What keeps plant roots growing toward gravity? Study identifies four genes

September 26 2022

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What happens belowground in a corn field is easy to overlook, but corn root architecture can play an important role in water and nutrient acquisition, affecting drought tolerance, water use efficiency, and sustainability. If breeders could encourage corn roots to grow down at a steeper angle, the crop could potentially access important resources deeper in the soil.

A first step toward that goal is learning the genes involved in gravitropism, root growth in response to gravity. In a new study published in the *Proceedings of the National Academy of Sciences*, University of Wisconsin scientists, in collaboration with researchers at the University of Illinois. identify four such genes in corn and the model plant Arabidopsis.

When a germinating seed is turned on its side, some roots make a sudden, steep turn towards gravity, while others turn a fraction more slowly. The researchers used machine vision methods to observe subtle differences in root gravitropism in thousands of seedlings and combined that data with genetic information for each seedling. The result mapped the likely positions of gravitropism genes in the genome.

The map got the researchers to the right neighborhood in the genome—regions of a few hundred genes—but they were still a long way from identifying specific genes for gravitropism. Fortunately, they had a tool that could help.

"Because we had previously performed the same experiment with the distantly related Arabidopsis plant, we were able to match genes within the relevant regions of the genome in both species. Follow-up tests verified the identity of four genes that modify root gravitropism. The new information could help us understand how gravity shapes root system architectures," says Edgar Spalding, professor in the Department of Botany at the University of Wisconsin and lead author of the study.

Matt Hudson, professor in the Department of Crop Sciences at the University of Illinois and study co-author, adds, "We looked at an under-researched trait in maize that is important for a number of reasons, especially in the context of climate change. And we did it by making the evolutionary differences between plants work in our favor."

Corn and Arabidopsis, a small mustard relative exhaustively described by plant biologists, evolved about 150 million years apart in evolutionary history. Hudson explains that although both species share basic plant functions, the genes controlling them have likely been jumbled within the genome over time. That's turns out to be a good thing for narrowing down common genes.

In closely related species, genes tend to line up in approximately the same order in the genome (e.g., ABCDEF). Although the same genes might exist in distantly related species, the order of genes in the region the trait maps to doesn't match (e.g., UGRBZ). After the researchers identified where to look in each genome, the otherwise mismatched gene sequences made the common genes (in this case B) pop out.

"I thought it was super cool that we could identify genes we wouldn't have found otherwise just by comparing genomic intervals in unrelated plant species," Hudson says. "We were pretty confident they were the right genes when they popped right out of this analysis, but Spalding's group then spent seven or eight more years getting solid biological data to verify they do, indeed, play a role in gravitropism. Having done that, I think we've validated the whole approach such that in future, you could use this method for many different phenotypes."

Spalding notes the method was probably particularly successful because precise measurements were made in a common environment.

"Often, maize researchers will measure their traits of interest in a field, whereas Arabidopsis researchers tend to raise their plants in growth chambers," he says. "We measured the root gravitropism phenotype in a highly controlled way. These seeds were grown on a petri plate, and the assay lasted just hours, as opposed to traits you might measure in the real world that are open to all sorts of variabilities."

Even when traits can be measured in a common environment, not all traits make good candidates for this method. The researchers emphasize traits in question should be fundamental to basic plant function, ensuring the same ancient genes exist in unrelated species.

"Gravitropism may be especially amenable to study through this approach because it would have been key to the original specialization of shoots and roots after the successful colonization of land," Spalding says.

Hudson notes gravitropism will be key to colonization of a different landscape, as well.

"NASA is interested in growing crops on other planets or in space and they need to know what you'd have to breed for to do that," he says. "Plants are pretty discombobulated without gravity."

More information: Leveraging orthology within maize and Arabidopsis QTL to identify genes affecting natural variation in gravitropism, *Proceedings of the National Academy of Sciences* (2022). DOI: 10.1073/pnas.2212199119

Provided by University of Illinois at Urbana-Champaign genes.html