Roots Are More Important Than Shoots, Says Prof

Growing plants in air makes roots easier to study

By Andrew Vowles
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Manish Raizada

"The next Green Revolution will come from below the ground." So says plant agriculture professor Manish Raizada, whose recently published study suggests corn growers aiming to use fertilizer more efficiently look not just at the plant's ears or leaves but at its roots.

He means "roots" both in the ground and in historical time. The study by Raizada and his Guelph colleagues shows for the first time that modern and ancient corn plants adjust their fine root structures under low nitrogen in different ways. That insight might allow canny breeders to marry old and new cultivars to yield strains that use this key fertilizer ingredient more efficiently, he says.

Up to half of the nitrogen applied by farmers in commercial fertilizer is wasted in the soil, with much of it ultimately winding up in lakes and streams.

Raizada hopes his root studies might help save money and fertilizer for farmers in developed countries and, at the same time, point a way to assisting millions of poor growers in developing parts of the world.

Contrasting what's under the soil with the plant parts above it, he says, "Roots are more important – we need to pay a lot of respect to what's going on underground."

Along with former grad student Amelie Gaudin and current undergraduate student Sarah McClymont, he published a paper on nitrogen adaptation in the journal *Crop Science* late last year.

Using corn plants grown aeroponically – with their roots entirely exposed to air – the researchers found significant differences in the roots of plants grown with low and high nitrogen. Variations also showed up when they used modern and ancient lines of corn.

Some lines adapt to varying nitrogen by growing more or fewer roots, or by lengthening or shortening those roots. Others alter the length or number of fine root hairs, where nutrients and water enter the plant.

Those differences might help geneticists and breeders, says Raizada. Breeders and farmers might benefit from looking at old-time lines dating back thousands of years to reclaim types better suited to varying nitrogen levels.

"Unconsciously those ancient people who bred for larger kernels not only changed the shoot architecture but dramatically changed the root architecture," says the Guelph scientist, who plans to continue screening corn plants for more efficient nitrogen-users.

Corn was domesticated in North America – notably Mexico – beginning about 9,000 years ago. Although today's tall stalks bearing cobs packed with kernels barely resemble their spindly ancestors, breeders can still cross old and new to yield viable plants. "Genetically they're very similar even though they look so different."

Few scientists have examined crop plant roots in detail. Indeed, he says some researchers and breeders look askance at the idea of focusing on plant roots, arguing that modern breeding already accounts for below-ground differences between corn types.

Raizada says that's not the case.

Needing to look closely at root structures, the Guelph team used aeroponics to grow their plants in a campus greenhouse. Greenhouse growers use this "air growing" method to spray water and nutrients over exposed plant roots. (Epiphytes such as orchids grow with their roots in the air.)

That allowed the researchers to examine the plants' "feet" without having to dig them up and damage them in the process. Pristine material was critical for this study, which involved painstaking counting and measurement of branching roots and even the fine threadlike root hairs that draw in water and nutrients.

They had considered hydroponics. But after testing various options, Gaudin designed an aeroponics system along with McClymont, undergrad student Bridget Holmes and Darryl Hudson, a PhD student in Molecular and Cellular Biology.

"Amelie built it from scratch," says Raizada. "I had never heard of aeroponics."

Gaudin still studies roots in her post-doctoral work at the International Rice Research Institute in the Philippines. Writing from abroad, she says, "Our aim is to provide smallholder farmers with drought-tolerant rice cultivars," particularly in Southeast Asia and South America.

So novel was the Guelph scientists' closed-loop mist-spraying system that they wrote a separate paper about the setup – and comparisons with pot-grown plants – published in *Plant Cell and Environment*. Says Raizada: "No one has ever used aeroponics for root architecture studies. This is the first time in any species."

Many of their 200-odd plants grew root systems up to six feet long. The scientists had to separate the roots and float them in water in a special flat-bed scanner that electronically measured their length.

That system wasn't detailed enough for the tens of thousands of finer root hairs. McClymont hand-traced the structures under a microscope to create images that were then analyzed by computer.

Raizada says they needed to include root hairs where individual proteins move nutrients such as nitrogen and phosphorus into the plant. He and PhD student Christophe Liseron-Monfils are now looking at genes coding for those proteins.

His ultimate goal is to tap into ancient genetic potential to help improve modern corn. Many of the plant's ancestors originally grew on slopes with little water and sparse nutrients. Those conditions resemble challenges faced by many poor farmers today in developing countries.

He hopes his work will yield new cultivars for those growers. "Tens of millions of farmers in Africa farm on hillsides that may resemble that of ancient Mexico from the region where corn originated."

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