Researchers breed tomato plants that contain the complete genetic material of both parent plants

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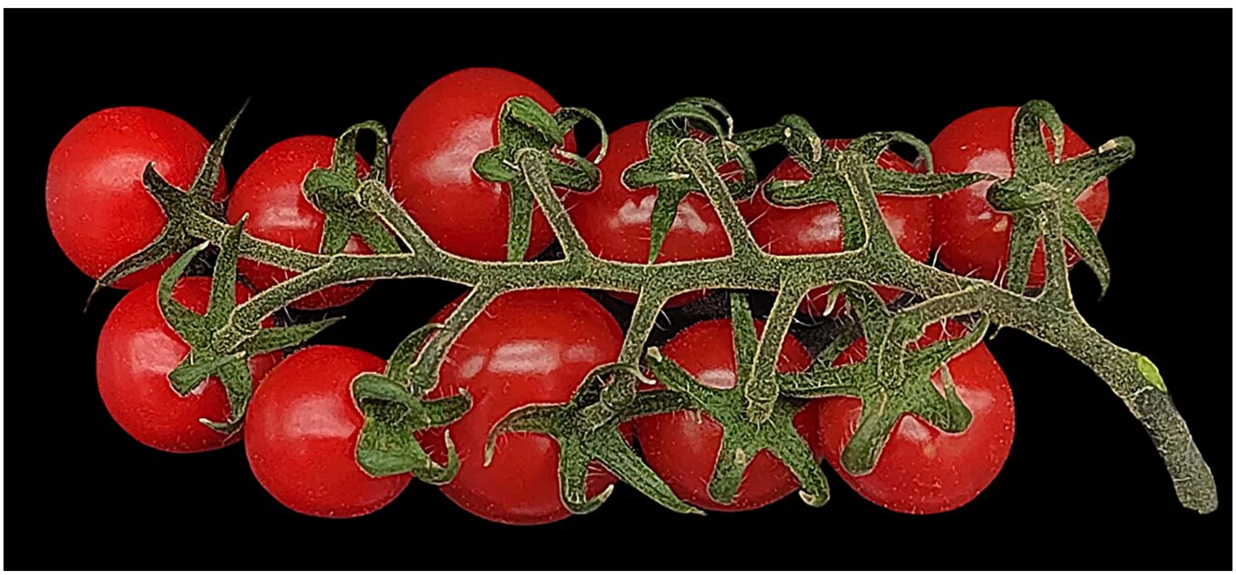

Tomato fruits produced by a tetraploid tomato plant (with 48 chromosomes) produced by crossing two different tomato MiMe parents. Credit: Yazhong Wang

In a new study published in *Nature Genetics*, led by Charles Underwood from the Max Planck Institute for Plant Breeding Research in Cologne, Germany, scientists established a system to generate clonal sex cells in tomato plants and used them to design the genomes of offspring.

The fertilization of a clonal egg from one parent by a clonal sperm from another parent led to plants containing the complete genetic information of both parents.

Hybrid seeds, combining two different parent lines with specific favorable traits, are popular in agriculture as they give rise to robust crops with enhanced productivity, and have been utilized by farmers for more than a hundred years.

The increased performance of hybrids is generally known as hybrid vigor, or heterosis, and has been observed in many different plant (and animal) species. However, the heterosis effect no longer persists in the subsequent generations of these hybrids due to the segregation of genetic information.

Thus, new hybrid seeds need to be produced every year, a labor-intensive and expensive endeavor that doesn't work well for every crop. So how can the beneficial traits, encoded in the genes of hybrid plants, be transferred to the next generation?

Typically, our genetic material undergoes reshuffling during meiosis—a crucial cell division occurring in all sexually reproducing organisms. This reshuffling, due to random segregation of chromosomes and meiotic recombination, is important in generating novel and beneficial genetic configurations in natural populations and during breeding.

However, when it comes to plant breeding, once you have a great combination you want to keep it and not lose it by reshuffling the genes again. Having a system that bypasses meiosis and would result in sex cells (egg and sperm) that are genetically identical to the parents could have several applications.

In this study, Underwood and his team established a system, in which they replace meiosis by mitosis, a simple cell division, in the most popular vegetable crop plant, the cultivated tomato. In the so-called MiMe system (Mitosis instead of Meiosis) the cell division mimics a mitosis, thus sidestepping genetic recombination and segregation, and produces sex cells that are exact clones of the parent plant.

The concept of the MiMe system has previously been established by Raphael Mercier, director at the Max Planck Institute for Plant Breeding Research, in Arabidopsis and rice. A breakthrough aspect of the new study is that for the first time the researchers harnessed the clonal sex cells to engineer offspring through a process they call "polyploid genome design."

Polyploid genome design

Usually, sex cells have a halved chromosome set (in humans, 46 chromosomes reduces to 23; in tomato 24 chromosomes reduces to 12) whereas the MiMe sex cells are clonal and therefore this halving of the chromosome set does not happen.

Underwood and his team performed crosses that meant that the clonal egg from one MiMe tomato plant was fertilized by a clonal sperm from another MiMe tomato plant. The resulting tomato plants contained the complete genetic repertoire of both parents—and is thereby made up of 48 chromosomes.

Hence all favorable characteristics from both hybrid parents are consolidated—by design—in one novel tomato plant. Because of the close genetic relationship between tomatoes and potatoes, the team around Underwood believes that the system described in this study can be easily adapted for use in potato, the world's fifth most valuable crop plant, and potentially other crop species.

In view of rising population figures and climatic changes, the development of high-yielding, sustainable, and stable varieties is crucial to securing the world's food supply in the long term. Therefore, it is critical to cultivate plants that exhibit heightened disease resistance and stress tolerance. Innovative approaches to plant reproduction technologies are essential.

Innovative technique seed production

The MiMe system and its application in polyploid genome engineering could be one promising avenue to tackle today's agricultural challenges.

"We are really excited about the possibility of using clonal sex cells to carry out polyploid genome design. We are convinced this will allow breeders to untap further heterosis—the progressive heterosis found in polyploids—in a controlled manner," says Underwood.

"The tomato MiMe system we have established could also be used as a component of clonal seed production—synthetic apomixis—in the future. This could massively reduce the cost of producing hybrid seeds," adds Yazhong Wang.

More information: Yazhong Wang et al, Harnessing clonal gametes in hybrid crops to engineer polyploid genomes, *Nature Genetics* (2024). DOI: 10.1038/s41588-024-01750-6

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