Genetic key discovered to dramatically increase yields and improve taste of hybrid tomato plants

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These are some of the improved hybrid tomatoes grown at the Hebrew University. Credit: Hebew University photo by Zak Lipman

Spectacularly increased yields and improved taste have been achieved with hybrid tomato plants by researchers at the Robert H. Smith Faculty of Agriculture, Food and Environment at the Hebrew University and the Cold Spring Harbor Laboratory (CSHL), New York.

The researchers have discovered the yield-boosting power of a single gene, which controls when plants make flowers and that works in different varieties of tomato and, crucially, across a range of environmental conditions. The discovery was patented by Yissum, the technology transfer arm of the Hebrew University, which is seeking potential partners for further development and commercialization.

"This discovery has tremendous potential to transform both the billion-dollar tomato industry, as well as agricultural practices designed to get the most yield from other flowering crops," says CSHL's Dr. Zach Lippman, one of the three authors of the study, which appears in the magazine Nature Genetics online . The study is co-authored by Dr. Uri Krieger and Prof. Dani Zamir of the Hebrew University.

The team made the discovery while hunting for genes that boost hybrid vigor, a revolutionary breeding principle that spurred the production of outstanding hybrid crops like corn and rice a century ago. Hybrid vigor, also known as heterosis, is the phenomenon by which intercrossing two varieties of plants produces more vigorous hybrid offspring with higher yields.

First observed by Charles Darwin in 1876, heterosis was rediscovered by CSHL corn geneticist George Shull 30 years later, but how heterosis works has remained a mystery.

Plants carry two copies of each gene, and Shull's studies suggested that harmful, vigor-killing mutations that accumulate naturally in every generation are exposed by inbreeding, but hidden by crossbreeding. But there is still no consensus as to what causes heterosis. A theory for heterosis, supported by this new Hebrew University-Cold Spring discovery, postulates that improved vigor stems from only a single gene - an effect called "superdominance" or "overdominance."

To find such overdominant genes, the US-Israeli team developed a novel approach by turning to a vast tomato "mutant library" - a collection of 5000 plants, each of which has a single mutation in a single gene that causes defects in various aspects of tomato growth, such as fruit size, leaf shape, etc. Selecting 33 mutant plants, most of which produced low yield, the team crossed each mutant with its normal counterpart and searched for hybrids with improved yield. Among several cases, the

most dramatic example increased yield by a whopping 60%.

This hybrid, the team found, produced greater yields because there was one normal copy and one mutated copy of only a single gene that produces a protein called florigen. This protein, touted as the breakthrough discovery of the year in 2004 in *Science* magazine, instructs plants when to stop making leaves and start making flowers, which in turn produce fruit.

In plants such as tomatoes, flowering (and therefore yield) is controlled by a delicate balance between the florigen protein, which promotes flowering, and another related protein that delays flowering. A mutation in only one copy of the florigen gene causes the hybrid to produce more flowers in less time - the key to improved yield. What the researchers found is that to maximize yield, there can't be too much or too little florigen. A mutation in one copy of the gene results in the exact dose of florigen required to cause heterosis.

The scientists have observed the gene's heterosis effect in different varieties of tomatoes and in plants grown in different climate and soil conditions, both in Israel and in New York at CSHL and the Cornell Horticultural Experiment Station at Riverhead, N.Y.

In addition to superior yield, the hybrids also display another, perhaps equally important quality - taste. Tomato plants only produce a finite amount of sugar, which they distribute equally among their fruits. So higher yields usually result in each fruit having a lower sugar content. But, remarkably, the florigen gene also boosted sugar content and sweetness of the individual fruits.

This study marks the first example of a single gene that consistently causes heterosis. The scientists are now looking to team up with agricultural companies to develop the hybrids for commercial use. The

concept that mutations in one copy of a single gene can improve yield has broad implications for breeders. Mutant plants are usually thrown away because of the notion that mutations would have negative effects on growth, but this study suggests that hybrid mutations might lead the next revolution of improved crops.

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