Genome duplication encourages rapid adaptation of plants

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Plants adapt to the local weather and soil conditions in which they grow, and these environmental adaptations are known to evolve over thousands of years as mutations slowly accumulate in plants' genetic code. But a University of Rochester biologist has found that at least some plant adaptations can occur almost instantaneously, not by a change in DNA sequence, but simply by duplication of existing genetic material.

Ramsey's findings are published in the current Proceedings of the National Academy of Sciences.

While nearly all animals have two sets of chromosomes—one set inherited from the maternal parent and the other inherited from the paternal parent—many plants are polyploids, meaning they have four or more chromosome sets. "Some botanists have wondered if polyploids have novel features that allow them to survive environmental change or colonize new habitats," says Assistant Professor Justin Ramsey. "But this idea had not been rigorously tested."

Plant breeders have previously induced polyploidy in crop plants, like corn and tomato, and evaluated its consequences in greenhouses or gardens. Such an experimental approach had never been taken in wild plant species, Ramsey said, so it was unknown how polyploidy affected plant survival and reproduction in nature.

Ramsey decided to perform his own test by studying wild yarrow (Achillea borealis) plants that are common on the coast of California.

Yarrow with four chromosome sets (tetraploids) occupy moist, grassland habitats in the northern portion of Ramsey's study area; yarrow with six sets of chromosomes (hexaploids) grow in sandy, dune habitats in the south.

Ramsey transplanted tetraploid yarrow from the north into the southern habitat and discovered that the native hexaploid yarrow had a five-fold survival advantage over the transplanted tetraploid yarrow. This experiment proved that southern plants are intrinsically adapted to dry conditions; however, it was unclear if the change in chromosome number, per se, was responsible. Over time, natural hexaploid populations could have accumulated differences in DNA sequence that improved their performance in the dry habitats where they now reside.

To test that idea, Ramsey took first-generation, mutant hexaploid yarrow that were screened from a tetraploid population, and transplanted them to the sandy habitat in the south. Ramsey compared the performance of the transplanted yarrows and found that the hexaploid mutants had a 70 percent survival advantage over their tetraploid siblings. Because the tetraploid and hexaploid plants had a shared genetic background, the difference of survivorship was directly attributable to the number of chromosome sets rather than the DNA sequences contained on the chromosomes.

Ramsey offers two theories for the greater survivorship of the hexaploid plants. It may be that DNA content alters the size and shape of the cells regulating the opening and closing of small pores on the leaf surface. As a result, the rate at which water passes through yarrow leaves may be reduced by an increase in chromosome set number (ploidy). Another possibility, according to Ramsey, is that the addition of chromosome sets masks the effects of plant deleterious genes, similar to those that cause cystic fibrosis and other genetic diseases in humans.

"Sometimes the mechanism of adaptation isn't a difference in genes," said Ramsey, "it's the number of chromosomes." While scientists previously believed polyploidy played a role in creating gene families—groups of genes with related functions—they were uncertain whether chromosome duplication itself had adaptive value.

Now, Ramsey says scientists "should pay more attention to chromosome number, not only as an evolutionary mechanism, but as a form of genetic variation to preserve rare and endangered plants."

Provided by University of Rochester

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