An insecticide that also protects plants against stress

A health farm for plants

Farmers have long used the chemical imidacloprid to keep insect pests under control. Scientists working for Bayer CropScience have now discovered that the insecticide also seems to improve plants' resistance to drought, heat and other environmental factors: an ideal basis for widening its use.

Stress-free: Bayer scientists investigate how crops can cope better with heat, drought and flooding (left). Anke Kuhlmann measures the length and branching of the roots – indicators for good development (above right).

Stress drains energy and impairs performance. Productivity declines noticeably under stressful conditions. That has long been known. What is less well known is that extreme strain causes problems not only for people. Stress also eats away at the strength of plants, because they have to expend energy to prevent or repair stress damage. "Stressed plants produce fewer leaves, flowers and fruit," says Dr. Wolfgang Thielert, a crop protection scientist working in Bayer CropScience's research department, as he lists the consequences. This leads to significant yield losses in arable farming. Reason enough for Dr. Thielert and his colleagues to take action against stress in the plant kingdom.

They are dealing with two kinds of plant stress. Biologists describe the harmful effects of pests, competing plants and micro-organisms as "biotic" stress. But plants are not just affected by pests and diseases; they can also suffer as a result of "abiotic" stress factors such as drought, heat, extremely wet conditions and sudden cold snaps.

Crop protection experts have a long history of success in combating biotic stress factors. Farmers growing arable crops, fruits and grapes for wine production all around the world have access to a wide spectrum of crop protection products to help them cope with insects, fungi and weeds. One of these products is imidacloprid, which has been on the market for 15 years. It is the active ingredient in Gaucho®, Trimax® and around 80 other insecticides approved in over 120 countries. A total of 140 different crops can be protected against pests by imidacloprid.

Chance discovery: imidacloprid protects against heat damage

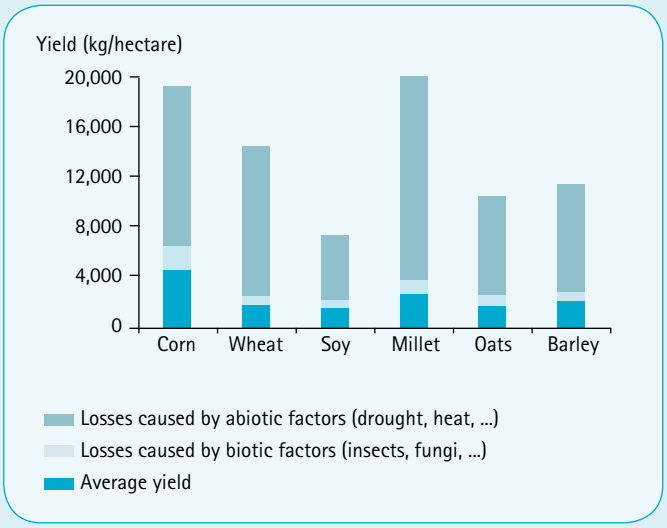
It seems that this is not the only string to its bow, however. In field trials, Bayer CropScience investigators made the astonishing discovery that crops treated with imidacloprid coped much better with drought and heat stress than untreated plants. This discovery was partly due to chance, as the actual purpose of the trials was to find out how unprotected and protected plants grew when exposed to insect infestation. "Sometimes pests do not reproduce as we expect," explains Dr. Thielert, an agricultural engineer by training. Under these circumstances both treated and untreated plants should theoretically grow at the same rate.

But this is not what happened: the plants treated with imidacloprid grew much better, especially if they were subject to drought and heat stress. For example, cotton plants in the USA growing in drought conditions produced significantly more leaves, flowered earlier, and produced ten percent more cotton on a three-year average when they were treated with Trimax®.

Multiannual field trials in the United States and Greece confirmed a further suspicion: Confidor® improves the resistance of tobacco plants to the fungus that causes the dreaded leafspot disease. "Overall we were able

Drought: lack of water and heat are two of the main stress factors that cause harvests to fail (left). Stress causes the plants to lower their rate of photosynthesis – measurable with a PAM (pulse amplitude modulation) fluorometer – which reduces their ability to supply themselves with energy and carbohydrates (above).
Water bed: Dr. Wolfgang Thielert examines the root lengths of tobacco plants in what is termed a floating box – a plastic frame which floats in a nutrient solution (right).

Stress causes dramatic harvest losses



Cereals appear to suffer in particular from abiotic stress caused by heat, cold, drought or oxygen deficiency due to water stagnation or compacted soil. Potentially record harvests (total beam length) are compromised on the one hand by insect pests, plant diseases and competition from wild herbs. Abiotic factors are however responsible for the majority of harvest losses.

to demonstrate that imidacloprid improves shoot and root growth in young plants, enhances plant health following transplant into the field, and leads to significantly higher yields," says Dr. Thielert in summary of the results of the field trials. The scientists concluded that imidacloprid appears to have a beneficial "side effect"; their observations suggested that the chemical could be further developed to afford protection against abiotic stress.

Strengthened resistance against harmful fungi

"Although abiotic stress factors cause significant yield losses to farmers, little attention has so far been paid to the development of 'stress shields' of this kind," explains Dr. Thielert. One more reason for Bayer CropScience to conduct systematic research to confirm this unexpected anti-stress effect. Dr. Thielert undertook this research along with seven other institutes and universities of international renown: "Each institute took a different approach."

All were successful. At the Jülich research center in Germany, for example, a team of scientists started by

developing a test matrix based on barley, where reproducible drought stress can be measured by leaf area growth. Bayer CropScience staff in Frankfurt then examined these plants and compared the genetic activity of imidacloprid-treated barley with untreated barley. Several effects were observed.

Firstly, imidacloprid was found to delay the activity of the drought stress marker gene. Another observation of genetic analysis was that imidacloprid has a positive impact on the efficiency of photosynthesis, and thereby on the plant's energy production. The latter finding was confirmed by Plant Research International, a Dutch institute based in Wageningen, which conducted chlorophyll fluorescence measurements using a new type of laser light camera. Chlorophyll fluorescence, a marker for low photosynthesis, was markedly reduced in cotton plants grown from seed dressed with Gaucho®. Thirdly, additional genetic tests have shown that imidacloprid appears to stimulate plants' own defense mechanisms against fungal disease.

Work carried out at Bayer CropScience in Monheim and Bayer BioScience in Ghent also showed that imidacloprid reduces stress caused by lack of oxygen. "Crops grown in stagnant water or compacted soil get less oxygen to the roots, and this restricts their growth," explains Dr. Thielert. Young tomato plants treated with imidacloprid, however, were less affected by oxygen deficits caused by waterlogged soil: they developed strong roots despite this stress.

Protection shield against stress ensures yields in the long term

The key to how imidacloprid combats stress probably lies in one of its decomposition products: the intermediate metabolic product 6-chloronicotinic acid (6-CNA) is produced when imidacloprid has been taken up by the plant. This substance is known to stimulate the plant's own defense systems that protect it against disease. Bayer CropScience investigators suspect that 6-CNA also triggers the physiological changes that eventually increase the plant's abiotic stress tolerance.

Bayer CropScience's chemists now face the task of tweaking the chemical and its administration form (formulation) so as to produce the ideal stress shield for use in practice. This would allow Bayer CropScience to make a major contribution to securing crop yields in the longer term.

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The imidacloprid project is presented in the 2006 Science Forum (News Room; Events & Presentations).