Crop scientists discover gene that controls fruit shape

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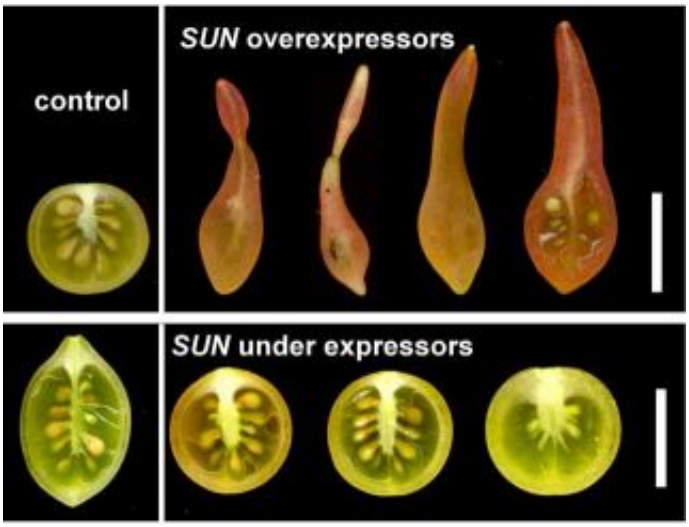

Tomatoes with SUN gene turned on and knocked out. Photo courtesy Ohio State University

Crop scientists have cloned a gene that controls the shape of tomatoes, a discovery that could help unravel the mystery behind the huge morphological differences among edible fruits and vegetables, as well as provide new insight into mechanisms of plant development.

The gene, dubbed SUN, is only the second ever found to play a significant role in the elongated shape of various tomato varieties, said Esther van der Knaap, lead researcher in the study and assistant professor of horticulture and crop science at Ohio State University's

Ohio Agricultural Research and Development Center (OARDC) in Wooster.

The discovery was reported, as the cover article, in the March 14 issue of the journal *Science*.

One of the most diverse vegetable crops in terms of shape and size variations, tomatoes have evolved from a very small, round wild ancestor into the wide array of cultivated varieties — some large and segmented, some pear-shaped, some oval, some resembling chili peppers — available through most seed catalogs and for sale in supermarkets. However, very little is known about the genetic basis for such transformations in tomatoes, and virtually nothing has been discerned about morphological changes in other fruits and vegetables.

“Tomatoes are the model in this emerging field of fruit morphology studies,” van der Knaap pointed out. “We are trying to understand what kind of genes caused the enormous increase in fruit size and variation in fruit shape as tomatoes were domesticated. Once we know all the genes that were selected during that process, we will be able to piece together how domestication shaped the tomato fruit — and gain a better understanding of what controls the shape of other very diverse crops, such as peppers, cucumbers and gourds.”

One of the first pieces in van der Knaap’s fruit-development puzzle is SUN, which takes its name from the “Sun 1642” cultivated variety where it was found — an oval-shaped, roma-type tomato with a pointy end. The gene also turned out to be very common in elongated heirloom varieties, such as the Poblano pepper-like “Howard German” tomato.

“After looking at the entire collection of tomato germplasm we could find, we noticed that there were some varieties that had very elongated fruit shape,” van der Knaap explained. “By genetic analysis, we

narrowed down the region of the genome that controls this very elongated fruit shape, and eventually narrowed down that region to a smaller section that we could sequence to find what kind of genes were present at that location.

“In doing that,” van der Knaap continued, “we identified one key candidate gene that was turned on at high levels in the tomato varieties carrying the elongated fruit type, while the gene was turned off in round fruit. And after we confirmed that observation in several other varieties, we found that this gene was always very highly expressed in varieties that carry very elongated fruit.”

Once SUN was identified, the next step involved proving whether this gene was actually responsible for causing changes in fruit shape. To do so, van der Knaap and her team conducted several plant-transformation experiments. When the SUN gene was introduced into wild, round fruit-bearing tomato plants, they ended up producing extremely elongated fruit. And when the gene was “knocked out” of elongated fruit-bearing plants, they produced round fruit similar to the wild tomatoes.

“SUN doesn’t tell us exactly how the fruit-shape phenotype is altered, but what we do know is that turning the gene on is very critical to result in elongated fruit,” van der Knaap said. “We can now move forward and ask the question: Does this same gene, or a gene that is closely related in sequence, control fruit morphology in other vegetables and fruit crops?”

Something else van der Knaap and her team found out is that SUN encodes a member of the IQ67 domain of plant proteins, called IQD12, which they determined to be sufficient — on its own — to make tomatoes elongated instead of round during the plant transformation experiments.

IQD12 belongs to a family of proteins whose discovery is relatively new

in the world of biology. So new that IQD12 is only the second IQ67 protein-containing domain whose function in plants has been identified. The other one is AtIQD1, discovered in the plant model Arabidopsis thaliana, which belongs to the same family as broccoli and cabbage. In Arabidopsis, AtIQD1 increases levels of glucosinolate, a metabolite that Ohio State researchers are studying in broccoli for its possible role in inhibiting cancer.

“Unlike AtIQD1, SUN doesn’t seem to be affecting glucosinolate levels in tomato, since these metabolites are not produced in plants of the Solanaceous family (which includes tomato, peppers, eggplant and other popular crops),” van der Knaap explained. “But there appears to be a common link between the two genes, which is that they may be regulating tryptophan levels in the plant. Thus, SUN may be telling us more about the whole process of diversification in fruits and across plant species, perhaps through its impact on plant hormones and/or secondary metabolites levels.”

In the process of identifying and cloning SUN, van der Knaap’s team was also able to trace the origin of this gene and the process by which it came to reside in the tomato genome.

Another unique characteristic of the SUN gene is that it affects fruit shape after pollination and fertilization, with the most significant morphological differences found in developing fruit five days after plant flowering. The only other fruit-shape gene previously identified — OVATE, a discovery by Cornell University plant breeder Steven Tanksley, van der Knaap’s advisor while she was a post-doctoral associate there — influences the future look of a fruit before flowering, early in the ovary development.

Source: Ohio State University

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