 different bee species.”

What are your plans for this collaboration with Bayer?

At Fraunhofer, we are increasingly involved in pollination studies, trying to understand the situation in Chile. Healthy bees are essential for an efficient pollination. Together with the colleagues at the Bayer Bee Care Center, we agreed on the following principal: Before we just start ‘doing things,’ let’s profoundly measure what is really going on with bee health in order to create a scientific basis for our ideas. There are lots of short-term data but we needed to scale it up before starting any decision-making and policy planning. You need long-term data, which has not been available so far.

How has the reception been to your results so far?

The Chilean agricultural community and government are very open to learning. They are interested in getting the most from their land by ensuring the most appropriate agricultural and apicultural practices are implemented.

At the end of this study, what would be optimal results?

That we would have deeply-analyzed data that helps to achieve a higher quality of farm and beekeeping management, to help both practices work in harmony and to ensure better productivity of the crops. Then there will be a question of motivation: How do you make people change how they think and what they do regarding how to better integrate bee pollination and agriculture? But with sound science, I believe we can assist them and change might come along much faster.



AT A GLANCE

- // Pollinators like bees are important in sustainable agriculture.
- // Integrated farming helps honey bees, wild bees and bumble bees to flourish alongside good crop yields.
- // Bayer is demonstrating how integrated farm management practices can work on their field stations in the UK.
- // Model farms will be opened around the world as part of the ForwardFarming Program.

Nature reserve for pollinators

Bayer's Orchard Farm is a former fruit plantation that covers 20 hectares of hilly terrain near Cambridge. The hard, rich clay soil used to be primarily planted with apple and plum trees. Today, mixed crops are cultivated on over half of the land. With its ash trees, oaks, sycamores and wild cherry trees, the area is a diverse habitat for birds, and many insect species thrive within the remaining woodland, including 23 species of butterflies and 140 species of moths. Additionally, beehives have been kept on the farm for over 20 years.

INTEGRATED FARM MANAGEMENT IN THE UK

SUSTAINABLE AGRICULTURE IN PRACTICE

Bee protection, sustainability and agriculture come together – thanks to Integrated Farm Management. With this system, Bayer’s Alice Johnston plans and coordinates measures that benefit pollinators such as honey bees, bumble bees and wild bees. Johnston demonstrates what integrated approaches look like in practice on Bayer’s Orchard Farm in the English countryside.

As the sun sets behind the trees of the Orchard Farm, Alice Johnston checks the farm’s beehives one more time: The honeycombs are full of honey and the bees are thriving. “For us, this is a sign of success,” explains Johnston. She is the Application and Stewardship Coordinator and is involved in the Integrated Farm Management at Orchard Farm, one of Bayer’s field stations near Cambridge, England.

Sustainable agriculture means flourishing bee colonies alongside good yields. “We are trying out different ways to optimize our less productive land use for bees and other pollinating insects, so that they can stay healthy and help secure productivity in the long term,” says Johnston. Bee protection and sustainable measures should be incorporated into everyday farming practices. Specifically, Johnston focuses on providing the honey bees, wild bees, bumble bees and birds on the farm with two key things they need, namely food and nesting places.

On her way back to the main building, Johnston walks through the old plum orchard: “We’ve kept this small plot of land as a conservation area. It’s a good example of what Integrated Farm Management can look like in practice,” she explains. The plum trees in the orchard are of the Marjorie’s Seedling variety, which blossoms particularly early. Come spring, they are one of the first ports of call for bees scouting for food sources. Many cultivated plants have a short flowering period, but bees have to be able to gather food over many months.



Alice Johnston
Application and Stewardship
Coordinator Integrated Farm
Management

“It’s important to stretch the blooming period for as long as possible through the year.”

Fruit trees and hedges are just one example of Integrated Farm Management methods used. “We are developing the farms so they enhance the local environment whilst keeping their primary focus of investigating new crop protection solutions and seed varieties intact,” explains Johnston. A second trial farm just a little further north, is a patchwork of flat fields. Johnston works with the farm team to help create the best possible environment for wild bees and other insects on both farms. The areas near field tracks also serve as habitats, and the tall tussock grasses – also known as bunch grass – on the sides of the track are ideal nesting sites for bumble bees and other insects. “It’s mostly bumble bees and wild bees that like to nest in these ‘beetle banks’, as they are called,” says Johnston. “They can find a large variety of food right by their nesting place because the fields are edged with strips of flowers.”

The Bayer expert believes that bee-friendly landscaping should not stop at farm boundaries.

She has been compiling material to inform the public about bee health and habitat requirements for pollinators. Visitors can also gain a good impression of integrated farming once a year at the local Open Farm Sunday, when a number of employees from Bayer help at local farms which open their gates to the public and specialist visitors. “We want to bring farmers, beekeepers and the general public closer together because healthy bees are extremely important for all of them. The event gives them the opportunity to understand what really happens on a farm and to discuss any issues face-to-face,” says Johnston.

Both farms demonstrate just how well bee protection, sustainability and agriculture can work together. Habitats are developed where the land cannot be cultivated profitably – on roadsides and at the edges of fields. But it’s not just up to farmers: “Everyone can do their bit – for example, plant hedges to create privacy rather than erect wooden partitions. Leave a patch of grass to grow, or plant a wide variety of flowers which will bloom and provide food throughout several months,” says Johnston. A garden in its natural state provides important nesting places for wild bees – in old tree trunks or tall grasses, for example; and where such areas are not available, Johnston proposes the placement of artificial bee hotels to encourage solitary bees to nest in the garden. “We all have the opportunity to support many bee species”, she adds.



Nutritious fields

An additional field station near Cambridge covers an open area of 20 hectares, with rows of fields separated by a network of wide field tracks. At this second station, the edges of the tracks and fields are lined with strips of flowers and beetle banks. About a hectare of the farm is reserved for the flowers which are a source of food for wild bees, bumble bees, hoverflies and other insects.



The ideal home

Wild bees and bumble bees nest in old wood, collapsed walls and abandoned burrows. They find very little shelter in cultivated forests or pristine gardens. Wild bees can even benefit from lawns that are not mowed too short. Tree trunks, fallen branches and man-made insect hotels like this one at Orchard Farm, are also suitable nesting places.



From above

The patchwork of fields around Orchard Farm is interspersed with hedgerows, fallow land, orchards and flower strips. Integrated farm management helps ensure farmland works as a suitable environmental habitat – not only for crops but also for bees and other insects.



Season-round food supply

Honey bees gather food from early April to late September. Many crops, however, have a very short blooming period. A good combination of different crops, hedges and flowers increases the amount of food available to bees and provides them with enough pollen and nectar throughout the year. Planting colorful strips of flowers along the edges of fields or a variety of flowers in home gardens also does wonders for the diet of pollinators.

ForwardFarms demonstrate great prospects for agriculture.

Sustainable farming can be adopted and practiced across the world. The goal of Bayer's ForwardFarming Program is to bring economics together with social and environmental elements. Typical farms in Belgium, France, Germany and The Netherlands are taking part in the program, each with a different focus in crops and balance of key elements being implemented. The ForwardFarming Program links plant protection, high-quality seeds, services and stewardship elements into a comprehensive integrated farming concept in many cases supported by partners with specific knowledge and expertise in the areas of sustainability. This is where bee health, sustainability and agriculture can work together. The farms employ various measures, from observing bee studies, monitoring parasites, or assessing nesting options for different bee species to planting flower strips.

www.forwardfarming.com

Fruitful cooperation between beekeepers and farmers

Beekeepers and farmers have a common interest: healthy honey bees. Farmers benefit from the bees' pollination work, and beekeepers harvest the honey. Regular discussions help both beekeepers and farmers to work together. Many field crops, trees and flowers are a source of food for bees and humans. However, farmers do have to protect the plants against pests. They need to use plant protection products responsibly and are encouraged to inform beekeepers about their intentions to spray insecticides. Although it may not be practical or needed in many cases, it does give beekeepers the option of moving their hives or closing them when fields are being sprayed. The key to improving bee protection in agriculture is also effective communication between farmers and beekeepers.

PROTECTING HUNGARY'S BEES

Systemic seed treatment products, applied as a coating around the seed, protect the emerging crops from fungal diseases and insects. However, if parts of this layer get rubbed off the seeds, crop protection products may be released into the air as dust particles. In order to minimize the chance of bees being affected by this, a campaign has been launched to help Hungarian farmers fit their planting equipment with so-called deflectors.

Seeds are the starting blocks of thriving plant life. As such, they require a particularly high degree of protection, so that e.g. the corn, soybean or oilseed rape seedlings they produce will grow into strong, healthy, productive plants. For this reason, the seeds are covered with protective products before they are planted. If this is done with a systemic seed treatment product, the substance is taken up by the roots as the young plants grow, protecting them from destructive insects or fungal diseases. The crop protection afforded by the seed coating also ensures that less spraying will need to be done, thereby reducing resource usage, costs for farmers and potential exposure of pollinating insects such as bees. "For the environmental safety of this approach to work, however, it is essential that the protective treatment sticks well enough to the seed," says Dr Peter Ohs, Senior Global Stewardship Manager at Bayer's division Crop Science. "And the treatments have to be properly applied to the seed by qualified experts, and the treated seeds must be handled, stored and used with care by the farmers," he explains. Otherwise, a small amount of the substance could rub off the seeds and be emitted into the environment or the air as they are being planted with vacuum-pneumatic drilling machines, causing potential risks for beneficial insects and other organisms. Bayer experts are therefore constantly working on making the entire seed treatment and planting processes even safer. "For example, it is important that we reduce the amount of dust emitted during planting," says Dr Ohs.

AT A GLANCE

- // Systemic seed treatment products protect seeds and young plants from pests.
- // Without precautionary measures, small parts of the seed treatment can rub off the seed surface and be released to the environment as dust during planting.
- // A campaign, launched to encourage Hungarian farmers to fit planting equipment with deflectors, was started in order to minimize the emission of dust.

Deflectors reduce the drift of seed treatment dust by 90 percent.

This is where deflectors come into the equation: Deflectors attached to the planting equipment direct 90 percent of any dust generated to the ground. This process protects not only the pollinators but also the farmers and environment.

Prior to the start of the project in Hungary, no reliable data was available to indicate how many drilling machines are operating in the country and if they were equipped with such a device. A market survey showed that smaller farms in particular, that comprise more than 50 percent of the farmers community, usually own drilling machines which have no deflectors. That is why standardized deflector kits have been developed, which are customized to fit the planting equipment commonly used in Hungary. “Parallel to this, we have also launched a campaign to raise awareness in the farming community that deflectors are an important part of environmentally friendly farming,” says Dr Ohs. The campaign was supported by all major stakeholder organizations including the National Chamber of Agriculture, the Hungarian Seed Association and the Hungarian Crop Protection Agency.

The Hungarian Ministry of Agriculture is also working along the same lines as Bayer. “We are trying to make farmers more aware of this important issue,” explains Gabor Szalkai from the Ministry. “At the same time, we want to introduce binding rules on equipping agricultural machinery to better protect our environment.”

The deflector campaign, therefore, comes at just the right time. The initiative, which has been running in Hungary since the end of 2014, includes a discount scheme for farmers. The discounts allow them to fit their planting equipment with deflectors more affordably, saving between 50 and 75 percent of the original costs. “In this way, smallholders can also afford the easy-to-install retrofit kits,” says Dr Ohs. Currently, about two thirds of farmers are aware of the upcoming regulations. Those who have already installed the deflector are saying every pneumatic drilling machine should be equipped with such a device as it requires only a small effort but can make a large contribution to sustainable crop protection and farming. A particularly positive aspect of the campaign is that small-scale farmers with whom the companies normally have no direct contact could also be involved. “We have opened the gates to the farmers,” says Dr Ohs, optimistically. After all, only if many farmers get on board with the campaign, will the goal of this stewardship measure be reached – to further reduce potential risk to pollinators.

So-called deflectors (left) reduce the amount of dust that could be released into the air from treated seeds during sowing.



Dr Peter Ohs
Senior Global Stewardship Manager
Bayer's division Crop Science

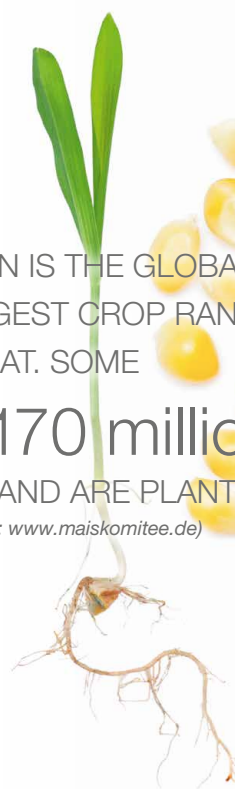
“The Bayer and Syngenta campaign for fitting Hungarian planting equipment with deflectors was well received and many small-scale farmers have been reached. Additionally, the Hungarian Agricultural Ministry is also committed to better protect bees and the environment.”

CORN IS THE GLOBALLY SECOND LARGEST CROP RANKING AFTER WHEAT. SOME

170 million hectares

OF LAND ARE PLANTED TO CORN.

(Source: www.maiskomitee.de)



PROTECTING BEES FOR GENERATIONS TO COME

Crop protection product research, as well as introducing new products to the market, is subject to strict regulations. The experts at Bayer have to make certain that their products are safe for bees, when used correctly. This is why they are also carrying out laboratory studies on the younger generation of these insects – honey bee larvae. In the future more tests – both in the laboratory and the field – will be conducted to develop methods for bumble bees and wild bees.



Dr Maria Teresa Almanza
Head of the Bee Testing and Risk Assessment Group of Environmental Safety at Bayer

“We are constantly investigating new testing methods to ensure we are protecting bees based on up-to-date scientific approaches.”

Farmers benefit greatly from the pollination services provided by honey bees, but at the same time they have to protect their crops against weeds, fungal diseases and harmful insects. Crop protection products, thus, play an essential role in farming. The products should be as selective as possible, to ensure they are safe to the environment, and especially to beneficial organisms, but can still control pests. This situation presents a challenge for plant protection researchers. Crop protection products have to comply with strict regulations before they receive approval: A specific use of every product must be safe for honey bees – and the standards are steadily increasing. “To meet these evolving requirements, we work with international experts on developing new procedures that allow us to optimize the safety testing of crop protection products,” says Dr Maria Teresa Almanza, Head of the Bee Testing and Risk Assessment Group of Environmental Safety at Bayer. The entomologist and her team study the bees’ sensitivity to crop protection products.

It has long been obligatory in the European Union and in many other parts of the world for crop protection products to be tested on adult honey bees before they can enter the market. But less has been known about how these products

affect the bee brood, in particular the larvae and this has subsequently been taken up in the scientific and regulatory communities. “There are cases where testing of adult bees alone would not cover all relevant aspects of the ecotoxicological profile of a substance,” says Dr Almanza.

This is why Bayer bee experts have teamed up with international experts since 2006 to investigate laboratory procedures that bring the bee larvae into direct contact with the substances. “This larvae test complements the toolbox of first-tier testing methods which are conducted in the laboratory under standardized conditions, and aims to gain information about the intrinsic toxicity of the tested substances,” says the bee laboratory director Dr David Gladbach. To work out exactly how these types of tests should be conducted, several institutions carry out preliminary research. In most cases, these so-called ring tests involve various separate laboratories from industry and research working together, with the key objective to generate robust and reproducible data. The final result may be an official guideline. In 2013, the International Organisation for Economic Co-operation and Development (OECD) published the acute larvae test as “Test guidance document 237”

AT A GLANCE

- // Bayer experts test crop protection products on honey bee larvae to optimize the safe use directions for the products in the field.
- // Prescribed standardized test procedures ensure that studies are comparable across different laboratories.
- // The researchers are also developing new testing methods for wild bees and bumble bees.



Dr David Gladbach
Bee Laboratory Director

“We want to develop reproducible tests to obtain comparable results.”

after seven years of development research. In addition to the acute exposure which is addressed in the OECD 237 design, there is also the chronic larvae test for which an OECD Guideline has been discussed recently.

“The acute larvae test is already part of the current requirements for the approval of many crop protection products in Europe and in the USA. The chronic larvae test is set to become compulsory in the USA in the near future,” says Dr Almanza. The latter test design will expose the bee larvae to the test substance for several days, comprising all juvenile life stages.

The specifications for developing and carrying out the larvae test are very precise: Researchers study at least 36 larvae from a minimum of three queens in one cycle. They must also have a control group of bee larvae that, for direct comparison, is not treated with the test substance. Even the temperature of the test surroundings is precisely stipulated to be 35 degrees Celsius. There is a strong reason for such strict rules: “The test results will only be comparable within and particularly between laboratories, if they comply with the standardized framework,” explains Dr Gladbach.

At the start of the test, young bee larvae are transferred from their cells in the combs of the beehive to the experimental test units. “There must be no more than 30 hours between the hatch of the oldest and youngest to minimize the age variation of larvae that go into the test,” says the scientist. The food intake of the bee offspring is also precisely specified and adjusted to the various stages of development. The food is a mixture of royal jelly, yeast extract, glucose and fructose. In the laboratory, scientists make sure the developing brood is fed exactly according to plan, and they keep a close eye on the young insects: “Four days old larvae are given a small amount of the test substance in their food. The dosage also depends on how the adult bees previously tolerated the chemical,” explains Dr Gladbach. In the days that follow, for the acute test, the larvae continue to receive their food without the test substance, and the researchers count how many larvae completed their development with the spiked food.



The bee larvae are kept in an incubator at 35 degrees Celsius (below). At least 36 bee larvae are studied in each trial (above).

The honey bee is the most researched of all bee species. Nevertheless, findings relating to their sensitivity of certain substances cannot always easily be transferred to other bee species such as bumble bees and solitary bees. “We are currently investigating new testing methods to make sure that we are also protecting these important pollinators based on scientifically sound approaches,” says Dr Almanza. “Bumble bees, in particular, are often used as commercial pollinators in greenhouses. It is very important for farmers to know how to avoid harming them.” These species display different nesting and feeding behavior, and even vary in terms of their biology. For example, solitary bees, almost by definition, do not build colonies in the way that honey bees and bumble bees do; instead, one female feeds her entire brood alone.

“We have to take into account the different biologies of bumble bees and wild bees and develop suitable testing methods to ensure the best possible testing conditions for these insects,” says Dr Gladbach.

To achieve these goals, Bayer experts work together both in the lab and in the field, collaborating closely with external experts as part of working groups within the OECD and the International Commission for Plant-Pollinator Relationships (ICPPR). One challenge for new tests is to create suitable conditions. “The laboratory and field environments should be correctly set up to be able to identify substance-related effects in the test,” explains Dr Gladbach. The researchers have already made a start on studying wild bees. They are carrying out initial trials with bumble bees and representative species of solitary bees in laboratory and semi-field tests. The aim is to establish new validated testing methodologies before products can be tested on a standard basis, which takes time, as illustrated by the example of the honey bee larvae test. Bee species are different, so ensuring the safety of crop protection products for bee species in all stages is an important requirement for sustainable agriculture.

CONCLUSION

Certain crop protection products may be of low intrinsic toxicity for adult bees but potentially more harmful for their brood.

Researchers at Bayer are, therefore, testing the products on bee larvae. Bayer is also supporting the development of new study types that look at bumble bees and solitary bees.

The experts at Bayer have to make certain that their products, when used correctly, are safe for bees. This is why they are also carrying out studies on the younger generation of these insects – honey bee larvae.



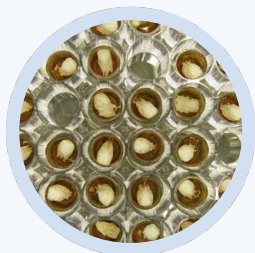
NEW CROP PROTECTION PRODUCT



**FIRST-TIER-TESTING
IN THE LABORATORY**



Bees are fed and brought in contact with the substance **under laboratory conditions**



Effect of the substance on larvae is tested **under simulated hive conditions**

**SECOND-TIER-TESTING
SEMIFIELD TRIAL**



Effect of the substance on bee colonies is tested **under controlled semi-field conditions**

**HIGHER-TIER-TESTING
FIELD TRIAL**



Substance is evaluated **under realistic field conditions**

Tests to keep pollinators healthy

For a crop protection product to receive approval, it must first pass a series of tests. This simplification of the test pathway for new plant protection products (above) shows the different stages of testing involved. The substance can only be declared “not harmful to bees” after having undergone thorough laboratory and frequently also field tests. Products that are found to be intrinsically toxic to bees can only be used under strict conditions – for example, they may not be used on flowering plants.

FIGHTING DUST WITH WATER

Seed treatment products form a layer around seeds, protecting both the seed and the emerging seedling, shielding them from insects and fungal diseases. However, fine particles of these substances can rub off and be released into the environment during sowing. Now, Bayer researchers in Austria have co-developed a new technology to combat this problem: The AirWasher filters dust particles out of exhaust air, reducing dust emission that can harm bees and other beneficial insects.

Systemic seed treatment is an efficient crop protection technology that works by coating seed with an ultra-thin layer of plant protection product. The product keeps pests at bay during germination and then continues to protect the seedling as the treatment is absorbed through its roots. When sowing treated corn, sunflower and other crop seed with certain types of sowing machines, dust particles from the coating may be released into the environment.

Highly-developed technology used for the chemical coating and stringent quality management ensure that the treated seeds are resistant to dust-off. Still, it is impossible to completely prevent the formation of any dust from being released in certain crops, for instance corn. All sowing machines may release some dust into the environment but mechanical and pneumatic pressure ones release significantly less than pneumatic vacuum ones. The use of special dust protection systems is already mandatory in the European Union. Most farmers use ‘deflectors’ – adaptors or pipe connections that redirect the exhaust – so that, instead of being vented upwards, the exhaust air is sent beneath the vehicle and vented towards the soil (see also page 48 “Protecting Hungary’s Bees”).

After the exhaust air is redirected by the deflectors, air-born dust particles can then be trapped with water droplets in the same way that roadwork and demolition sites often prevent dust drifting by dousing heavily with water.

Now this same principle is being applied in agriculture. Bayer experts in Austria have devised a new technology to reduce even further the amount of dust that is released from sowing machine exhaust air.

“We originally used the dust-binding method of road construction works,” says Karl Neubauer, Head of Development at Bayer, Austria.

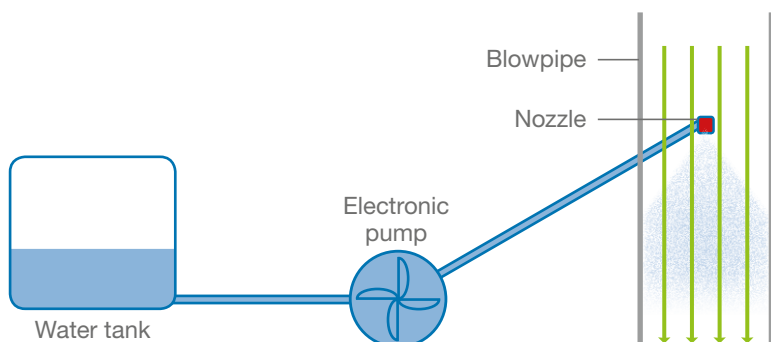
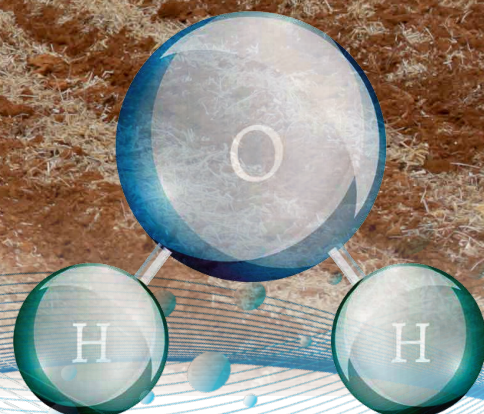
“Water is pumped out from a tank and sprayed. So we adapted this idea for farmers.” Building on existing deflector technology, Neubauer teamed with Dr Reinhard Friessleben and Armin Lind from the Application Technology team at Bayer, Monheim. Working with German agricultural nozzle manufacturer Lechler, the team developed a new, innovative technology: the AirWasher – a kit that can easily be fitted as an upgrade to deflectors currently in use on all conventional planters. “Deflectors already greatly reduce environmental dust emission, but the AirWasher removes considerably more dust from the air,” explains Neubauer. The AirWasher works by spraying the exhaust air from the planter with a fine mist of water. The water droplets mix with the dust particles and drain into the field.





AT A GLANCE

- // When pesticide-treated seeds are sown, dust may be released into the environment. This could cause potential risks for pollinating insects such as bees.
- // Using water droplets, the AirWasher takes out 97 percent of chemical dust particles from the outlet air of planters.
- // The AirWasher can easily be retrofitted to existing deflectors and uses very little water.



Sprinkler system on the field

During sowing, exhaust air is blown out from the machine. The principle of the AirWasher is to filter out potential fine dust particles from this exhaust air. To do this, water is pumped from a reservoir tank through a nozzle, and sprayed into the exhaust air in the blowpipe. Fine dust particles in the outlet air bind to the water droplets as they come into contact with them. Due to this process of trapping them, the water-bound dust particles are removed from the air which is exhausted to the environment. Instead, the particles drip down to the soil.

The Julius Kühn Institute (JKI) in Germany has been carrying out tests in comparison to a reference machine to determine how much dust can be emitted in a worst-case scenario when planting treated seeds. Their results show an enormous improvement in such a scenario by using the AirWasher: “In comparison to conventional planters with no dust protection devices, this new technology reduces dust emissions by up to 97 percent,” says Neubauer. Retrofitting existing deflectors with an AirWasher is both cost-effective and simple. And to further ensure that implementing this technology is economically worthwhile, the developers have also made the device particularly efficient in water consumption: Only around 15 liters of water would be required for a field of one hectare. This means farmers would only need to fill the AirWasher once a day.



Easy to add on: Conventional planters with deflectors can also be upgraded with the AirWasher technology. The kit (small photo above), which includes a tube and an electrical pump, is user-friendly and economical.

CONCLUSION

The AirWasher technology is compatible with most seed treatment products, including neonicotinoids, some of which have been restricted in certain crops in the European Union.

Technologies like the AirWasher can make the application of plant protection products even safer as it ensures that chemical substances remain only where they are needed. Thus, potential exposure of the environment to plant protection products can be greatly reduced.

INTERVIEW

Protecting Plants and Bees

What is the significance of the AirWasher technology?

Farmers need plant protection products to ensure good harvests and a secure income. With deflectors, and now the AirWasher, we have developed a way of providing outstanding plant protection while minimizing the exposure of bees.

Why is it particularly important to reduce the risk of dust emission during the planting process?

Farmers mostly sow their seeds between mid-April and early May – a time when many early blossoming plants are growing and bees are active. This is a time of year when it is particularly important to keep dust emission to a minimum. The AirWasher can make an important contribution to this effort.



Karl Neubauer is Head of Development at Bayer in Austria. He is involved in the development and safety assurance of products and was part of the team behind the AirWasher technology from its inception.



PORTRAIT MARION ZAWORRA

ON THE HUNT FOR ENZYMES

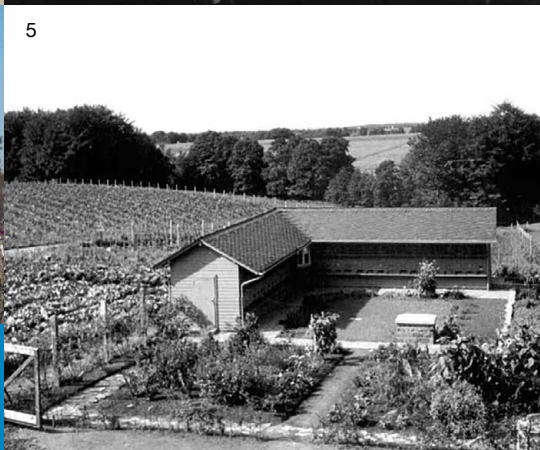
Marion Zaworra is a PhD candidate studying the detoxification mechanisms of honey bees. Equipped with a Master of Science in Biology, Marion Zaworra is now pursuing a Doctoral degree with an Applied Research component at Bayer. This goal-oriented research assistant is investigating how honey bees break down pesticides using specific enzymes.

“I am very connected to the applied part of my research here at Bayer. Our discoveries are unique and may be instrumental to further improve the safety of pesticides to bees.”

Marion Zaworra’s main research focus is on complex protein molecules in honey bees known as metabolic enzymes. These particular enzymes are crucial to the process of breaking down a number of chemicals that bees are exposed to, including crop protection products. Armed with these enzymes, honey bees are able to detoxify some crop protection products they may come into contact with; however, others remain toxic and may lead to the death of bees, if they are exposed at a high enough concentration. At the Bayer Pest Control laboratories in Monheim, Marion Zaworra characterizes and analyzes which enzymes are particularly involved in the metabolism of crop protection products. She intends to establish how honey bees break down certain molecules, what kind of intermediate products – so-called metabolites – emerge throughout this process, and how these chemicals affect honey bees. Zaworra’s work is part of a larger research study, “Bee Toxicogenomics,” under the direction of Dr Ralf Nauen from Bayer (see also page 15 “In pursuit of the key enzymes”). In a joint effort with her team colleagues, Dr Cristina Manjon and Bettina Lueke, Zaworra aspires to learn more about how the honey bee body functions so that, consequently, crop protection products can be made even safer for them.

Since 2014, Marion Zaworra has been conducting research in the Department of Pest Control at Bayer as a PhD candidate from the University of Bonn in Germany. Insects have always fascinated the young scientist. At Bayer she is now investigating the effect of crop protection products on bees. Her daily research routine is very diverse: It includes growing insect cell cultures, creating tests for enzymes and bioassays and working on newly-evolving research questions. To merely ‘observe’ is not an option for Zaworra. She goes above and beyond in dedication to the field and is fully committed to making a difference. Even on weekends, she remains completely engaged with her research subject: “Not everyone understands my passion for research; however, my goal is to learn and participate as much as possible,” says the 26-year old. In the Monheim laboratory, she has the resources to conduct the elaborate technical experiments she has long wished to do.

Zaworra enjoys working with her research team. “I am proud to be part of such an important project and truly contribute to the current dialog in the honey bee research community,” the young scientist states. She also greatly appreciates the tangible team spirit and the remarkable support of Dr Ralf Nauen, her advisor. While doing research work at Bayer she also has to attend courses at university to receive her PhD in Agricultural Science under the supervision and generous guidance of Professor Dr Florian Gundler in the Department of Plant Biology and Resource Management. “To explore the unknown and push forward development: These are the reasons I have always wanted to become a scientist,” the doctoral student says. And alongside her drive for research, Zaworra has developed a fondness for bees: “I find everything about them fascinating: how they build and organize their colonies and how they actually live. We can learn so much from insects,” she says. That’s why she has learned about beekeeping and knows how to properly care for them. “Next year, I would like to set up a beehive at home and harvest my own honey,” the entomologist explains. Only when her inquiring mind is momentarily satisfied does Zaworra devote time to other things she enjoys in life, including horse riding, spending time with friends and traveling.



AT A GLANCE

- // The Höfchen estate is Bayer's longest-standing crop field trial station.
- // Researchers at the experimental station test new crop protection products for their safety to honey bees and their colonies.
- // Semi-field trials under insect-proof netting tunnels apply a realistic worst-case scenario to investigate the effects of new products on honey bees.
- // Researchers investigate acute toxicity and possible long-term effects.

HÖFCHEN ESTATE FIELD TRIAL STATION:
ENSURING CROP PROTECTION PRODUCTS DO NOT AFFECT BEES

PUTTING PRODUCT SAFETY TO THE TEST

Crops provide food, which is why farmers need to protect their harvests against destructive pests, weeds and diseases by using effective crop protection products. Equally, healthy pollinators such as honey bees and bumble bees are important for ensuring abundant harvests. Therefore, crop protection products must work alongside pollinators in a way that does not harm them. Bayer uses the Höfchen field trial station to perform semi-field tests as part of the pollinator safety test process.

It is spring and the sound of buzzing fills the giant white tents standing in the blossoming apple orchard. Thousands of honey bees are whizzing around in them on the search for pollen and nectar. The insects land on trees that have been treated with a new product to protect against fungal infection. Later, researchers observe and analyze whether the fungicide application has impacted the pollinators in any way.

Bee safety is one of the most important criteria crop protection products must fulfil if they are to be approved for the market.

Bayer uses the Höfchen estate field trial station near Burscheid, Germany, to conduct many of these tests on its herbicides, fungicides and insecticides. “We have over 60 years of experience in testing whether crop protection products are safe for beneficial insects such as honey bees,” says Dr Dirk Ebbinghaus, trial station manager at Bayer’s division Crop Science. His 17-strong team conducts semi-field studies to investigate if pesticides affect honey bees and their colonies. This involves applying the product to about 50 square metres of flowering plants, covering everything with a white tunnel tent and positioning a hive containing up to 3,000 honey bees inside. The tent prevents the insects from escaping to look for food outside the test area. This set-up allows the researchers to simulate a worst-case scenario. The bees spend up to twelve days collecting nectar and pollen from the treated plants only, which means they gather the largest amount of the substance that is realistically possible. “We measure the worker bees’ mortality to determine the acute toxicity,” explains Dr Ebbinghaus. “Worker honey bees usually live for up to six weeks. If the bees die after just a few days or hours, the product is not fit for further use in flowering crops that are visited by bees.” Another crucial factor for Dr Ebbinghaus’ team is whether the bee brood hatches unharmed after the experiment as these young bees will be needed to keep a strong colony going.

- 1 | Spring check: Agricultural experts Dr Dirk Ebbinghaus, Head of Höfchen Trial Station (right) and Lars Harnischmacher (left) examine young pear tree blossoms for pests.
- 2 | Honey bee health has been a priority for Bayer for more than 60 years now.
- 3 | Beekeeper Volkmar Krieg examines a beehive comb to look for effects of new products on honey bees.
- 4 | The field trial station stretches for a hundred hectares. The white tents are used for pollinator tests during the blooming season.
- 5 | The Höfchen’s apiary was established in 1941.
- 6 | Functional aid: The Bayer employees use spraying technologies that are height-adjustable to apply crop protection products on fruit trees.
- 7 | Originally, the honey bees at Höfchen were there to help pollinate fruit crops but for over 60 years they are also needed for the testing of crop protection products.



In a field of flowering Phacelia, new products are tested. The honey bee colonies in the tents collect food from treated flowers.



In addition to the effects that are immediately visible, the experts also evaluate a potential long-term impact in other study types. “If fewer bees in the test hive survive the winter than in reference colonies, the substance may be weakening the bees,” says Dr Ebbinghaus. The team puts the substances through at least three randomized replicates in every trial. Afterwards, the results are passed on to the environmental experts at headquarters who analyze the data. These experts also developed the bee larval test (see also “*Protecting bees for generations to come*”, page 50). These intensive tests, though lengthy, are necessary to ensure there is no compromise on safety. It can take up to ten years for a product to pass from the first laboratory investigations through to the market launch. “It’s also not uncommon for us to re-test approved products to verify their pollinator safety profile when new questions on their environmental profile have been brought up by the environmental authorities,” says Dr Ebbinghaus. His team is also involved in the development of similar tests for bumble bees in close collaboration with colleagues from Bayer’s Ecotoxicology Department.

Bayer has been running its experimental station since 1940, and the first apiary was built in the following year. These days, the station is used for more than just testing the safety of crop protection products – it also puts new technologies for the safe application of the products through their paces. For instance, the experts have investigated Dropleg systems, which allow farmers to spray products onto oilseed rape plants from underneath, further minimizing the exposure of pollinators (see “*Lower Application for Higher Protection*”, *BEENOW 2015*). “Almost every farming-related product or new technology from Bayer gets thoroughly tested here,” says Dr Ebbinghaus. And that helps farmers and bees alike.

CONCLUSION

Bayer is continually striving to make crop protection products even safer for pollinators. Bees have long been of interest at the field station, from the time when honey bees were only used to help pollinate fruit crops, through to today when testing of crop protection products and new technologies for the safe application of those products are put through their paces.

MAINTAINING SAFETY IN THE APPLICATION OF CROP PROTECTION PRODUCTS

FIGHTING DRAGONS, SAVING CITRUS

Scientists are facing a real-life challenge: how do you stop a particularly aggressive pest from spreading and destroying citrus plantations around the world, on the one hand not harming honey bees which may be foraging in the citrus trees while on the other hand ensuring the necessary treatment? An innovative area of study may address the problem by keeping bees away from the crop, allowing application whenever needed.



60 million

“Citrus Greening Disease is estimated to have killed over 60 million trees worldwide (10 million in Brazil alone), causing crop losses of up to 100 percent in countries such as South Africa.”

Source: FAO <http://www.fao.org/americas/perspectivas/hlb/en/>

Asian Citrus Psyllid (ACP)



Netting is traditionally used to keep bees away from citrus trees during the blooming period.



At the feeder station, a research team member takes photographs as part of the monitoring process during the study.

In the last decade, the Yellow Dragon Disease, also known as Huanglongbing (HLB) or Citrus Greening Disease, has severely damaged the world's citrus production. This bacterial disease, spread by an insect called the Asian Citrus Psyllid (ACP), has migrated from China into major citrus-growing regions around the world such as Florida, California and parts of Brazil. Once a citrus tree, such as lemon, orange or grapefruit, is infected with HLB, it will die. Currently, there is no cure, and the only prevention is to control the psyllid. Bayer has developed crop protection products to directly manage this insect so as to minimize the spread of HLB. The great challenge: For effective disease control there must be complete psyllid vector control, so application is needed at times honey bees may be present in the crop.

Ordinarily, registered crop protection products can be used safely without harming bees. In cases such as with the management of ACP, there are extremely few products available and some of them are intrinsically toxic for bees. Normally, they cannot be applied during flowering. However, due to the long flowering period of many citrus crops, if an infestation of the psyllid occurs, there is no option to wait until flowering is over. As a result, what is needed is a solution which allows for the application of intrinsically toxic products during flowering – without harming bees.

Bayer's North America Bee Care Center, the Chemistry Department in Research Triangle Park, North Carolina, and the Bayer Pest Control Department in Monheim have teamed up to lead a pioneering study on how to keep honey bees away from the plantation, when ACP must be managed in order to combat the spread of Yellow Dragon Disease. Dick Rogers and Tai-Teh Wu are the lead scientists behind this study alongside a dedicated

research team who prepare and conduct many repetitions of exploratory and proof-of-concept experiments. Since late 2012, the testing has consisted of feeder station trials, microplot and semi-field trials and laboratory trials, to test numerous substances that might emit scent that keeps bees away – so-called repellents.

They also analyze methods of repellent delivery and measure potential effects on bees, both from a health and behavioral perspective.

The study theorizes that by 'herding' bees – guiding them away from specific locations using repellent substances – crop protection products can be applied while giving the greatest protection to local honey bee populations.

As citrus crops are usually not dependent on insect pollination, repelling bees does not influence fruit set. The first tests have already proved successful: "In one semi-field trial, 100 percent of honey bees were safely repelled for several hours, and there was reduced repellency for up to 24 hours," says Wu.



Researchers observe bee reactions when drops of potential repellent substances are applied to feeder stations.

Safety, efficiency, and practicality of any solution have been priorities from the study's start. The research team began with a number of specific qualities they wanted for a bee repellent. According to Rogers: "The repellent needed to be safe for humans, animals and plants; easy to apply; provide a high level of short-term efficacy; be cost-effective; and it should be something that could be used in small quantities." The study has already yielded valuable information. Rogers and Wu can state that the goal in agricultural systems should be using a targeted application of repellents. Field testing has shown that honey bees are more safely and effectively kept away from areas of potential exposure when repellents are targeted to more defined areas rather than widely sprayed over a field, for example.

Rogers and Wu have successfully identified a specific compound that might be used to repel honey bees. Therefore, it may play a significant role in deterring bees from visiting citrus during ACP crop protection treatment. The research team is convinced that repellents are an innovation that warrants further investigation and experimentation. Continuing this valuable research could lead to even greater precision in pest management and offer new possibilities to protect citrus and other crops.



Team leaders from Bayer Bee Health & Integrative Apiculture Research: Dick Rogers (above) and Tai-Teh Wu (below).

CONCLUSION

Rogers and Wu hope to expand the current bee repellent study to full project status. In addition to its application in citrus production, this process-product repellent method may be useful in other large-scaled field crops such as cotton, making application of crop protection products even safer for bees. With this study's promising leads, there may be a meaningful way to combat the rise of Yellow Dragon Disease – while minimizing potential risks for honey bees.

OUTLOOK

Dear reader,

Thank you very much for your interest and for taking the time to read our latest BEENOW magazine.

Following the very positive feedback received on our 2015 issue, we are proud to present our latest edition, bringing to life some of the new projects and partnerships related to our Bee Care Program.

In working together with partners from research institutes and universities, beekeepers and industry around the world, we aim to make a difference to the health of bees and other pollinators.

Bee health is impacted by a combination of stressors including pests, diseases, weather and nutrition, the effect of which differs greatly from region to region, depending on local agricultural, apicultural, geographical, meteorological and environmental factors. As such, input from local specialists whose expert knowledge will enable a more targeted approach is key to finding locally tailored solutions. Whether through crop attractiveness studies to understand which pollinators are present, new technologies to further reduce potential risks of agricultural practices or new scientific methods which enable scientists to study bee behavior, genetics or metabolism pathways – each one has a role to play in advancing our knowledge for the benefit of pollinator health.

We would hereby like to thank all our project partners – both internal and external – for their engagement and willingness to collaborate and for their contributions and support for this magazine. We look forward to continuing our current project partnerships and to starting new ones, to jointly develop solutions to further improve pollinator health around the world.



A handwritten signature in black ink, reading 'C. van Breukelen-Groeneveld'.

Coralie van Breukelen-Groeneveld
Head of Bayer Bee Care Center

If you would like to know more about our activities or other projects, would like to share feedback on this magazine, or have a great idea for a collaboration opportunity in your part of the world, we would love to hear from you.

Throughout 2016, we will be sharing information with you online about new projects and provide updates and results from currently running ones. As a life science company, our commitment to bee health via our collaborative efforts continues, be it to even further reduce potential risks from our products, “Feed a Bee” or to promote healthy hives.

So please visit www.beecare.bayer.com to follow our work and contact us to share your ideas!

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Pollinators need us
to join forces and,
together, use our
resources.

BEE PART.





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