

Vaccination for plants

Dialogue instead of a chemical maze – new strategy for sustainable crop protection

Climate change creates stress. This provides an opportunity for pests to exploit plant weaknesses and reproduce. For the infested plant, this can be catastrophic and often fatal. But instead of continuing to protect harvest yields with toxic substances as before, the transnational DialogProTec project is now taking a completely new approach: researchers want to intervene in the communication between plants and pests to keep them healthy. Among other things, they are developing a 'vaccination for plants' to preventively strengthen the plants' immune system.

Our native plants – like all other living organisms on earth – are suffering from increasing temperatures and drought, especially in the summer. Unlike animals, plants cannot run away from climate stress. Weakened, they find it difficult to assert themselves against pathogens and invading competitors.

So far, agriculture's only possible response to this has been to use fungicides or herbicides. This is not good for humans or the environment, as many substances are toxic, accumulate in the soil and promote resistance. Worldwide, losses due to weeds – i.e. competing plants – are estimated at 12 percent, and rise to as much as 20 percent for plant diseases. The trend is for these figures to increase, because as the climate changes, pathogens and plants that are not yet native to certain countries will invade areas where they were previously unknown.¹⁾

Huge damage caused by esca and other fungal diseases

Alternatives to poisons are therefore urgently sought. This is the goal of the Interreg Upper Rhine-funded interdisciplinary 'DialogProTec' project, which was launched in 2019 with five research institutions coordinated by the Karlsruhe Institute of Technology (KIT).

The experts are focusing on grapevines, which are suffering from new climate-related diseases, especially wood-destroying pests such as fungi, which cause esca syndrome, for example. "Vines still grow very well in our region," explains Prof. Dr. Peter Nick, project coordinator and head of the work at KIT. "But in two or three decades' time, it is quite conceivable that England, Norway or Iceland will dominate viticulture, while vintners in Alsace will be organising camel safaris for tourists in the Upper Rhine desert. In 2018 alone, when the summer was particularly hot and dry, fungal diseases such as esca caused huge losses of around a billion euros in Alsace. Already, there is no new planting in the Kaiserstuhl region without artificial irrigation. Even if climate change doesn't continue, we have to contend with this new reality and do something about it."

Climate stress, not pathogens, is to blame



Prof. Dr. Peter Nick is head of Molecular Cell Biology at KIT and project coordinator of DialogProTec.
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Esca (Latin 'bait') is caused by wood-decomposing fungi and is considered one of the most dangerous grape diseases. "Esca and similar fungal diseases have been known for a very long time, but are a new problem for us because they have become more common in the past twenty years," says Nick. "Normally, such fungi live as harmless commensals of cell residues in the healthy wood of the vines. But if they perceive that their host is weakened by drought and heat stress, they abruptly change their behaviour. They produce toxins to kill their host, using energy to form spores and thus seek a new home. The vine collapses, and within a week the entire vine is dead."

"Rats leaving the sinking ship," is how the professor describes the process. "So the disease results from impaired communication between the plant and the fungus. How the fungus behaves depends on the condition of the host plant. The fungus and the plant engage in a kind of chemical wrestling match, in which the vine tries to produce defensive substances that kill the fungus. The latter, in turn, tries to manipulate the plant so that it produces as many wood components as possible – the fungus' favourite food."

Communication is disrupted

This is the basis of the idea behind DialogProTec: the researchers were seeking to elucidate the signals of this mode of communication and find a way to be able to restore the balance of chemical communication even under climate stress. To this end, they developed a microfluidic bioreactor consisting of two chambers. Plant test cells were cultivated in the first chamber. The chamber was part of a microfluidic flow via a membrane that is permeable to nutrients and molecular signals (but not to the cells themselves). In another, upstream chamber, cells can be cultured that may release signals into the microfluidic flow. In this way, cells can communicate with each other chemically, without having to come into physical contact – and this includes the cells of fungus and grapevine.

This approach was successful: sought-after substances were identified once the researchers were able to show by means of the microfluidic chip that the fungus emitted chemical signals that decided between disease and health. After separation via preparative HPLC (high-performance liquid chromatography), the researchers tested which fractions had an effect on fungal and plant cells. Under climate stress, ferulic acid is produced in the plant, which triggers the formation of fusicoccin A in the fungus, a signal that in turn triggers a suicide programme in the plant. If the fungus perceives the defence substance resveratrol (a stilbene derivative) instead of ferulic acid, it takes this as a sign that its host is healthy, and instead forms 4-hydroxyphenylacetic acid, thereby mimicking a plant growth hormone (auxin).



If plants are weakened by climate stress, colonizing fungi such as esca-associated fungi begin to use a sophisticated strategy to ensure their continued existence – at the expense of the plant.

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New cultivars and vaccination to stop fungi

Extremely positive results! But unfortunately these alone cannot save any of the vines. Therefore, based on the findings, the researchers devised two options: a long-term and a short-term strategy. "Our long-term strategy is to breed vines that are resistant to esca, so-called Kliwi vines," says Nick. "Unfortunately, that takes more than just a few years to work. However, we have a source of resistance in the KIT Botanical Garden with the entire gene pool of the European wild grapevine. This is also fully sequenced, so that we can screen the gene sequences for heat, drought or UV tolerance criteria and then cross these genes into cultivated vines."

A short-term strategy and alternative to breeding is currently being developed in the follow-up project M4F (Microbes for Future). The idea here is to stimulate grapevines to produce more stilbenes, thereby avoiding the fatal ferulic acid signal even under climate stress. "We want to achieve this by giving the plants a supportive, immune-boosting microbiome – something like our gut flora – in the root zone. We already have candidates for this that significantly improve the plants' resistance. Our long-term goal would be to be able to dope the immune system more permanently with benign microorganisms, for example in the form of agar capsules. In other words, to have a kind of 'vaccination' with plant fortifiers to hand."



The disrupted communication between the fungus and the plant drives the vine to its death – and very quickly there is little left of it.

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Info box: Project DialogProTec

Title: Chemical dialogue as a protective technology in sustainable crop protection

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Partners: Botanical Institute of the Karlsruhe Institute of Technology KIT (project sponsor), Institute of Pharmaceutical Sciences of the University of Freiburg, Institut de Biologie Moléculaire des Plantes of the University of Strasbourg, Institute of Biotechnology and Drug Research (IBWF) and Research Institute of Organic Agriculture (FiBL).

The **M4F** (Microbes for Future) follow-up project is funded by the KIT steering committee.

References:

1) Schaller M, Weigel HJ (2007) Analyse des Sachstands zu Auswirkungen von Klimaveränderungen auf die deutsche Landwirtschaft und Maßnahmen zur Anpassung, Landbauforschung, Sonderheft 316

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