Researchers show potential for improved water-use efficiency in field-grown plants

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From left to right: Emily Gibson (Cornell), Liana Acevedo-Siaca (Illinois), Coralie Salesse-Smith (Illinois). Credit: Claire Benjamin/RIPE project

Water deficit is currently one of the most significant limiting factors for global agricultural productivity, a factor further exacerbated by global

climate change, according to a 2019 water report from the Food and Agriculture Organization (FAO) of the United Nations. As a result, researchers worldwide have been working to improve water-use efficiency in crops to better cope with water-scarce conditions.

In a recent study published in the *Journal of Experimental Botany*, a team from the University of Illinois, the Volcani Center (Agricultural Research Organization, Israel), and the University of Cambridge found that by overexpressing a sugar-sensing enzyme, called hexokinase, in field-grown tobacco plants, they could improve intrinsic water-use efficiency (iWUE) without decreasing photosynthetic rates or biomass production.

Tobacco was used as a model crop because it is relatively easy to work with within the laboratory, greenhouse, and field. Results in this crop can be seen at a much quicker pace than in food crops, which are more difficult and time-consuming to modify and grow. Therefore, tobacco was chosen as the initial test crop to see if similar results could be proven. After showing success in the model crop, the researchers can then confidently mirror the developments in food crops, such as cassava, cowpea, rice, and soybean.

This study demonstrates the potential to generate plants with more conservative water-use throughout the growing season under field conditions and moderate water limitation, without significant yield penalty. For farmers, this could decrease soil water depletion throughout the growing season and reduce reliance on irrigation.

This work is part of Realizing Increased Photosynthetic Efficiency (RIPE), an international research project that aims to increase global food production by developing food crops that turn the sun's energy into food more efficiently.

During photosynthesis, plants open tiny pores in their leaves, called stomata, to take in CO_2. However, when the pores are open, water is also allowed to escape through transpiration. This leaves plants with a trade-off between losing too much water for the sake of taking in CO_2.

"Stomatal pores consist of a pair of guard cells that control the opening and closure of the pores," said Liana Acevedo-Siaca, who led this study at Illinois during her time as a postdoctoral researcher. "Previous studies have shown that genetic manipulation of signal elements that trigger stomatal movement, such as overexpressing Arabidopsis Hexokinase 1 (AtHXK1) in the guard cells, can stimulate stomatal closure and adjust that trade-off for plants." Acevedo-Siaca now works as an Associate Scientist in the Global Wheat Program at the International Maize and Wheat Improvement Center (CIMMYT) in Mexico.

It was previously shown that guard-cell-targeted expression of AtHXK1 can improve WUE in crops, as well as their tolerance to drought conditions and salinity stress because hexokinase signals to the pores that there is enough sugar, eliminating the need to fix more CO_2. However, these previous studies were only evaluated in crops grown in controlled environments, such as greenhouses.

"To improve our understanding of the potential benefits of guard-cell-targeted AtHXK1, our study used two homozygous transgenic lines expressing AtHXK1 and a line that had guard-cell-targeted overexpression of AtHXK1 that were evaluated relative to wild-type field-grown tobacco to test WUE for traits related to photosynthesis and yield," said Johannes Kromdijk, assistant professor at the University of Cambridge, who started this study in 2018.

"Our results confirmed that constitutive overexpression of AtHXK1 decreases productivity. We also showed that guard-cell-targeted overexpression of AtHXK1 could improve iWUE relative to wild-type

without negatively impacting CO_2 assimilation. Still, this difference was strongly dependent upon leaf age, and recent rainfall could eliminate differences in performance."

More information: Liana G Acevedo-Siaca et al, Guard-cell-targeted overexpression of Arabidopsis Hexokinase 1 can improve water use efficiency in field-grown tobacco plants, *Journal of Experimental Botany* (2022). DOI: 10.1093/jxb/erac218

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