Soil microbes can make for a greener revolution

A new and fascinating aspect to hybrid vigour is the rhizomicrobiome

SPEAKING OF SCIENCE

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Benign bacteria: Rhizobacteria associate with roots of plants, and many of these are plant growth promoters. ▪GETTY IMAGES

Plants appear to be simple enough in their organisation. Whether small shrubs or tall trees, all they seem to be made up of is leaves, flowers, fruits, stems and roots. But simple they are not. Being rooted to one spot has required very special personality traits. The ability to make food from sunlight and the carbon dioxide in air has given them a central position in life forms on earth. They cannot run, but ably defend themselves. A fascinating aspect of their abilities lies out of sight, in the soil from which they sprout, and from which they derive water, micronutrients, and a host of other benefits.

Ancient association

The association between plants and fungi is ancient. Fossils of plants from about 400 million years ago show the first evidence of roots, and these roots are fungus associations - rhizoids - suggesting that roots co-evolved with fungi. One good example is species of *Penicillium*, the fungus from which Alexander Fleming isolated the antibiotic penicillin. Fungus-root associations, called mycorrhizae, appear at first glance to be simple mutualisms that are beneficial to both. The root-invading fungus gains nutrients made by the plant, and the plants get difficult-to-find minerals like phosphorus from the microbe. But the association is deeper.

The Wood Wide Web

Suzanne Simard of the University of British Columbia, working in the dense forests of the Pacific Northwest, made an interesting finding. In carefully controlled experiments with saplings of birch and fir trees enclosed in clear plastic bags that contained some radioactive carbon dioxide gas, she showed that the birch converted this labelled gas to radioactive sugars by photosynthesis, and within two hours, traces of this radioactive sugar appeared in the leaves of the fir saplings growing nearby. The exchange is mainly though the mycelia of fungi, and may extend through the whole forest, with young trees that are struggling on a dry patch being helped out by carbon transfer from their luckier counterparts. A reviewer writing in the journal *Nature* called such systems as the Wood Wide Web.

Bacteria that associate with roots are called rhizobacteria, and a very wide range of these species are plant growth promoters. Like the fungi, mutualism operates in these relationships too. In exchange for sugars, these bacteria offer plants a wide range of benefits. They may help plants ward off pathogens that cause diseases of the root. They may even trigger systemic resistance to a pathogen throughout the plant.

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Hybrid vigour

The green revolution brought a sea change in the growing of agricultural produce in our country. The key to this was the establishing of hybrid varieties of crop plants. Today, a vast majority of commercially grown crops are hybrids, where two inbred lines are crossed, with their first-generation hybrid offspring exhibiting a vigour that is lacking in either of its parents. The property of hybrid vigour, called heterosis, has been known for centuries, but remains only partly understood.

Root cause

A new and fascinating aspect to hybrid vigour has been found in the rhizomicrobiome - the rich collection of microbes that surround the roots of every plant. Maggie Wagner of the University of Kansas (at the heart of one of the great corn-producing areas of the world) addressed heterosis from the viewpoint of plant-root microbe interactions. Using maize as the model crop, her group has recently shown that the rich biomass of roots in hybrid maize, as well as other positive traits, is reliant on appropriate soil microbes (*PNAS*, Volume 118(30), July 27, 2021). In laboratory-sterilised soils that are totally devoid of microbes, both the inbred parents and hybrid offspring grow equally well, there being no sign of vigour in the latter. Then they started to 'rebuild' the soil environment, one bacterium at a time.

They could attain the normal parent-offspring difference in vigour by introducing just seven species of bacteria into the sterile soil. The experiment could be extrapolated to the fields too: Fumigating, or steaming the soil in one experimental plot led to decreased heterosis, because this soil was depleted of microbes.

Agronomists estimate that depending on the fertility of the soil, hybrid maize requires 180-225 kg of artificial fertilizer for a yield of nine tons of grain per hectare. Producing this fertilizer is an energy intensive task.

As our nation strives towards lofty goals for sustainable agriculture, using simple microbial ways of improving crop quality (and quantity) would be a small step in that direction.

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