Alternative to phosphate fertilizer: Biochar basis controls plant response

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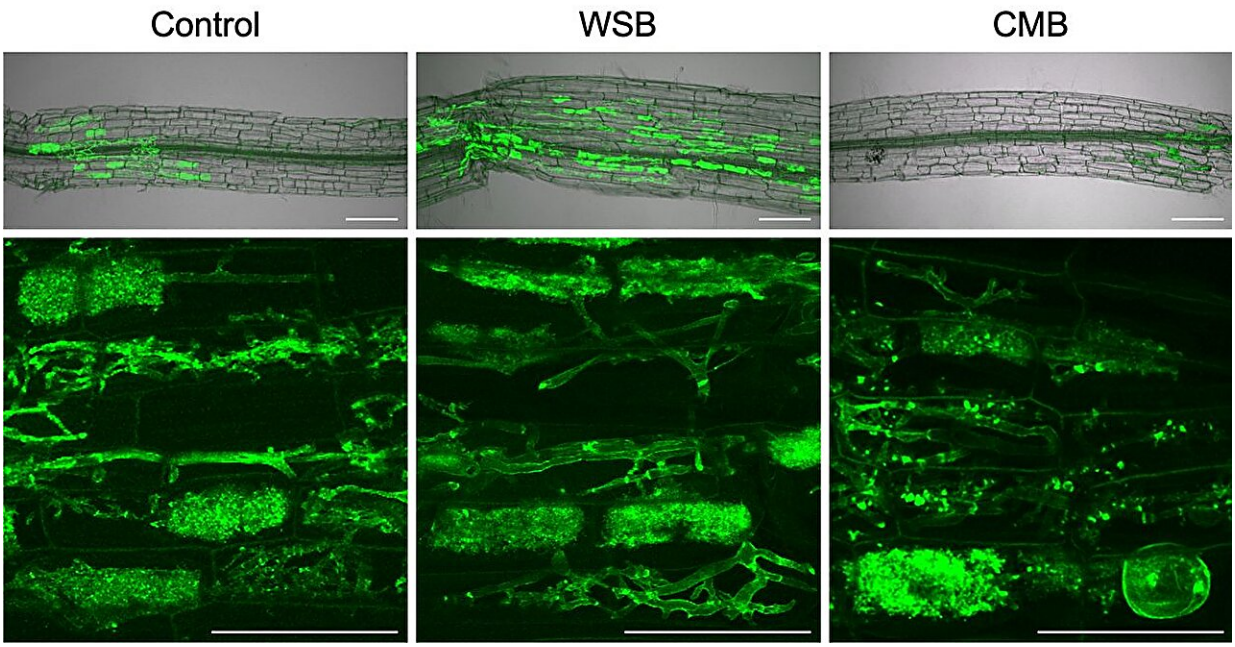

Comparison with the control plant (microscopy on the left) reveals that symbiosis with mycorrhizal fungi is stronger when tomato seedlings are fertilized with biochar based on wheat straw (center). When biochar based on chicken manure is used for fertilization, symbiosis is weaker (right). Credit: JKIP, KIT

For some years now, biochar has been studied extensively as an alternative to phosphate fertilizer. Biochar is a recyclate produced by biomass pyrolysis, i.e., organic feedstocks are incinerated without

oxygen at temperatures ranging from 400°C to 700°C. The biochar bases may differ considerably. Waste wood, chicken manure, or leaves can be processed to fertilizers.

Past research has revealed, however, that plants responded differently to biochars. Some grew better, others reacted as if they had not been fertilized at all, and others were even intoxicated by the biochar fertilizer.

An interdisciplinary team of KIT researchers from the Joseph Gottlieb Kölreuter Institute for Plant Sciences (JKIP) and the Institute for Technical Chemistry used tomato seedlings and found that the origin of the biochar biomass was crucial to symbiosis with arbuscular mycorrhizal fungi (AM fungi) existing in the soil.

In a first experiment, the team studied the effect of biochars made of wheat straw and chicken manure. The chicken manure biochar contained nine times as much phosphate as biochar based on wheat straw. Phosphate is the soluble form of phosphorus bonded to oxygen. It is a molecule essential to the growth of plants. "As expected, tomato seedlings fertilized with chicken manure biochar grew quickly and brilliantly," says Professor Natalia Requena, expert of molecular phytopathology at JKIP. "Very much phosphate was available for direct processing."

Symbiosis with AM fungi ensures long-term growth of the plant

In a second experiment, researchers made AM fungi colonize the tomato plants. For more than 400 million years, these microfungi have been living on Earth in the roots of 80% of the land plants. They colonize the bark, take up phosphate, and transfer it to the plant. In turn, the plant

supplies them with sugar and lipids.

When observing selected molecules, researchers found that the phosphate-rich biochar based on chicken manure impaired this symbiosis between tomato and AM fungi: Molecular exchange hardly took place. The biochar based on wheat straw did the opposite—the plant and microfungi developed an active symbiosis. "In the long run, plants fertilized with wheat straw biochar are more compatible with other microorganisms and protected much better against pathogens," Requena explains. "We did not expect such a complex molecular response of the plants."

Understanding the cells better, fertilizing less

The team used gene expression analysis to provide proof of these results. "This is a complex, expensive method, but it enables us to see what happens in the genes of the plant and which markers are triggered or not," Requena says. Further experiments will be required to even better understand the response of plants. "When we will succeed to decode this response, we can program plants in the long term such that they need less phosphate and, hence, less mineral fertilizer," Requena points out.

More information: David Figueira-Galán et al, Exploring the synergistic effects of biochar and arbuscular mycorrhizal fungi on phosphorus acquisition in tomato plants by using gene expression analyses, *Science of The Total Environment* (2023). DOI: 10.1016/j.scitotenv.2023.163506

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