'Battle of the Sexes'—How inhibition of male flower production lets female flowers emerge

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Cucumber unisexual flowers: right: male, left: female

These are cucumber unisexual flowers: Male (right) Female (left). Credit: Prof. Rafael Perl-Treves

Most people don't know this, but the cucumbers we buy in the supermarket are purely female - grown from plants which were carefully cross-bred to produce female-only flowers. But while farmers have long known that "femaleness" factors into agricultural success - the greater the percentage of female flowers, the greater the yield of both seeds and fruit - it is only recently that scientists have revealed the molecular basis of plant sex determination.

In a study published in *Science* on November 6th, 2015, Prof. Rafael Perl-Treves, of Bar-Ilan University's Mina and Everard Goodman Faculty of Life Sciences, has shown how the gene that codes for "androecy" - a state in which a plant produces male flowers only - mediates the production of a key plant enzyme that determines whether an early-stage bud will develop into a flower that is wholly male or wholly female. When the level of this enzyme is manipulated within a microscopic bud, it is possible to direct flowers' sexual "identity" at will.

The Plant Kingdom's "Unisex" Minority

"Most plants are hermaphroditic, meaning that their individual flowers contain both male and female reproductive organs, which produce both pollen and seeds," says Perl-Treves. "My research, on the other hand, focuses on the minority of plant species: the ten percent of flowering plants whose flowers have only male, or only female reproductive structures. This is a hot topic, because the greater the percentage of female flowers, the greater the crop yield. Our study shows that a particular family of these plants possesses a specialized strategy for sex determination: they produce female flowers through an enzyme-driven mechanism that represses the emergence of male organs and promotes the development of an ovary."

Perl-Treves is an expert on the molecular genetics of cucurbits - a family of plants which includes cucumber, squash, watermelon and cantaloupe.

In this and previous work performed together with his French colleagues, Dr. Abdelhafid Bendahmane and Dr. Catherine Dogimont, of the Institut National de la Recherche Agronomique (INRA), Perl-Treves isolated two of the three genes known to play a role in cucurbit sex expression (the third gene was isolated years ago by another Israeli, Dr. Tova Trebitsch). Now, Perl-Treves and his colleagues have deciphered the molecular mechanism that mediates cucumber sex determination.

"Our work focused on the androecy gene, which produces the phenotype of all-male flowers," Perl-Treves explains. "We discovered that it is this very gene that also controls the production of flowers that are female. It does so by producing an enzyme - ACS11 - that limits the biosynthesis of a natural plant hormone called ethylene. When ACS11 is active - that is, when ethylene is produced at the correct location - female flowers develop. However, when a mutation causes ACS11 to be inhibited, the result is a lower level of ethylene in the developing flower bud. Under these circumstances, male rather than female flowers result."

Choosing Your (Plant) Sexual Preference

Perl-Treves has not yet characterized the exact molecular mechanism by which ethylene represses the emergence of male flowers. However, he says that the discovery of this gene-mediated dynamic can already be of practical significance.

"Ethylene production can be quantitatively modified, thus switching the sex of a developing plant," he says, adding that, even before the isolation of the genes involved, sexual fine-tuning had already been accomplished through the use of classical cross-breeding techniques and chemical hormone treatments. "Now that we understand the very specific role this gene plays in sex determination, it may be possible to use direct DNA 'diagnostics' to select plants that are agriculturally advantageous.

Although this study involves cucurbits, this approach could theoretically form the basis of strategies for improving the productivity of other crops. For example, in unisexual trees like the palm date and pistachio, DNA tests that predict tree's sex in the nursery would have great economic importance since it take years for the tree's gender to become apparent, and female trees are the ones needed to harvest fruit."

The discovery may also create more efficient, genetics-based cross-breeding methods for commercial seed production.

"To create hybrid seeds by crosses, seed producers emasculate flowers by hand, which is a very labor intensive process," Perl-Treves explains. "Now that we know the cucurbits' mechanism for repressing maleness, this gene-based mechanism could conceivably be genetically engineered into non-cucurbit species some time in the future."

Artifact from the "Sexual Evolution"

After isolating the sex-determining gene in cucumbers, Perl-Treves's colleagues discovered the same gene in a cucurbit "cousin" - the melon. Like a pair of concurrently-minted coins found in two separate archaeological sites, the discovery makes it possible to determine how long ago in botanical history this mechanism was known to occur.

"Melon and cucumber are two species that evolved from the same family," he says. "Based on the time that these two species are believed to have broken off from one another, we can estimate that this shared genetic mechanism has been determining the sex of plants for about ten million years."

On a significantly shorter time scale, Perl-Treves says that while it took years of intensive gene mapping efforts to isolate the DNA responsible for sex determination, there is still a long scientific road ahead.

"Our future goal is to understand exactly how ethylene biosynthesis represses the male flowers, allowing females to emerge," he says. "This is just one of the developmental-genetic questions about plant reproduction that might someday yield significant biotechnological assets."

More information: A. Boualem et al. A cucurbit androecy gene reveals how unisexual flowers develop and dioecy emerges, *Science* (2015). DOI: 10.1126/science.aac8370

Provided by Bar-Ilan University