Using Ancient Genes to Improve Modern Crops

Today's corn crops require high amounts of nitrogen (N) to produce optimal yield. For decades, corn has been grown with synthetic fertilizers, but thousands of years ago, corn was just a wild grass indigenous to the Mexican Balsas River Valley. Known as Balsas teosinte, this ancient maize grew in a mountainous environment where nutrient-availability varied, and competition was fierce.

A study from the University of Guelph in Ontario suggests that future of crop improvement may lie in the genes of the past. As it is estimated that modern corn roots take up only 50% of added nitrogen fertilizer, PhD student Amelia Gaudin in the Laboratory of Manish Raizada at the University of Guelph hypothesized that Balsas teosinte may contain adaptive traits to low nitrogen that aren't present in domesticated corn. Specifically, Gaudin was curious how the roots of teosinte plants respond to a low amount of ammonium nitrate fertilizer.

Examining dynamic responses by roots of a mature teosinte plant was a challenge. Mature corn roots are known to be 3 to 6 feet long. Excavating roots this long from soil would damage root hairs and fine tissues. Hydroponics wasn't an option because roots develop poorly when constantly bathed in nutrients.

To address these challenges, Gaudin grew her roots in the air, a technique known as aeroponics. Large garbage cans from a local hardware store were fitted with spray jets that gently misted roots with a nutrient solution for a few seconds every minute. This method allowed Gaudin to measure her fine root structures at any time.

"Root traits are notoriously difficult to select for in breeding programs involving large crops," says Gaudin. "Aeroponics offer new prospects for root phenotyping and as a tool for genetic and physiological studies of root traits under a wide array of root environments."

By using this technique, Gaudin and undergraduate assistant Sarah McClymont discovered that teosinte and a modern maize inbred (W22) achieve a similar overall objective when faced with limited nitrogen, but often use different strategies.

Above ground, both types of plants reduce shoot biomass in response to low nitrogen in order to decrease nitrogen demand. However, while the inbred reduces average leaf size to compensate for nitrogen limitation, teosinte reduces tiller number and hence leaf number. This result matched an earlier observation made by Garrison Wilkes of the University of Massachusetts in 1977.

The University of Geulph researchers also found that modern corn's response of increasing root system depth to scavenge further away from the stem under low nitrogen is an ancient trait that was actually exaggerated in teosinte. To compensate for the energy required to lengthen its roots, Gaudin discovered that teosinte reduces tiller number to reduce the number of thick roots that initiate from each stem's base. Modern maize instead reduces its total root number, independent of tillering. This suggests that maize evolved a new adaptive trait to low nitrogen after domestication.

After analyzing more than 96,000 images of root hairs over the course of four months, Gaudin and McClymont showed that both teosinte and modern maize reduced root hair length in response to low nitrogen. While the modern inbred reduced the average root hair length, teosinte instead reduced root hair density.

Finally, the researchers found evidence that the wild ancestor of corn may possess nitrogen-uptake proteins better adapted to a lower nitrogen ecosystem than in the modern inbred.

These results identify important traits for possible genetic improvement of modern corn in years to come. Gaudin believes it is worth breeding in genes that control root elongation during low nitrogen from the wild ancestor into modern corn. Breeding nitrogen-uptake proteins suited for low-nitrogen conditions found in teosinte into modern corn may be another worthwhile objective.

"In light of the challenges ahead, there is now considerable interest in the opportunities for improving crop root architecture to enhance nutrient uptake," says Gaudin. "I hope to show the scientific community and maize breeders that root systems should be considered, even if challenging, in breeding strategies to develop better crops to ultimately improve the resilience, sustainability and conservation of our agro-ecosystems."

The full results from this study can be found in the November/December 2011 issue of *Crop Science*.

Material summarized from:
The Nitrogen Adaptation Strategy of the Wild Teosinte Ancestor of Modern Maize, *Zea mays* subsp. *parviglumis*
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