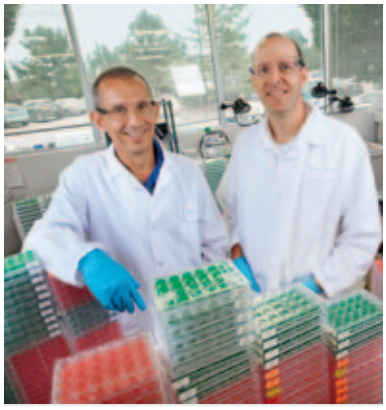
Robust wonder bean

Soy is one of the world's leading staple crops, but nematodes frequently destroy high percentages of the soybean crop. To avoid this, Bayer CropScience researchers are developing a seed that sprouts nematode-resistant soybean plants.

Our story begins in Iowa, USA, where real dramas are played out in the soil under the soybean fields. Thin, transparent nematodes attack the roots of the leguminous plants by the thousands, devouring the roots and causing devastating damage. These tiny creatures can destroy up to 30 percent of a soybean crop, and thus a critical building block in the global food supply, because the "wonder bean" or "Cinderella crop," as the small, beige legume is also dubbed, is indispensable to the food supply in many regions of the world. Soy is rich in protein, low in cholesterol and contains valuable oils. For this reason, it is more than just a tofu dish on the menu of vegetarians: soy is found in chocolate bars, muesli, margarine and bread, and is also a common, nutritious animal feed.



Pest specialists: Alain Sailland and Brian Vande Berg (left to right), scientists at Bayer CropScience in Research Triangle Park, North Carolina, USA test in the laboratory which naturally produced toxins provide in vitro resistance to pests.

Soybean may be in great demand worldwide for both humans and livestock, but the oilseed is also a favorite of the soybean cyst nematode (SCN), a pest that infects the roots of the soybean plants, forming cysts and multiplying very rapidly. Farmers in the USA alone lose crops worth up to US$ 1.5 billion each year as a result. "Compared to other soybean pests and diseases, nematodes cause by far the most damage, and they turn up virtually everywhere the crop is grown," says Alain Sailland of Bayer CropScience in Research Triangle Park, North Carolina, USA.

3.5 million tons of soybeans could be protected every year in the USA with nematode-resistant plants.

Nematodes are true survival artists. Their eggs can survive underground for years, and some species can even withstand a few hours at minus 270 degrees Celsius. Bayer's scientists have already developed a system that provides seeds with a biological protective coating (see "Bioprotection against nutrient robbers," *research* 23). Now Sailland is working with an entire team of Bayer researchers on a new seed for the soybean plants of the future. They are designed to be not only nutritious, but also resistant to soybean cyst nematodes. "Our tests in greenhouses and in the field have shown that the new soybean plants are resistant to the soybean cyst nematodes," Sailland explains. To finally tame this stubborn pest, the team of researchers from Bayer CropScience used genetic engineering: they incorporated DNA from the bacterium Bacillus thuringiensis (Bt) into the DNA of the soybean plants. This gene segment contains the blueprint for a protein that is one of the "Bt toxins."

Nematodes are real survival artists: their eggs can persist in soil for years

The effect is overwhelming. Presumably it begins in the pest's digestive system. "Bt toxins are usually not harmful to other plants and animals," Sailland explains. They are even used in organic farming as insecticides.

"Finding the right bacterial genes was like looking for the proverbial needle in the haystack," Sailland remembers. The researchers combed through a library of microbes with over 85,000 strains of bacteria. They put nematodes in direct contact with the different strains to select nematicidal strains, or selected promising new target genes based on DNA analysis, and then tested the effects of the new toxins on SCN in trials. "We were able to see quickly which microorganisms produce nematode-effective toxins, but finding which toxin affects SCN was

Coveted meal: not only nematodes but also green stink bugs infest soy plants in large swarms. When threatened, they excrete an odorous pheromone.

Photos: Peter Ginter/Bayer AG (5), American Soybean Association (1)

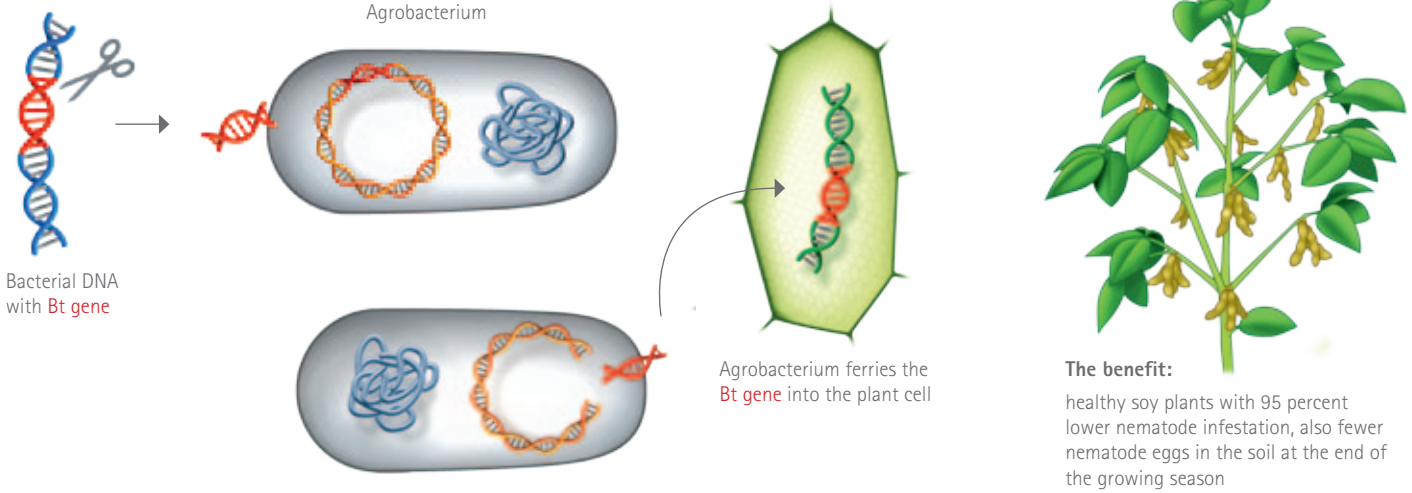
Damage surveyors: while Yiqing Xu (photo, above) selects promising new, genetically modified cells in the cell biology lab and grows them into seedlings, Brian Vande Berg and Alain Sailland (photo right, left to right) examine corn plants from greenhouse tests whose roots are infested with corn rootworms.

very work-intensive," the Bayer CropScience researcher reports. The scientists isolated the coding sequence from DNA material of these bacteria and used another bacterial species – agrobacteria – to carry it into the soybean plants. The plant tissue and agrobacteria need only mix for a few hours to obtain an effect. In the next step, the modified soybean cells were grown into young plants, planted in greenhouses and multiplied.

The greenhouse and field tests – for example with over 1,300 plants in Iowa – were a success. "Nematode infestation in the genetically modified plants was up to 95 percent lower," Sailland says. The researchers even achieved another positive effect: at the end of the growing season, significantly fewer nematode eggs were found on those sections of the field where the new soybean plants were growing. "In other words, the risk of infection the following year drops considerably," Sailland points out. That is a decisive advantage because infected soil was untreatable until now.

A gene to protect against hungry foes

To effectively protect new soybean plants against nematode infestation, Bayer CropScience scientists identified a bacterial gene, a specific Bt gene that is harmful to nematodes but leaves other organisms unscathed. Using biotechnology methods, they succeeded in incorporating the Bt gene into the DNA of soybean plants. They did this by using a soil bacterium as a "gene ferry": it picks up the Bt gene and transports it into the plant cell. The effect of the new gene was clearly visible in tests: the level of nematode infestation was up to 95 percent lower and significantly fewer nematode eggs were found in the soil as well.



The next generation with great prospects: Bayer's scientists still have to carry out numerous tests to determine which soybean seedling is ultimately the most promising and capable of being developed into a marketable product.

The genetically modified plants are now advancing to the development stage. "We will be conducting various tests to identify the soybean plant with the best characteristics," Sailland says. He also has his sights set on other bacterial genes which have already delivered promising results in tests. Furthermore, Sailland's team wants to find out if the new soybean is also resistant to other nematode species, because the soybean cyst nematode may be the most common species, but it is not the only one. The researchers must also prove that the genetically modified soybean plants are not harmful to mammals or other plants and organisms. But Sailland has virtually no reservations in this regard. "We've already had good experience with similarly genetically modified cotton plants that are resistant to caterpillars, and we didn't find any unwanted harmful effects," he says. In about ten years, following regulatory and market approvals, the new soybean seed would then be introduced to the market. Genetically modified corn which is resistant to the Western corn rootworm has already completed this process. It likewise incorporates a gene from active strains of Bacillus thuringiensis.

Corn harvests could also be protected by new, modified plant varieties in future

"This corn has been on the market for about ten years," explains Brian Vande Berg, a biotechnologist at Bayer CropScience. However, in the fight against the root-devouring pest, which still causes crop losses in excess of US$ 1 billion in the USA, scientists must now prime their weapons. "The corn rootworm seems to have developed some resistance to one of the Bt toxins over the last two to three years," Vande Berg reports. Bayer's researchers are therefore working at full speed to find new genetic material that can help control this corn destroyer, and they have already found the first promising candidates. "These newly discovered genes have a different protein sequence than the usual Bt genes, and presumably therefore also a different mode of action," Vande Berg explains. He is optimistic that the new, modified corn can fend off the rootworms. The first greenhouse and field tests have already shown successful results. The researchers now want to move into the development stage as fast as possible. If they are successful, both soybean and corn harvests could be protected worldwide.

DANNY MURPHY

"Our most valuable agricultural export"

Danny Murphy is President of the American Soybean Association. research *spoke with him about the economic significance of soybeans and future trends.*

What role does soy play for the economy of the United States?

Soybeans play a huge part in both the American and global economies. Soybeans are the second-largest crop produced in the United States, and the country's most valuable agricultural export. In 2012, American farmers produced more than 3 billion bushels (80 million tons) of soybeans with a total value of US$ 43 billion.

What trend do you see?

Both production and yield of soybeans in the United States are on an upward trend. The real upward trend for the industry is in the value of the U.S. soybean crop overall. American soybean farmers have had record crop values in each of the last seven years, and the 2012 crop outperformed the previous year by almost US$ 5 billion.

What impact do transgenic plants have?

Biotechnology plays a vital role for soybean farmers, allowing us to produce more on the same amount of land, while at the same time using far fewer resources and inputs. In 2012, 72.6 million acres – or 94 percent of the U.S. soybean crop – was enhanced with biotechnology.

www.research.bayer.com/soy
Further information on this topic