Science Societies

A new model for salt tolerance in tomatoes

By DJ McCauley

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Hui Yang with experimental tomatoes in a greenhouse at New Mexico State University. Photo by Manoj Shukla.

- In the southwestern United States, drought conditions are driving greater groundwater pumping for agricultural irrigation, and with deeper pumping from aquifers comes increased water salinity.
- New *Vadose Zone Journal* research tests the salinity threshold of tomatoes to see how much salt plants can tolerate before yields fall.
- The team created a model that can be applied to a variety of horticultural and agricultural crops to predict yield and evapotranspiration responses to saline irrigation water.

The Elephant Butte Reservoir perches near Truth or Consequences, and it's severely short on necessary irrigation water for farmers in southern New Mexico.

The Elephant Butte Irrigation District (EBID) allocates 36 inches of water per acre per year for its farmers; but since 2005, it's only provided the full allocation one time. Last year's inflow to the Reservoir was described as "dismal," by EBID, which predicts that only 4% of the Reservoir's capacity will be met in 2021 (**https://bit.ly/33cEL5r**).

"It's a serious shortfall of water," says SSSA member Manoj Shukla. "Farmers have to turn to pumping the groundwater quite a bit, and that's a big problem. These aquifers in New Mexico are not contiguous, and they are saline. Depending on where you are, they can be *highly* saline."

Shukla is a Professor of Environmental Soil Physics at New Mexico State University. With his then-graduate student, Hui Yang, at the helm, the team investigated the limits of salt tolerance in an important horticultural crop: tomatoes.

Their research was published in a recent *Vadose Zone Journal* special section, “Transdisciplinary Contributions to Soil Physical Hydrology.” Here, they tested tomato yield and evapotranspiration in the greenhouse under irrigation with water of varying salinity and created a new, simplified model for predicting when salinity will negatively impact tomato growth (**https://doi.org/10.1002/vzj2.20074**).

Saline Groundwater

By one estimate, 1,125 million hectares of land worldwide are affected by salt with 76 million of those hectares negatively impacted by human contributions to soil sodification through irrigation with saline water (**https://bit.ly/3lYhewl**).

Though groundwater aquifers are an important source of irrigation water, the deeper you pump, the more saline they become. As water travels through the aquifers, it lives up to its name as the “universal solvent,” dissolving salt from the surfaces it contacts. The denser, salty water sinks below less saline water over time, creating a gradient within the aquifer.

Not only is the water saline, but it’s not exactly a renewable resource. Sustained groundwater pumping leads to water depletion, which in turn, can lead to decreased water flow in groundwater-fed streams and lakes, not to mention higher costs for pumping as the depth to water increases (**https://on.doi.gov/39cetnN**).

Disregarding the eventual depletion of groundwater sources, a proximal issue remains: how much salt can plants tolerate before their growth and yield decrease?

In arid climates, soil irrigated with saline water can accumulate salts over time, increasing soil salinity. For plants grown in salty soils, irrigation with saline water creates a one-two punch of abiotic stress.

But if accumulated soil salinity is low enough, irrigating with saline water will still leach some salt from the soil, and most plants—except those particularly sensitive to salt stress—will still grow.

This is the question Shukla and Yang took to the greenhouse. Here, they tested the effect of a range of saline irrigation water on tomatoes grown from seed, looking at the specific point at which water salinity negatively impacts evapotranspiration and yield.

A panoramic view of Elephant Butte Reservoir in New Mexico. Photo by Richard Stephen Haynes and courtesy of Wikimedia Commons.

Salt and Tomatoes

Yang spent a year at New Mexico State on exchange from her home institution, China Agricultural University (CAU), where she recently earned her doctorate.

Back at CAU, Yang had already done lots of work with tomatoes. In fact, China grows more tomatoes than anywhere else in the world—61.5 million tonnes in 2018, according to the Food and Agriculture Organization of the United Nations (**https://bit.ly/3kZfguE**). America ranks third at 12.6 million tonnes, behind India and only narrowly ahead of Turkey.

In an earlier experiment, Yang mixed salt directly into soil. At New Mexico State, Yang and Shukla used locally sourced irrigation water to test the impact of varying salinity.

Yang filled grower pots with sandy loam soil mixed with a small amount of fertilizer and planted two tiny tomato seeds. She chose the hardier seedling of the two and ran treatments.

They used tap water from the greenhouse as a control and four irrigation water salinity treatments with electrical conductivity (EC) of 2, 3, 4, and 6 dS m^{-1}. Electrical conductivity is a common metric used by farmers and irrigation engineers for gauging water salinity. For reference, the stock brackish groundwater the team sourced from the Brackish Groundwater National Desalination and Research Facility at Alamogordo, NM clocked in at an EC of 4 dS m^{-1}.

Plant growth, evapotranspiration, and the number of tomatoes produced as well as their biomass were measured. Though not part of this study, Yang noticed other changes.

“Under salt stress, the leaves are smaller and thicker,” Yang says. “Smaller, thicker leaves decrease evapotranspiration, which decreases the amount of energy a plant needs to spend on water uptake.”

Plants could tolerate high salinity, up to 2.52 dS m^{-1}, before evapotranspiration decreased markedly. Yield was much more sensitive to salt stress. Average fruit biomass dropped off at 1.73 d dS m^{-1} though the plants still produced the same number of tomatoes.

But how do they taste?

"They're sweeter!" Shukla says. "There's a whole area of research using salinity as a value-added product. For example, when you subject chili [pepper] to higher salinity and it becomes stressed, its heat index increases. Stressing tomatoes actually increases their sugar content. They're smaller but sweeter."

A New Model for Salt Stress

With greenhouse results in hand, the team sought to test its findings against four existing models of relative evapotranspiration and relative yield as a function of soil. Soil salinity was measured using the electrical conductivity of soil saturated paste extract (EC_e). Commonly used by soil physicists, EC_e gives an accurate measure of dissolved salts present in the soil (**https://bit.ly/2UU2DXb**).

Tomatoes grown under experimental conditions in a greenhouse at New Mexico State University. Photo by Manoj Shukla.

Researchers design these models to estimate the point at which a measurement of plant growth drops off due to salinity stress: the break point.

The researchers tested their proposed model against previous models using both their own collected greenhouse data as well as data mined from other studies using different tomato varieties.

"The previous models didn't take the plant's real response into account. There's another break point, after which the slope of the yield reduction as a function of salinity was reduced…the curve gradually stabilizes to a constant, which reflects a more realistic plant adaptation to salinity."

That is to say that there are two break points. First, a plant can tolerate a certain amount of saline irrigation before it shows a response to salt stress. Eventually, even under high salinity, there is a second break point where the model levels out, showing no further yield decreases due to salt stress.

Yield biomass was found to be more sensitive to salt stress than evapotranspiration.

"The water content of the tomato fruit is as high as 93 to 95%" Yang says. "When the plant is under saline conditions, the first thing it decreases is the water content of the fruit."

With a model hinged on only three parameters—water salinity, evapotranspiration, and yield—the researchers created a system that can work for many different crops, giving farmers and irrigation engineers insights into how much salinity they can use for irrigation before it will negatively impact their crops.

Finally, the team made sure that the model is useful for farmers and irrigation engineers. It's a matter of units: soil scientists typically measure soil salinity in terms of EC_e, but translating the model to units of water salinity makes it simple for farmers and irrigation engineers to see how the specific EC of their water will impact plant growth.

"There's a big disconnect in soil physics between researchers and local farmers and other people because soil physicists usually talk in terms of mathematics," Shukla says.

This study helps break down the communication barrier that could prevent irrigation engineers and farmers from using the model. In a move as simple as translating the units into terms commonly used by other disciplines, a simple and useful tool was created for dealing with saline irrigation water.

Dig Deeper

View the open access article, "Modeling Tomato Evapotranspiration and Yield Responses to Salinity Using Different Macroscopic Reduction Functions," at **https://doi.org/10.1002/vzj2.20074**. This is part of a special section, titled, "Transdisciplinary Contributions and Opportunities in Soil Physical Hydrology," available at **https://bit.ly/3qNGmJg**.

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