

Grafting can improve tomato plants' tolerance to salt in irrigation water¹



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Note: Fresh tomatoes at a market in Buraydah, Saudi Arabia.

Common tomato varieties face dual challenges of increasing demand and water scarcity in Saudi Arabia

Tomatoes, known for their nutritional and health benefits,³ are among the most cultivated vegetables in the world. Increasing demand for them in Saudi Arabia is supporting substantial domestic production but also creating strong incentives to improve yields. While greenhouse cultivation and other forms of protected cultivation already account for upwards of 40% of the Kingdom's tomato production, "sustainable intensification," including protected soilless culture systems, has been proposed to increase production efficiency and reduce environmental impact.

At the same time, farmers in arid regions with limited access to freshwater, such as Saudi Arabia, are turning increasingly to brackish water for irrigation, but the salinity of that water can stress tomato plants, reducing their growth and crop yields. Efforts to increase the plants' salt tolerance through plant breeding, biotechnology, and farming practices have had limited success, as has genetic engineering. This deficit prompted the research team to explore whether grafting, focusing on protected soilless cultivation, can hasten progress.

The bottom line

- This collaboration between KAUST² and other Saudi researchers shows the potential of grafting high-yielding commercial tomato varieties onto salt-tolerant rootstocks, developed locally at KAUST, to improve plant performance when irrigation water is brackish.
- A recent patent application from the KAUST members of the research team demonstrates potential for creating marketable stress-tolerant plants.
- The study also suggests that tomato plants perform better growing in volcanic rock than in sand, regardless of salinity, and that volcanic rock can help mitigate the adverse effects of salinity.
- Faced with freshwater scarcity, farmers in Saudi Arabia are turning increasingly to brackish irrigation water, which can stress tomato plants, but they are also seeking higher yields to meet increasing domestic demand for tomatoes.

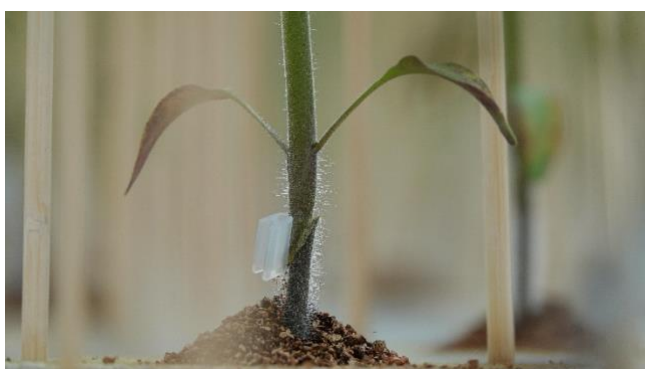


Grafting high-yielding commercial varieties onto locally developed, stress-tolerant rootstocks can help address challenges

This innovative study suggests that grafting may be an effective route to addressing dual challenges of meeting increasing demand for tomatoes and water scarcity in Saudi Arabia. The research shows that grafting locally preferred commercial tomato varieties as *scions* (top plants) onto novel *rootstocks* (bottom plants) developed from salt-tolerant wild tomato relatives can improve plant performance under local growing conditions, including those depending on brackish water for irrigation. This approach can introduce resilience through the root system without requiring replacement of the preferred commercial fruit variety.

The team used a high-yielding commercial tomato variety commonly cultivated in Saudi greenhouses as the scion and tested it on several different rootstocks. These included a commercial rootstock, the Saudi variety “Alawamiya365,” and two novel rootstocks, “X-218” and “X-238,” developed locally at KAUST in Saudi Arabia by crossing cultivated tomato with a wild tomato relative native to South America known for its salt tolerance.

The photo below shows details of a grafted tomato plant in a greenhouse. Grafting the high-yielding scion onto the stress-tolerant rootstock yielded a single plant that combines the best features of each: a productive plant that can tolerate the stresses of Saudi cultivation. The KAUST members of the research team took the idea further in a patent application for grafting that represents a step toward marketability.⁴



Source: ©Shutterstock/Andrei Shcherbinin 2022.

Note: Tomato seedling grafting technology close-up.

Figure 1. shows how tomato grafting works, by joining scions, the upper parts of plants with rootstocks, the lower parts. The scion determines the fruit produced, allowing growers to retain preferred commercial tomato varieties, while the rootstock provides the root system and can contribute traits such as tolerance to environmental stresses. After the graft heals, the two parts grow together as a single plant.

Saline irrigation adversely affects tomato plant performance, but less so for grafted plants

Grafted plants generally performed better than non-grafted plants under saline irrigation, although all plants performed equally better under the lower-salinity treatment. In particular, the commercial scion grafted onto X-238 showed strong growth and productivity under salt stress. These results support grafting as a practical strategy for improving tomato resilience when brackish water must be used for irrigation.

Across every measured plant trait, higher salinity reduced plant performance, while grafting generally improved performance relative to non-grafted plants. Grafted plants also accumulated higher levels of proline, an amino acid associated with plant responses to salt and other stresses.

Volcanic rock can further mitigate adverse effects of saline irrigation

Volcanic rock and sand are two types of growing media, both of which are abundant and suitable for use in protected cultivation systems in Saudi Arabia. Tomato plants grown in volcanic rock performed better than those grown in sand. This was true for plants with saline and non-saline irrigation. Volcanic rock provided the plants with good drainage, a slightly neutral pH, and adequate root aeration.

Sand is a less porous medium for growing plants. Salt accumulated around the roots of plants grown in sand and irrigated with salt water. This accumulation stresses the plants and adversely affects their height, diameter, and leaf size. Even with non-saline irrigation, plants grown in sand did not grow as well as those in volcanic rock.

The difference between plants grown in volcanic rock and those grown in sand shows that the choice of medium — in this case, volcanic rock or sand — can either buffer or exacerbate the effects of salinity on tomato plants.

Research team systematically compared options

The research team sought to identify the combination of high-yielding plants and stress-tolerant rootstocks that would perform best across different irrigation methods and growing media. The team considered six grafting treatments, two irrigation methods (saline and non-saline), and two types of growing media (sand and volcanic rock). They evaluated the varieties' performance by growth, physiological characteristics, and yield under the same controlled conditions.



Across all scenarios, the high-yield commercial variety grafted onto X-238 performed the best in growth, other physiological characteristics, and yield, while the same high-yield commercial variety, not grafted onto any rootstock, generally performed the worst. Grafting onto X-238 increased yield compared with the non-grafted treatment in both sand and volcanic rock, including under salt stress.

Summing up

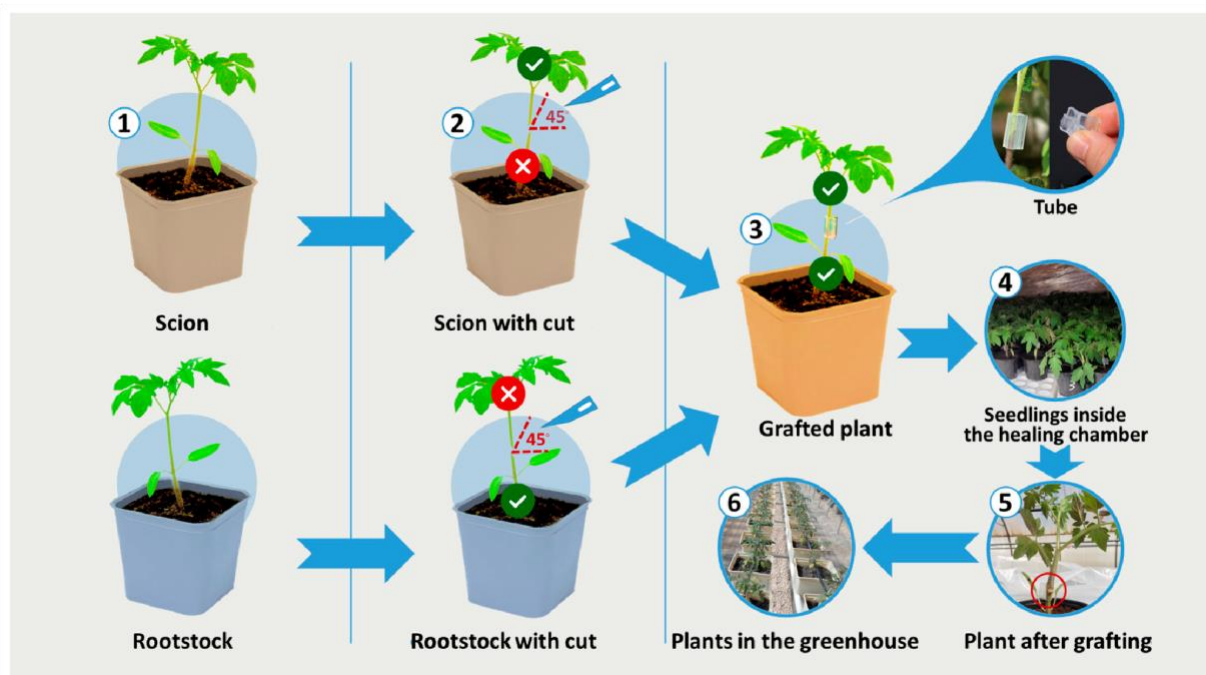
The increased demand for tomato in Saudi Arabia, as well as environmental constraints on growing them, suggests the need for innovative strategies to ensure sufficient crop production. One strategy is developing plants that are better able to grow in prevailing conditions, including with saline irrigation, which occurs in arid areas such as Saudi Arabia, and soilless growing media, such as sand and volcanic rock, which are abundant there.

The research team explored grafting a high-yielding commercial variety onto a diverse set of rootstocks, including commercial material, a Saudi variety, and novel rootstocks developed at KAUST. The strongest-performing rootstock, X-238, was developed from a cross between a cultivated

tomato and a wild tomato species. The results illustrate how developing new rootstocks can draw on wider tomato genetic diversity to provide useful stress-resilience traits without employing lengthy breeding programs. This approach also retains the commercial scion variety that local growers and consumers prefer. Related KAUST work on rootstocks has also led to an international patent application, indicating a pathway toward commercialization.

Altogether, the research supports wider use of grafting as a promising strategy for tomato production in water-limited environments. By grafting established high-yielding commercial varieties onto resilient rootstocks, growers can potentially improve performance under saline irrigation without changing the fruit variety supplied to consumers. The strong performance of the locally developed X-238 rootstock also highlights the opportunity for researchers in Saudi Arabia to make greater use of tomato genetic diversity, including traits from wild relatives, to develop rootstocks adapted to the Kingdom's production challenges. Among the two growing media tested, volcanic rock also performed better than sand and may help mitigate some adverse effects of saline irrigation.

Figure 1. Illustration of the tomato grafting method, often called tube grafting or splice grafting



Source: Alqardaeai et al. 2024.⁵

Note: A scion is a plant grafted onto a rootstock, which supplies the root and stem.



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1. This Policy Brief summarizes findings from Alqardaeai, Thabit, Abdulaziz Alharbi, Mekhled Alenazi, Abdulrasout Alomran, Ahmed Elfeky, Mohamed Osman, Abdullah Obadi, Abdulhakim Aldubai, Nathaly Rodriguez Ortiz, Vanessa Melino, Mark Tester, and Yveline Pailles. 2024. "Effect of Tomato Grafting onto Novel and Commercial Rootstocks on Improved Salinity Tolerance and Enhanced Growth, Physiology, and Yield in Soilless Culture." *Agronomy* 14 (7): 1526. <https://doi.org/10.3390/agronomy14071526>. All rights and any third-party permissions remain with the respective rightsholders. In addition, Dr. Pailles provided further insight into the implications of the research.
2. King Abdullah University of Science and Technology (KAUST).
3. Tomatoes are abundant in minerals and antioxidants and can protect against chronic diseases.
4. Red Sea Farms, Claudia Yveline Pailles Galves, and Mark Alfred Tester. 2024. *Polyploidization of Interspecific Tomato Hybrids to Create Stable and Fertile Rootstocks*. International patent WO 2024/200554 A1, filed 27 March 2024, and published 3 October 2024.
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