The roots of breeding

Aeroponics trials give Guelph researchers a unique worm's eye view of crop development

Written by **Natalie Osborne**

Little is known about corn's extensive root system, even though it's responsible for absorbing nutrients and can account for up to half of the plant's biomass. In the past, researchers and breeders neglected to examine roots as extensively because of their complexity and limited accessibility underground.

Aeroponics research containers at the University of Guelph.
PHOTO COURTESY AMELIE GAUDIN

Now, the secrets of corn root architecture are being unearthed by a greenhouse system known as aeroponics, where plants are grown in air instead of soil. University of Guelph researchers are using aeroponics to discover what makes roots more efficient at absorbing nitrogen and other important nutrients for plant growth.

For centuries, corn has been selectively bred to improve grain productivity without realizing its effects below ground. Prof. Manish Raizada and PhD student Amelie Gaudin from the Department of Plant Agriculture examined corn and its ancestors, to discover which root systems were ideal for production and why.

"Our project is about how to capture and use nitrogen more efficiently, so we can reach 100 per cent yield potential using fewer resources, such as nutrients and water," says Gaudin. "This will help us face the challenges ahead where we'll have to produce using less."

HOW CAN CROPS BETTER ABSORB NITROGEN FERTILIZER?

■ Normally, only 30 per cent of the nitrogen fertilizer applied to corn will end up in the grain. And when farmers apply nitrogen fertilizer to their fields, about 50 per cent of it is lost to the environment where it can pollute groundwater or get converted into greenhouse gases. That's why making corn more efficient at absorbing nitrogen has both economic and environmental significance.

Little is known about corn's extensive root system.
PHOTO COURTESY TOP CROP MAGAZINE

Finding a realistic and reliable way to examine roots was the researchers' first step towards better understanding nitrogen absorption. They said they needed a system that would allow them to examine mature root systems dynamically in order to detect changes in root architecture under different growing conditions.

The idea for using an aeroponics system in a greenhouse was inspired by epiphytes – plants whose roots naturally grow in the air. For this reason, aeroponics can be used to grow vegetables such as tomatoes and lettuce in greenhouses.

AN UNOBSTRUCTED VIEW OF THE ROOTS

■ Gaudin set up a greenhouse aeroponics system where the roots were growing in darkness inside empty barrels, and then misted with a nutrient solution. With this method, the corn was able to reach maturity while the roots grew unobstructed in the air, giving researchers an unprecedented look at mature corn root systems.

Gaudin treated the plants with high and low nitrogen solutions to see how root systems responded to different nitrogen stresses. The greenhouse aeroponics system allowed her to use realistic concentrations to simulate a nitrogen stress the plant would actually experience in the field.

She tracked plant growth by staining the roots with a red dye and then examined them 24 hours later. The white, unstained root tips allowed the researchers to see the segments that had grown in the time since the last staining.

DEVELOPING HIGHLY DETAILED THREE-DIMENSIONAL IMAGES

■ Gaudin also scanned the roots, which involved meticulously separating the long crown roots, the smaller, more numerous lateral roots and the microscopic root hairs. With just one mature plant, Gaudin would scan around 600 metres of root material to develop highly detailed, three-dimensional computer images to characterize and compare the extensive root systems.

The goal is to breed more efficient crops that require less fertilizer.

In soil and in air, roots will grow towards nutrient sources, a phenomenon known as root plasticity. Gaudin discovered that this plasticity contributed more to nutrient uptake efficiency than the size of the root system. She noted that plants that can change their root architecture quickly can access water and nutrients more efficiently.

Gaudin also wondered if selective breeding had altered the plant's root systems, for better or worse. She compared corn to its wild ancestor, teosinte, which grew 10,000 years ago in Mexico's hot, tropical climate with limited access to water or nutrients. Over the years, farmers have selectively bred teosinte to create modern corn. But above ground, it no longer resembles its hardy ancestor.

"I wanted to know what teosinte's roots looked like," says Gaudin. "I thought they might be more efficient in capturing resources, which turned out to be true. So we could incorporate the gene pool from teosinte and other plants into our modern corn breeding to improve roots."

Corn's root system is three times smaller than teosinte, with fewer crown and lateral roots, and shorter root hairs. Gaudin believes teosinte's long root hairs may improve its ability to dissolve phosphorus, a mineral vital to plant health that is usually immobile within the soil.

HOW PLANTS ADAPT TO NITROGEN STRESS

■ The plants also have different strategies to deal with nitrogen stress. In low nitrogen conditions, corn develops more second order lateral roots, while teosinte reduces the number of shoots above ground.

Overall, the eventual goal is to breed more efficient crops that require less fertilizer. Gaudin says this could be achieved by using the genetic resources of corn's efficient ancestors in combination with information on the genes responsible for beneficial root characteristics.

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