Plant protection of the future may come from the plants themselves

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Researchers from AU Flakkebjerg have studied how plants can keep pests, diseases and fungi at bay by secreting certain substances. This could be used as a plant defense of the future. Credit: Enoch Narh Kudjordjie

Humans and animals all have chemical and microbial signatures that influence their well-being in one way or another. In medicine, the use of probiotics rather than antibiotics has become high on the agenda. However, humans and animals are not the only ones who have a close

relationship with their microflora. Plants exhibit similar relationships with their environments too. Just as they do in humans, microbes play a major role in plant health and resistance to plant diseases.

At Aarhus University in Flakkebjerg, Denmark, researchers are studying plants, plant health and plant diseases caused by microbial pathogens. The ability of plants to fight microbial pathogens such as bacteria and fungi is to a large extent determined by plant genes that regulate plant defense capabilities. In a new study, researchers from AU Flakkebjerg have studied how plants with different resistance traits interact with their microbes to respond to pathogen attack.

The research is published in the journal *Microbiology Spectrum*.

"We have investigated what happens in plants when they are attacked by a pathogen. What changes occur in the plant itself as well as its associated microbial communities (i.e., microbiome) during a pathogen attack? What makes some plants resistant while others are not? To answer these questions, we explored the interaction between plant chemical compounds and the plethora of microbial communities associated with the plant. This is not really a new research area, but by applying new and modern technologies in this study, we have been able to get a much more detailed insight into what is actually going on, in terms of interactions between plant chemicals and microbes," says Assistant Professor Enoch Narh Kudjordjie, one of the lead researchers from the Department of Agroecology at Aarhus University.

Plants have their own integrated defense system

Like humans, plants have their own immune system, which plays a huge role in disease prevention. Plant defense is tightly regulated by plant secondary metabolites, hormones, and beneficial microbes in and around the plant.

This defense system and its activation are complex, and we have yet to understand in detail how these components come together to help the plant protect itself from attack. However, there is light at the end of the tunnel as scientists are making strides in studying these defense components by analyzing different plant genotypes, using new techniques such as next-generation sequencing and analytical chemistry platforms.

"We have been working with a model plant known as Arabidopsis thaliana. Arabidopsis genotypes have different levels of resistance to Fusarium oxysporum, a fungal pathogen that attacks several plant species. In the present work we used two Arabidopsis genotypes; one that is resistant and another that is susceptible to Fusarium oxysporum. These contrasting genotypes were chosen to enable us to gain a comprehensive insight into the metabolic and microbial changes which underline resistance and susceptibilities of plants during pathogen attack," explains Kudjordjie.

Disease infection

To begin with, the researchers infected two-week-old Arabidopsis genotypes growing in field soil in a greenhouse with the fungal pathogen Fusarium oxysporum. To examine the changes during the period of infection, they collected root and shoot samples at 5 day intervals, starting from 5 days after infection and lasting until day 25 after infection. They confirmed the infections by qPCR and by monitoring disease symptoms.

"This way we were absolutely sure that the plants were actually infected. The qPCR test showed a clear difference between the two genotypes, with the resistant genotype having a much lower level of the pathogen than the susceptible one."

Plant chemistry and microbiome are unique

Kudjordjie continues, "We then continued to explore the differences that may exist in the chemistry and microbiomes in the two genotypes, and we found large differences. As expected, the plant metabolites and hormones studied were distinct in both the healthy and diseased plants, confirming the involvement of certain plant chemical molecules in mediating plant defense. Likewise, we found that microbial composition, as well as microbial community networks, were distinct in healthy and diseased resistant and susceptible plants. Moreover, beneficial bacteria such as the genera Pseudomonas and Rhizobium were mostly enriched in the rhizosphere of infected plants, suggesting an active recruitment of microbes to resist pathogen invasion."

Plant genes, chemistry and microbial communities are key players

"From a more comprehensive perspective, the present work has deepened our understanding of how plants defend themselves against a fungal pathogen. More importantly, we found a strong and unique association between individual defense metabolites and specific microbes in the healthy and diseased plants of the different genotypes. Further analysis of the genes responsible for plant defense against the pathogen revealed several mutations in various chemical and hormonal pathways in the susceptible plant compared with the resistant plant. These results strongly confirmed that three underlying host components (genes, metabolites and microbiomes), interactively control the plant defense," explains Kudjordjie.

"Simply put, we found that individual plant genotypes have a unique set of genes that regulate biological activities including metabolic processes mediating the assembly of specific microbiomes during different

physiological states of the plant. However, the microbes in the soil also influence what happens in the plant."

Natural plant protection in the future

Can we imagine a future where plants are cultivated with optimized yield and other agronomic and economic gains without the use of synthetic chemicals? That will improve human health and also eliminate environmental pollution from agrochemicals. So far, accumulating evidence is pointing to that possibility, and the current findings from the AU researchers are pivotal to future research efforts in developing natural products for plant protection.

"Although these findings are exciting, we need to harness our knowledge and integrate it into future disease control strategies. One approach from the plant side would be to develop plant genotypes with enhanced levels of defensive metabolites to attract certain microorganisms to fight specific pathogens. This implies that plant breeders would have to include the plant chemistry in their toolbox. Another strategy is to develop microbial inoculants including several beneficial microbes that can optimally enhance plant fitness in varying environments. We are quite optimistic of utilizing microbiomes as plant protectants as well as a possibility to grow 'super' crops that are capable of defending themselves against pathogens in the future," says Kudjordjie.

More information: Enoch Narh Kudjordjie et al, Fusarium oxysporum Disrupts Microbiome-Metabolome Networks in Arabidopsis thaliana Roots, *Microbiology Spectrum* (2022). DOI: 10.1128/spectrum.01226-22

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