Learning from wild grapevines

Grapevines are treated with pesticides more frequently than any other crop. Peter Nick from the Botanical Institute at the Karlsruhe Institute of Technology is pursuing an ambitious goal: sustainable viticulture rather than toxins. Sustainable viticulture takes into account plants' natural capacities of resistance.

Nick uses the European Wild Grape, the ancestor of cultivated grapevine varieties, for his research as the plant is able to successfully fight off many pathogens.

Georgia, where humans started to cultivate grapevines around 8000 years ago, is thought to be the cradle of viticulture. Over time, grapes got bigger and sweeter, and the plants grew faster and faster. However, breeding success came at a high price: cultivated grapevines gradually lost their natural defence systems. In addition, grapevines were one of the first victims of globalisation; in the mid-19th century, pathogens were introduced from North America into Europe where they infested the European grapevine species which were evolutionarily completely unprepared for the pathogen attack. Today, they are completely defenceless against the large number of pests, and winegrowers often resort to toxins. This is expensive in the long term and also pollutes the environment, which is why scientists are looking for ways to make the plants more resistant to pathogens.

Prof. Peter Nick, director of the Department of Molecular Cell Biology at the Botanical Institute of the Karlsruhe Institute of Technology (KIT), hopes to solve the problem using wild grapes, which unlike their highly cultivated relatives are often able to effectively ward off a pathogen attack. “Evolution has already solved the problem. We just need to understand how,” says Nick.

Resistant wild grape relatives

To begin with, Nick purchased wild grapevines from around the world to find out whether and how they protected themselves against pathogen attacks. He then infected them with Plasmopara viticola, the causal agent of grapevine downy mildew. Plasmopara is a feared pest that was introduced from North America to Bordeaux around 150 years ago. As none of the European grapevines was able to fight off the pathogen, the disease spread throughout Europe. The pathogen was long believed to be a fungus, similar to the one that causes powdery mildew diseases. However, Plasmopara is an alga that lives inside vine leaves where it cannot be reached by pesticides. The algae leave their host only for the purpose of propagation. As winegrowers do not know exactly when this happens, they are forced to apply pesticides to grapevines on a regular basis.

Wild grapes have developed various defence mechanisms against Plasmopara: cells of American grapevine species commit suicide when the pathogen gets inside them, thereby removing everything the pathogen needs for growth. Asian wild grapes “put on perfume” to protect them against the algae: Plasmopara enters the leaves via stomata, which release a specific fragrance that attracts the pathogens, enabling it to find entry points into the leaf. If the perfume is distributed across the entire leaf, the pathogen becomes confused and is unable to find its way in.
Nick came across the European Wild Grape (Vitis sylvestris) while working on a nature conservation project. As director of the Botanical Institute, he is also responsible for the Botanical Garden at the Karlsruhe Institute of Technology which is, amongst other things, a kind of current-day Noah’s Ark where threatened plant species are bred. Vitis sylvestris is only found in lowland forests that are few and far between nowadays, which is why the plant is almost extinct. “We wanted to find out whether we could cultivate the plant and return it to the wild,” recalls Nick.

Valuable wild grapes

Nick and his team successfully reproduced the genetic variety of the original wild Vitis grape (around 100 different genotypes). The different genotypes are grown in the KIT’s Botanical Garden and are a unique collection in Europe and, as it turned out, a truly valuable genetic resource.

Wilder Wein

Die Wildrebensammlung am KIT
Some of these European Wild Grape varieties were found to be resistant to Plasmopara algae. “This surprised us at first because we knew that the plant had not previously been in contact with the pathogen,” says Nick. Plants have defence systems composed of two layers. The first, weaker basal layer, is relatively unspecific as it targets ubiquitous molecules in pathogens and is thus effective against many microorganisms. The second layer is stronger and protects the grapes against specific organisms. However, in order to be able to develop the latter, plants and pathogens need to evolve sympatrically. Native American Vitis species and Plasmopara have co-evolved for millions of years, so that the grapes have had enough time to cope with these pathogens. The question is therefore, what makes the European Wild Grape so resistant to Plasmopara?

“The European Wild Grape has a very strong and rapid basal defence, and produces resveratrol that has antifungal activity against grapevine pathogens,” said Nick, illustrating his point using the example of medieval defence systems. “Wild grapes pull up the drawbridge and prepare hot pitch as soon as the slightest dust cloud appears on the horizon while cultivated grapevine varieties only pull up the drawbridge once the enemy is already inside the castle.”

Nick and his team have also found a particular genetic difference that is responsible for the difference in amounts of resveratrol produced by wild and cultivated Vitis species. Cultivated grapevines lack a piece of the genetic switch that switches on the resveratrol gene, and thus only produce low amounts of resveratrol. Differences in resistance factors between wild and cultivated grapevines have opened up new breeding possibilities. For more than a century, resistant North American grapes have been crossed with cultivated European grapes in order to create plants that carry the North American resistance factors. However, the drawback of the crosses is that the grapes do not taste good. The new findings can now be used to introduce intact gene switches into the cultivated grapes by crossing them with the more aromatic European Wild Grape.

First breeding experiments with Pinot Blanc grapes

Nick and his team have already tried this with a Pinot Blanc variety. At present, 300 offspring of the cross are growing on the institute’s fields. “In the past, it would have taken many decades and a lot of money and space to find out which offspring have inherited the sought-after switch of the wild grapevine,” says Nick. Grapevines grow very slowly. Molecular breeding makes this a lot faster. “We know the DNA sequence of the switch and can make a marker that we use to identify whether the plants carry the switch or not. The plants are already big enough so it does not matter when we cut off leaves for our investigations. We then extract the DNA, add the marker and identify the plants that have inherited the switch,” says Nick, pointing out that this is resistance breeding rather than genetic engineering.

But it will still take a long time before a perfect grapevine is available. The European Wild Grape has undesirable characteristics such as smaller grapes and lower growth, which have to be removed by crossing and selecting plants that lack these characteristics.

The KIT researchers are looking for more resistance factors in order to make the crosses more sustainable and stable: “If possible, we try not to focus on just one gene. Experience shows that pathogens learn to overcome resistances relatively quickly. A combination of several resistance factors would be much harder to break,” says Nick.

The European Wild Grape is and will continue to be a treasure chest. It is also resistant against Esca disease, which attacks the wood of the plants and is causing more and more devastation around the world. The exact cause of the disease is not yet known. “Species diversity has a concrete practical use,” says Nick.