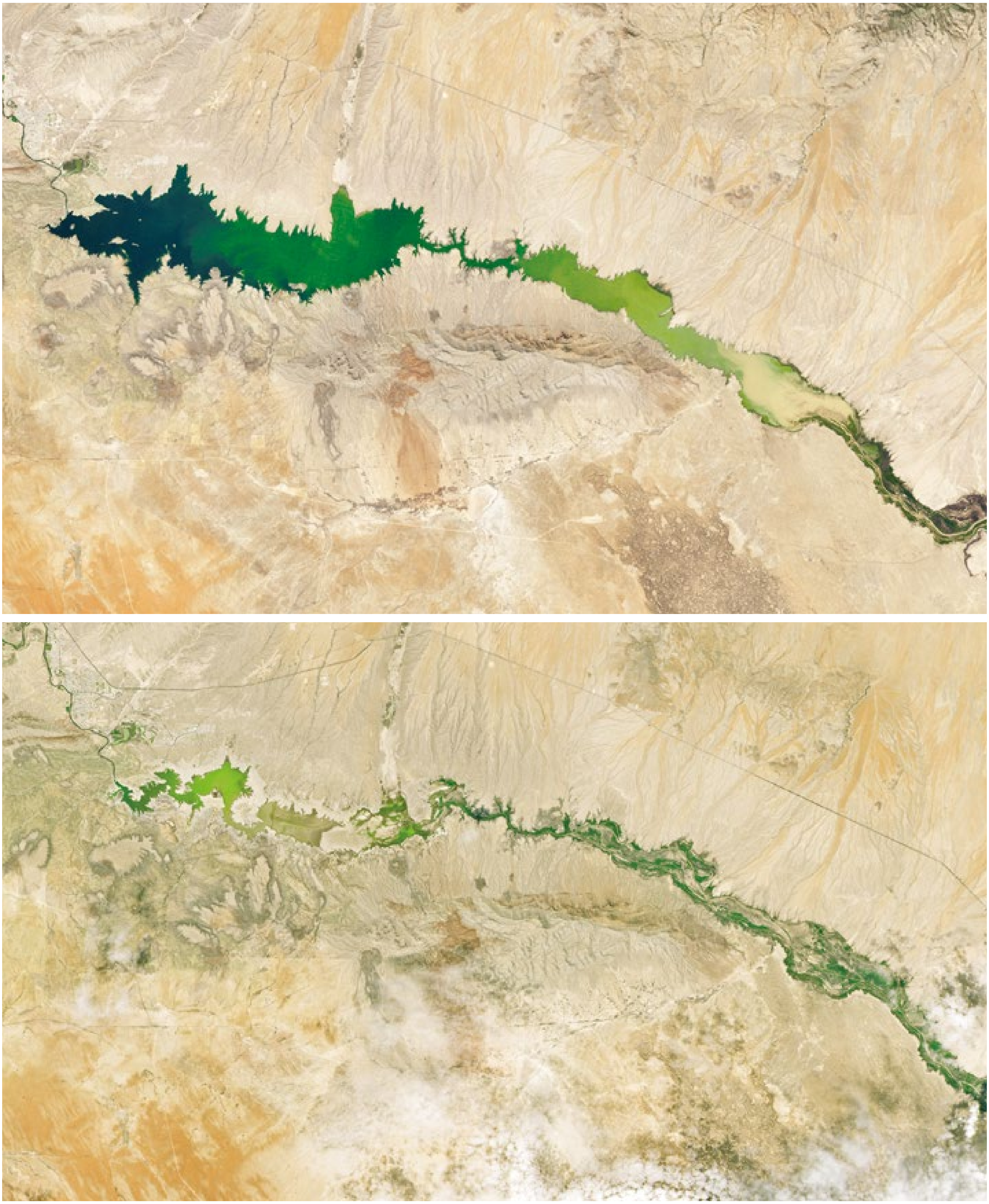


Drought dries Elephant Butte Reservoir in New Mexico, USA. Two images taken in the summers of 1994 (top) and 2013 (bottom) show how the water level dwindled to its lowest value in forty years. Due to climate change, drought periods are projected to increase in the future.

Link
www.sysbiol.wzw.tum.de

Thought **for Food**

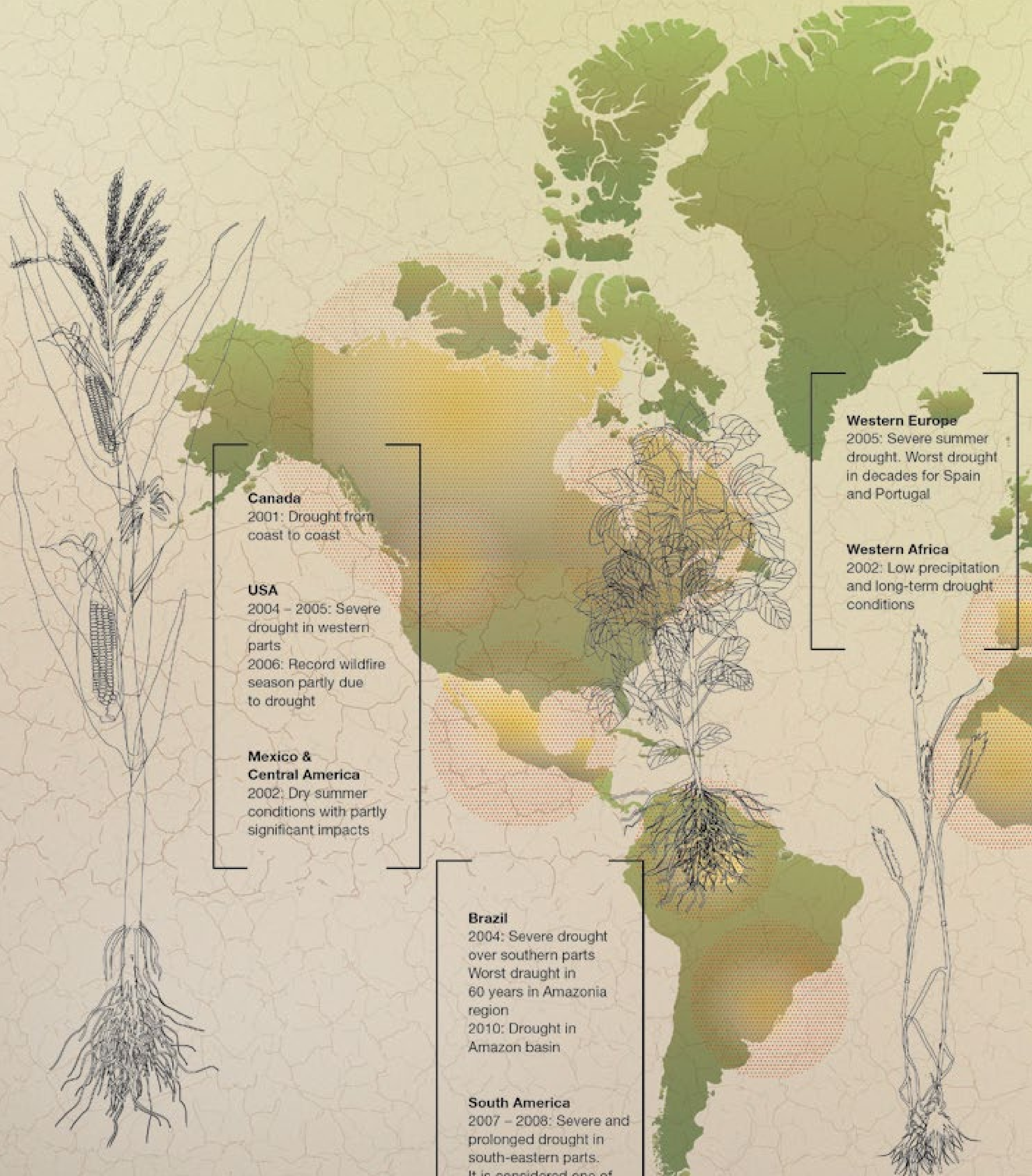
The StressNetAdapt project, led by Dr. Pascal Falter-Braun, investigates protein networks and complex signaling pathways in plant cells. Against the backdrop of climate change and its impact on food production, his research focuses on strategies that enable plants to overcome unfavorable environmental conditions such as water shortage or high soil salinity. The findings could pave the way to generate new, stress-tolerant crops using biotechnology.

Karsten Werth

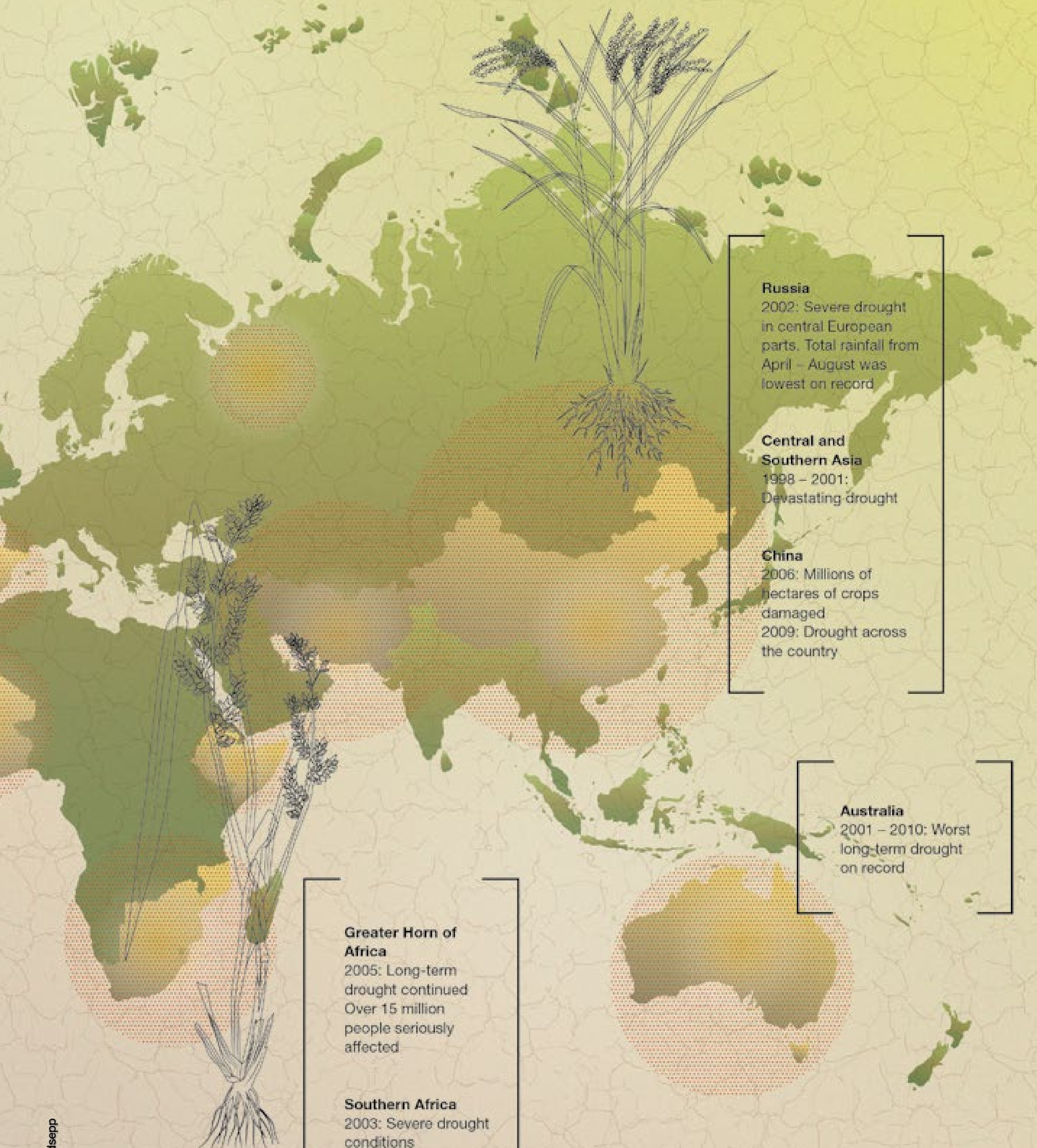
Netzwerkforschung für mehr Nahrung

In Zeiten des Klimawandels wird die Frage immer dringender, warum manche Organismen besser mit widrigen Bedingungen wie Trockenheit oder Krankheitserregern zurechtkommen als andere. Pascal Falter-Braun ist überzeugt: Das Erfolgsgeheimnis liegt in der Interaktion der Proteine, die sich in komplexen Netzwerken organisieren. Für sein jüngstes Forschungsvorhaben, das fünf Jahre lang solche Netzwerke untersuchen soll, erhielt er einen Grant vom Europäischen Forschungsrat (ERC) aus Brüssel. Am Wissenschaftszentrum Weihenstephan leitet Falter-Braun eine zehnköpfige Forschungsgruppe des Lehrstuhls für Systembiologie der Pflanzen. Ziel ihrer Grundlagenforschung ist es, herauszufinden, wie sich die molekularen Netzwerke von stresstoleranten Pflanzen von denen ihrer stressempfindlichen Verwandten unterscheiden. Die Forscher untersuchen jeweils 5.000 proteinkodierende Gene aus vier eng verwandten Arten der Familie der Kreuzblütler, kartieren molekulare Netzwerke und wollen anhand ihrer Überlagerung die Schlüsselproteine für die gewünschten Phänotypen identifizieren. Der biochemische Netzwerkvergleich ist zum Teil inspiriert von einer Ähnlichkeit der Proteinnetzwerke mit technischen oder sozialen Netzwerken, wie sie sich zum Beispiel in den sozialen Medien widerspiegeln. Die Erkenntnisse aus dem Projekt könnten langfristig dazu beitragen, durch Modulierung der Proteinnetzwerke und Züchtung stresstoleranter Arten die landwirtschaftlichen Erträge in Trockenperioden oder auf Böden mit hohem Salzgehalt zu verbessern und damit einem wachsenden Ernährungsproblem der Menschheit zu begegnen. □

Picture credit: NASA



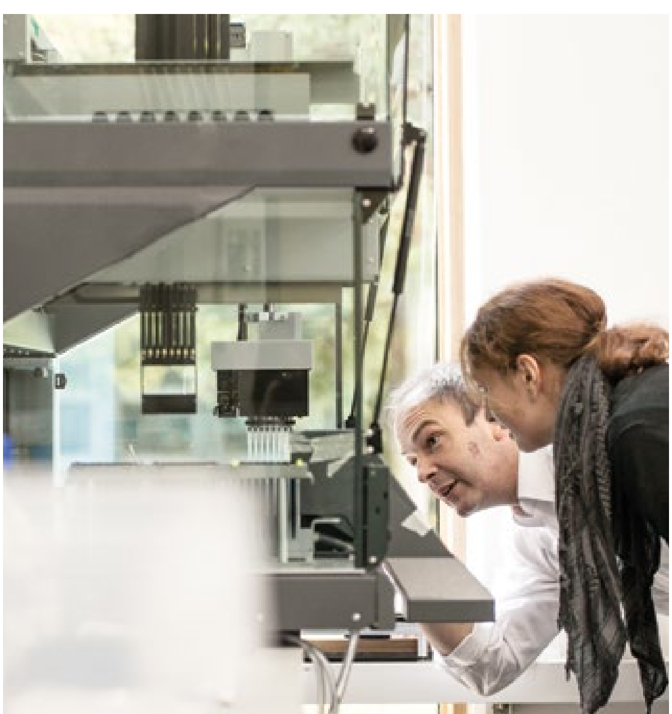
An assessment of the most significant droughts which occurred in different parts of the world between 2001 – 2010 (WMO, “2001 – 2010 A decade of climate extremes”). Agricultural regions growing essential crops were affected simultaneously. Drought is not the only stress factor. Increased irrigation – such as in California – can also gradually increase salt levels in the soil. High soil salinity has a very similar physiological impact on plants as lack of water.



Picture credit: ediundsepp

The prospects are dim: according to the 2014 report of the UN's Intergovernmental Panel on Climate Change (IPCC), weather extremes are projected to increase as the climate gets warmer. Experts see an increase in the frequency and extent of droughts as one of the greatest threats to global food production. Exemplifying the trend: historic droughts occurred between 2000 and 2010 in several key staple-food producing regions around the world including Brazil, North America and China. To reduce the risk of famines and resulting social unrest, it is critical to develop crop varieties that can thrive even in extreme climate conditions. TUM researcher Dr. Pascal Falter-Braun approaches the quest for stress-tolerant plants on a molecular level.

All living organisms owe their lives to the successful interplay of molecules inside their cells. But why do some organisms tolerate adverse environmental conditions better than others? Falter-Braun is convinced that the answer lies in the interactions between proteins, which are organized into complex networks. His latest research project will examine these networks over a five-year period – and has secured him one of the prestigious grants awarded by the European Research Council (ERC) in Brussels. At TUM's School of Life Sciences Weihenstephan, Falter-Braun leads a group of ten scientists at the Chair of Plant Systems Biology. The goal of their research is to determine how the molecular networks of stress-tolerant plants differ from those of their stress-sensitive counterparts. Thanks to his ERC Consolidator Grant of two million euros, Falter-Braun can focus on this question over the next five years. ▹



Dr. Pascal Falter-Braun

3 questions for …

Dr. Pascal Falter-Braun (43) was born in Essen, Germany, studied biochemistry at the Freie Universität Berlin and then spent over ten years engaged in research at Harvard University and Harvard Medical School in the US. He has been a research group leader at the TUM Chair of Plant Systems Biology since 2012 and a TUM Junior Fellow since 2014. Falter-Braun has published numerous papers in some of the most prestigious scientific journals such as "Science". He lives in Munich and is married with one daughter.

Dr. Falter-Braun, how did you get into your chosen subject?
My time in Boston coincided with the Human Genome Project, which brought me into contact with genome-wide research approaches very early on. I started on my first plant project in 2010, then working alongside colleagues from the Arabidopsis genome project; that was my first point of contact with plant science. Ultimately I came to the conclusion that, on a global scale, food and energy issues are the most important to me. Diseases certainly cause a lot of suffering but energy problems, water shortages, and related issues affect us all as a global community – and will certainly keep us on our toes for the next two decades. I was also drawn by the fact that not much research had been done in this area yet. So I switched to plant science fairly late in my career, as a newcomer to the field.

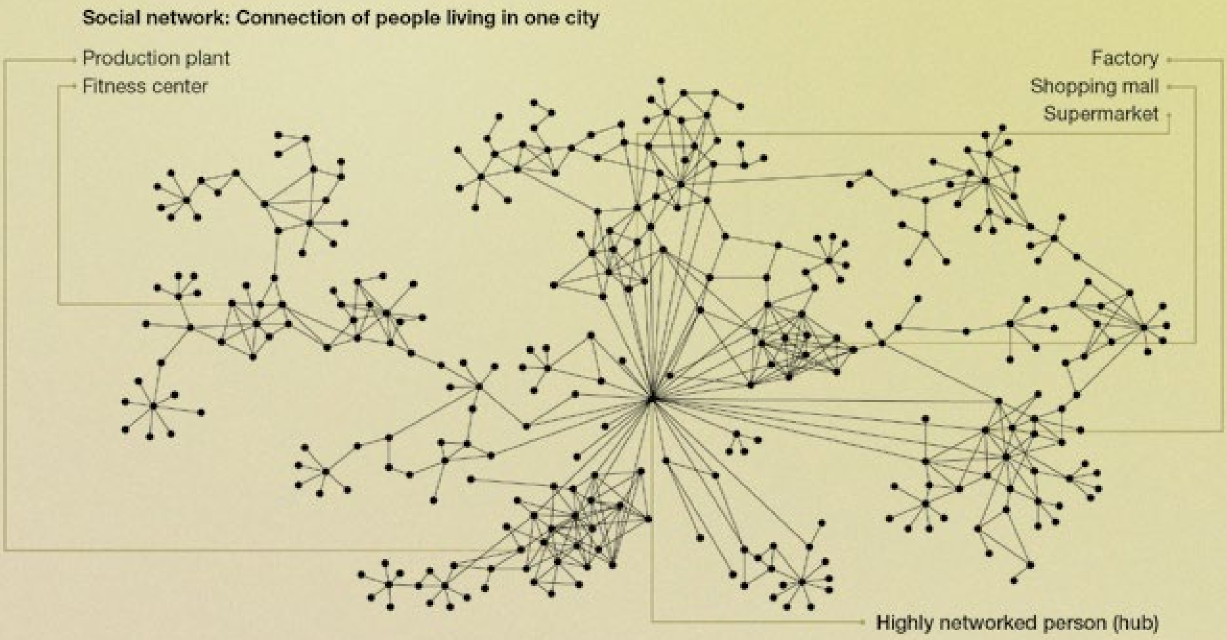
What does the ERC grant mean to you?
This is my most exciting project to date. We can make substantial progress here and it's great to have that recognition. I'm also very glad to be at TUM, where ERC grants lead to professorships through the Tenure Track system. That's obviously important when, like me, one is at the group leader level.

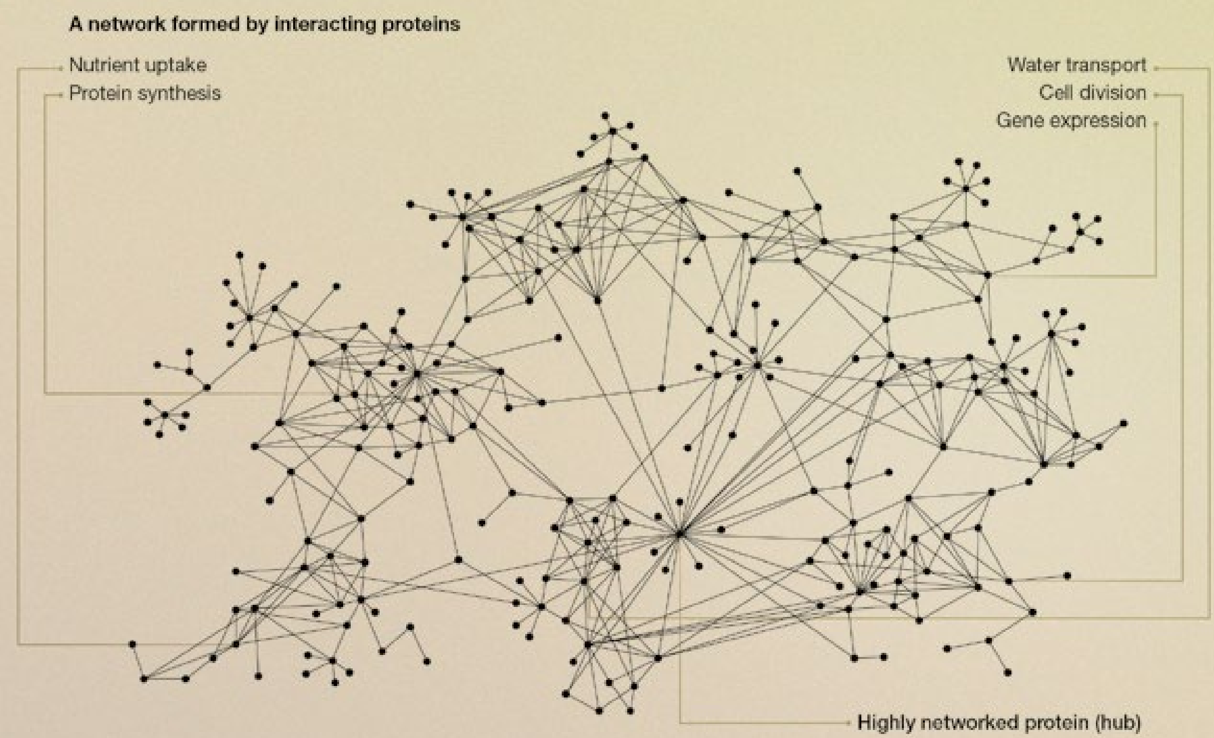
Would you encourage young people to become researchers?
Certainly, as long as they bring passion in addition to talent. It's not the best career path if you want to get rich quick. But as long as you have a certain amount of resilience, it can be a very rewarding and exciting path – especially when you reach the point where you can substantially realize your own ideas and find your own new and creative approaches. Not many careers afford that degree of freedom.

"Scientists have been trying to understand molecular networks for several years now."

Pascal Falter-Braun

Picture credits: ediundsepp





Social and molecular networks are similiar in various ways: They are comprised of several communities – in the case of proteins functionality clusters such as for water transport – connected via interaction between individual persons/proteins. Just like highly networked persons act as hubs and enable fast information flow throughout the network, highly networked proteins support the fast propagation of signals. Pathogens act on these hubs to effectively affect an organism.

Picture credits: ediundsepp

Mapping and understanding networks

Proteins are elementary to every cell of every living organism. They are responsible for transporting substances and signals, they interact with other molecules and they give structure to cells. "Scientists have been trying to understand molecular networks for several years now – since completion of the major genome projects," says Falter-Braun. He continues: "All building blocks of life have now been identified. We know which proteins are encoded in a genome and have a complete parts list." Yet sequencing the genome did not reveal the desired "circuit diagram" of life. A parts list alone does not tell us anything about the links between them and the way they interact. "It's like a phone directory," describes Falter-Braun: "We can't use this list to find out which parties communicate and how." However, this is precisely the crux of the issue. Translation of genomic information into plant characteristics results from the diverse and complex interactions among the components of the molecular networks. In crop plants, agricultural yield and stress tolerance are particularly important properties. Thus, the initial goal of Falter-Braun's research is to map and understand these networks.

Similarity to social networks

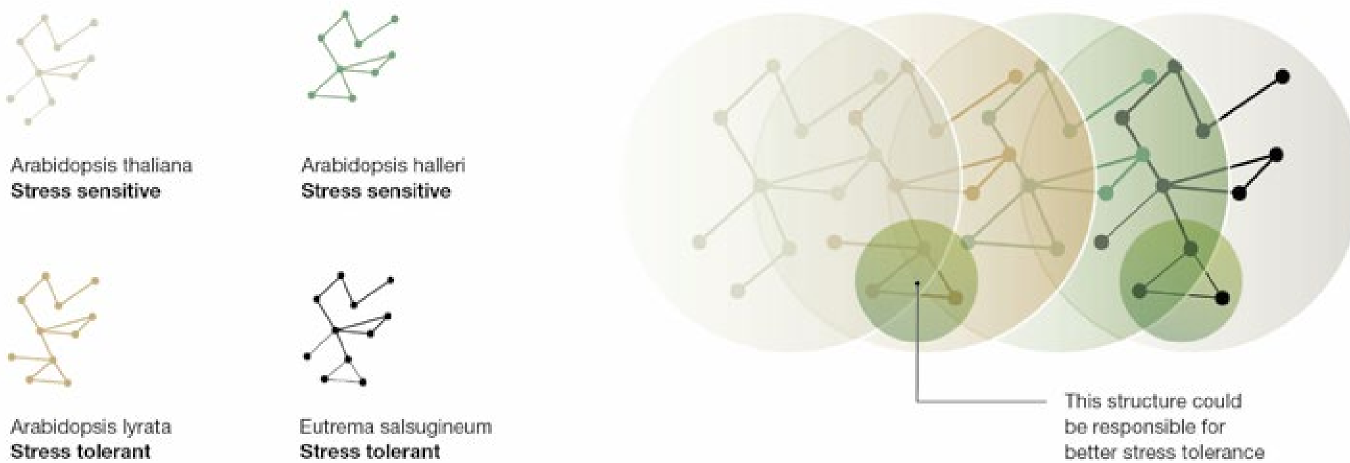
Insights gained into molecular networks to date have revealed their structural similarity to social and technical networks. Falter-Braun is particularly interested in information exchange and robustness. He gives an example: "In social networks many people have comparatively few friends. However, there are also a few people with very extensive contacts who are vital to the flow of information. On Facebook and Twitter, news spreads fastest via these highly networked participants. "Such strongly networked components, so-called hubs, are also found in complex technical networks, for example in air traffic. Here, most connections go through a few central hubs, such as Frankfurt, Charles de Gaulle and Heathrow. These hubs are important for the stability of air traffic operations. If several hubs were to go down at the same time, air traffic in Europe would collapse – with consequences around the globe. The complex molecular networks within cells have a similar structure: there are many proteins with few connections and a few major hubs.

Hubs as strategic targets for pathogens

The TUM researchers have already investigated how three evolutionarily diverse plant pathogens – representatives of bacteria, fungi and brown algae – attack plant networks. Falter-Braun summarizes: "We found that all three pathogens target the hub proteins of the host network. Moreover, we could show that the targeted host proteins have important functions – if we switch them off, the consequence is either increased resistance or increased susceptibility to the pathogen." So there appears to be a "strategy" behind the attacks on these highly networked hubs. Falter-Braun considers the possibility of universal network laws, which may also apply to biological phenomena.

"On a global scale, food and energy issues are the most important to me." *Pascal Falter-Braun*

For some plant species, the sequencing of many individual genomes has delivered significant insights into their natural genetic variation. To a certain extent, scientists today are able to watch evolution in action by identifying highly variable regions of the genome. "In our pathogen project, the results of this analysis surprised us," says Falter-Braun. "Above all, we were expecting to see variability in the targeted hubs that would serve to thwart attacks by the pathogens. Instead, the most variable proteins turned out to be direct interaction partners of the hubs. This indicates that the network structure has a strong influence on evolutionary processes. The selection pressure that pathogens exert on the plant via the hubs appears to be intercepted and absorbed by proteins in the network environment." Falter-Braun suspects that it is difficult for the hub proteins to change because they are so highly connected. Any changes in their shape would likely impact many different aspects of the network. Thus evolutionary adaptation of the network must take place in the neighborhood of the hub. This question continues to be investigated. ▷



The molecular networks of the four investigated plants are mostly similar but differ in details. Superimposing the networks reveals that Arabidopsis lyrata and Eutrema salsugineum share one specific structure which might be the key to more stress tolerance.

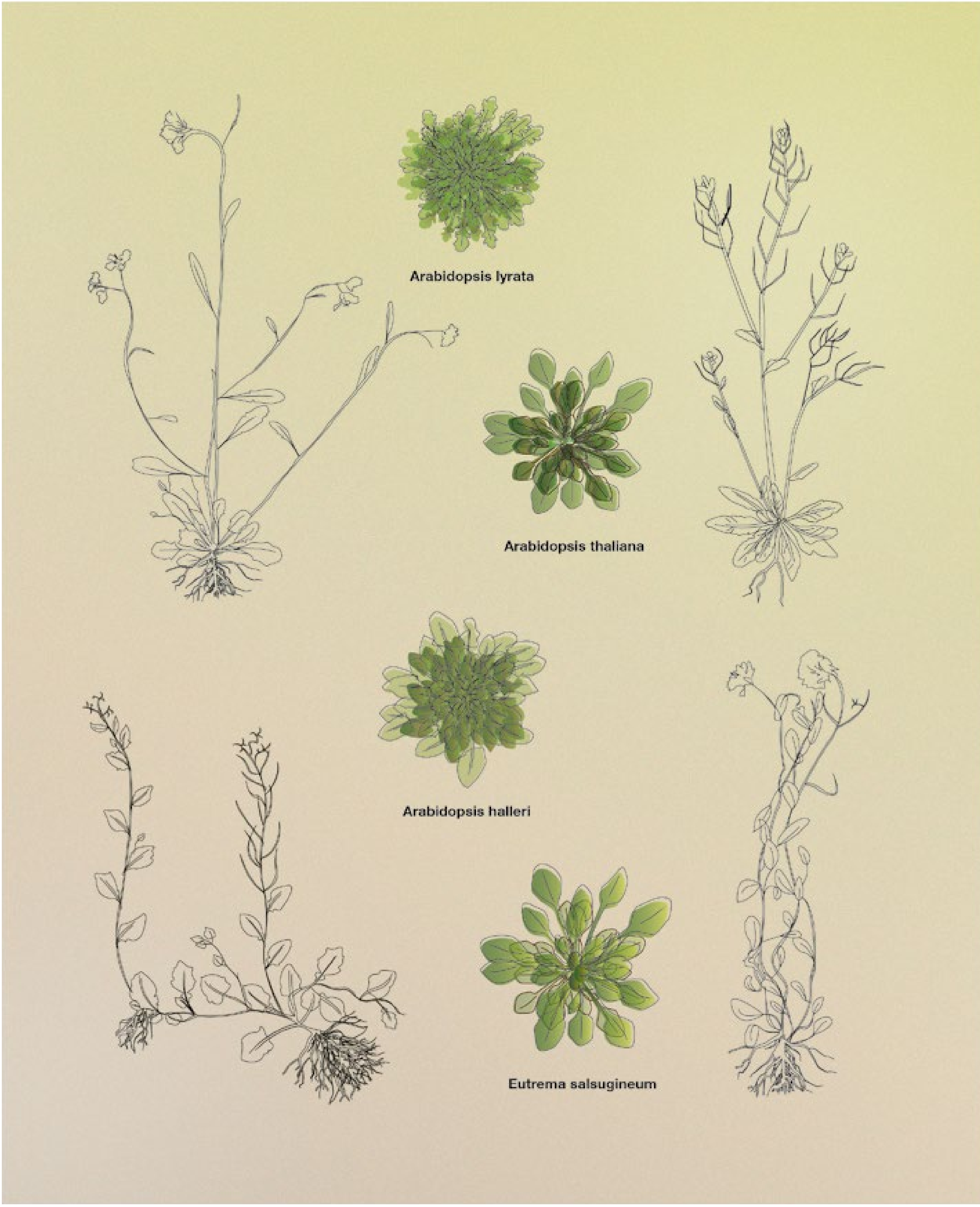
StressNetAdapt

Falter-Braun's ERC project StressNetAdapt started in September 2015. In this project, the scientists will compare the protein networks involved in drought stress of four closely related cruciferous plants: Arabidopsis thaliana (thale cress), Arabidopsis lyrata, Arabidopsis halleri and Eutrema salsugineum. These plants are close relatives of rapeseed and cabbage varieties. Arabidopsis thaliana is one of the most important model organisms in plant research, analogous to the mouse in medical research. Falter-Braun and his colleagues generated an initial map of the protein interaction network for A. thaliana some years ago. In StressNetAdapt, the Weihenstephan researchers now attempt to find out why some of these evolutionarily close species are particularly tolerant to drought or salt stress and how plant breeding may benefit from this. Arabidopsis thaliana and Arabidopsis halleri are highly sensitive to drought stress, whereas Arabidopsis lyrata and Eutrema salsugineum can tolerate drought stress very well.

As a first step the molecular networks of these four species need to be mapped by protein-protein interaction analysis. To this end the researchers will examine 100 million protein pairs using a state-of-the-art pipetting robot and the yeast-2-hybrid system – a biochemical technique to identify protein-protein interactions. Since the four species are closely related, it is expected that the networks will be largely identical. At the same time some proteins may only occur in one species. In addition, some proteins may be differently connected. Falter-Braun's hypothesis is that on one hand there will be a core network that looks identical in all four crucifers, and on the other hand there will be network variations, of which some account for the increased tolerance to drought stress. The researchers aim to superimpose the four networks to reveal the differences. By this approach they hope to identify key proteins that could increase drought stress tolerance in sensitive plant species. The team then plans on introducing these to rapeseed to test their hypothesis. "Our research is intended to deliver a proof of principle for new biotechnological strategies that may be transferable to other crops in the future." According to Falter-Braun, the insights gained from this project could be used to modulate protein networks through selective breeding and thus deliver more robust crops. In the light of climate change and increasing food insecurity this could be progress that saves lives.

Karsten Werth

> *"Fascinatingly, all three pathogens that we investigated target the host's hub proteins – just as network theory predicted."*
>
> *Pascal Falter-Braun*



Why are some plants more tolerant to stress than others? Pascal Falter-Braun compares the protein networks involved in tolerance to drought stress across four closely related plants. He hopes to find network structures that could lead the way to breeding more robust crops.

Picture credits: ediundsepp (source TUM)