Using genetic engineering to turn annual crops into perennials could bolster global food production

The last several decades have witnessed a remarkable increase in crop yields — doubling major grain crops since the 1950s. But a significant part of the world still suffers from malnutrition, and these gains in grains and other crops probably won't be enough to feed a growing global population.

These facts have put farmers and agricultural scientists on a quest to squeeze more yield from plants (and livestock), and how to make these yield increases more sustainable. The best land is already taken and could be altered by climate changes, so new crops may have to be grown in less hospitable locations, and the soils and nutrition in existing lands need to be better preserved.

Several methods are being used to boost yields with less fertilizer or pesticides, including traditional combination techniques, marker-assisted breeding, and, of course, trans- and cis-genic modifications.

One way to get more food from a plant is through another genetic switch. It may be possible to genetically, either through hybridization, mutagenesis or genetic engineering to alter a plant so that it transforms from an annual (one you have to replant every year) to a perennial (which you plant once and can thrive for many years).

This video from Washington State University discusses some advantages of perennial crops:

Most staples, like corn, wheat, sorghum and other grains are annuals. About 75 percent of US and 69 percent of global croplands are cereal, oilseed and legumes, and all of those are annuals, said Jerry Glover, plant geneticist at the Land Institute in Salina, Kansas, and John Reganold, a geneticist at Washington State University. This means, they wrote:

> They must be replanted each year from seed, require large amounts of expensive fertilizers and pesticides, poorly protect soil and water, and provide little habitat for wildlife. Their production emits significant greenhouse gases, contributing to climate change that can in turn have adverse effects on agricultural productivity.

Perennials, meanwhile, have longer growing seasons and more extensive roots, making them more productive, and more efficient at capturing nutrients and water from the soil. Replanting isn't necessary, reducing pesticide and fertilizer use, and reducing the need to use tractors and other mechanical planters in fields. Erosion also can be reduced. It's been estimated that annual grains can lose five times more water and 35 times more nitrate than perennial grains.
All plants at one time were perennials, and breeders and farmers concentrated on breeding new annuals that could meet a farmers' (and consumers) needs.

Now, the table has turned. Genetics may make the annual-to-perennial transformation easier.

The switch to perennials is not a new avenue of research, but it's been a rocky road. Scientists in the former USSR and the US tried to create perennial wheat in the 1960s, but the offspring plants were sterile and didn't deliver on desired traits. Since then, scientists worldwide have looked at deriving perennials from annual and perennial parents using molecular markers tied to desirable traits (and the genes responsible for them). This technique, and knowing the genotypes of more and more plants, has made it possible to combine desirable genes — with traditional and genetic engineering methods — to find these desirable perennial plants.

Glover has pointed out that molecular markers tied to desirable traits (higher yields, disease resistance, etc.) can allow for faster breeding by determining the sources of plant variation, and that plant genomics has facilitated the combination of genes without having to field test over years at a time. Genetic modifications can also help spur this along.

Andrew Paterson, head of the plant genome laboratory at the University of Georgia, has studied for years the development of perennial sorghum — one of the top five cereals on the planet. Sorghum's drought resistance has made it useful as a grain and biomass source in degraded soil, and a perennial version (which has happened spontaneously twice) could reduce drought losses even to other crops. Paterson's genetic analysis of wild perennials and cultivated annuals has shown the genes involved in perennial "ism" and offered DNA markers for more precise breeding.

Techniques like CRISPR/Cas9, which can precisely edit, insert or delete genes at specific locations, are being studied for their possible role in transforming perennials, but a few challenges remain. Chung-Jui Tsai at the University of Georgia, showed that CRISPR could be used to alter genes in existing perennials (like fruit and nut trees, for example), once some hurdles like frequent polymorphisms and other variations could be overcome.

Still others are not so optimistic about using genetic modification to enact the perennial-annual switch. First, the whole field would require much more research funding than currently exists, Glover warns. Then, as Paterson told Brooke Borel in her article in Popular Science, perennial traits are much more complicated than those currently addressed by genetic engineering. We don't really know all of the genes involved, not yet:

> We don’t actually have any of the genes in hand. We know where they are in the genome and we are working on their locations more and more finely, but there aren’t any of these genesthat we can yet point to the specific gene among the 30,000 or so in sorghum. Even if they didknow the exact genes, most GMOs that are currently available only insert a single new traitrather than information from multiple genes. The technology isn’t yet able to handle somethingso complicated as perennialism.

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