From hunger to profitable harvest: How GMO, CRISPR-edited plants can help curb $220 billion in annual crop losses

Plant diseases arguably pose the biggest threat to agriculture, exacting a dramatic economic toll and endangering the livelihoods of farmers all over the world. Between 2012 and 2015, for example, an outbreak of the fungal disease coffee rust caused an estimated $1 billion in losses throughout Central and Latin America and the Caribbean.

In 2015, the California grape industry alone spent approximately $239 million combating the fungus that causes powdery mildew. The annual economic losses from banana wilt in Uganda are thought to fall somewhere between $200 million and $295 million. Summing up the severity of the problem, The United Nations Food and Agricultural Organization has estimated that “each year, plant diseases cost the global economy around $220 billion.”

Fortunately, powerful innovations in plant genetics are inoculating globally important food crops against these devastating diseases. Such innovations include new breeding techniques (NBTs), particularly gene-editing tools like CRISPR, as well as more established breeding methods like transgenesis, used to develop GMO crops. Collectively, these technologies are helping farmers safeguard their yields with sustainable, environmentally friendly disease-resistance measures. In developing countries this could be the difference between a profitable harvest and going hungry.

Boosting plant immunity

Like humans, plants have evolved an immune system that helps them fight off infections spread by insects, bacteria, viruses and fungi. But in the nonstop Darwinian struggle for survival, these microorganisms often outsmart the defenses plants muster to protect themselves. The tools of biotechnology were developed to give food crops a leg up in this struggle. Scientists can use CRISPR, for example, to delete DNA segments that make plants susceptible to infection. Writing in the journal BioTechniques, science journalist Sarah Webb elaborated on this approach in 2018:

> Plant pathogens, which deliver disease-causing molecules known as effectors to their hosts, can devastate a farmer’s crop, often causing financial ruin or food insecurity within a region.

While the plant's immune system works to clear these effector molecules …. conserved sequences within specific plant genes can prove to be weak points, and the pathogen's effectors can exploit them to cause disease. Once established within the plant's genome, such sequences are known as susceptibility genes.

'If you remove the targets of effectors, then the pathogen would struggle in causing disease and modifying the plant to make it susceptible,' explains Sophien Kamoun, who studies plant–pathogen interactions at the Sainsbury Laboratory in Norwich, United Kingdom. CRISPR offers a convenient tool for both identifying such genes and producing plants resistant to the disease.'

Dozens of crops engineered to resist disease have already been developed and approved by regulators in the US and other countries. The best-known example comes from Hawaii in the early 1990s, when the state's papaya industry was nearly wiped out by the ringspot virus. Production declined by 50 percent between 1993 and 2006. But the industry was revived by the introduction of a GM papaya that has effectively immunized the fruit against viral infection. About 90% of all the papayas grown in Hawaii are now genetically modified.

GE Papaya is a GMO success story, using viral snippets to counteract the ringspot virus and credited with saving the Papaya industry

The genetically modified papaya is just a preview of what genetic engineering technologies can do to eradicate plant diseases. Scientists are conducting research on many staple crops using a variety of breeding techniques to immunize them against deadly diseases. These biotech crops are in various stages of development, though some are rapidly approaching commercialization.

Wilt-resistant bananas

Bananas are a popular fruit in the developed world, but in Africa their production is a crucial source of food and income for many people. Diseases that cut banana yields are therefore very serious threats. Fortunately, A GM solution has been developed to combat banana wilt, which causes huge crop losses in central and western Africa. The resistant banana is created by inserting a sweet pepper gene into its genome.

Field tests in Uganda have been successful and commercialization may begin in 2021 if the nation's Biosafety Act, which was initially passed by the Parliament in 2017, is finally signed by the President. Farmers in the country have been clamoring for access to the banana and other GMO crops since the law made its way through the legislature.

Wheat that doesn't rust

Wheat is one of the most important staple foods in the world. In 2019, world wheat production reached 767 metric tons. But this vital crop is threatened by notoriously deadly pathogens, powdery mildew and stem rusts being some of the most formidable. As in the case of bananas, though, biotechnology is poised to improve the prospects of wheat growers in their battle against these diseases.

In 2017, the Minnesota-based biotech firm Calyxt, which specializes in creating gene-edited crops, announced it had begun field trials of a powdery mildew-resistant spring wheat variety. Once the trials are completed, the company expects to commercialize the product relatively quickly, since the USDA has already said the mildew-resistant wheat won't be regulated.

The 2Blades Foundation, a charitable organization dedicated to developing disease-resistant crops, in collaboration with the University of Minnesota and the Commonwealth Scientific and Industrial Research Organization of Australia, has developed a GMO wheat variety that is immune to stem rust diseases. Some of the lines of wheat developed were field tested in the summer of 2018 and they demonstrated strong resistance to stem rust. "In my 30 years of conducting stem rust experiments in the field, I have never seen a clearer demonstration of the effectiveness of host resistance against this devastating disease …." University of Minnesota researcher Brian Steffenson said following the trials.

Blight-tolerant spuds

Potatoes have been developed that are immune to late blight disease, which was a major factor in the Irish Potato Famine that killed an estimated one million people between 1845 and 1849.

PotatoBlight

Image not found or type unknown

Late blight is major threat to potato

plants. Credit: Fry, Molecular Plant Pathology (2008)

Scientists in the Netherlands and Ireland have successfully carried out field trials of a disease-resistant genetically engineered potato. The new variety was created through a process of cisgenesis, in which genes from a wild potato were used to confer disease resistance on its domesticated relative. The disease-resistant crop reduced fungicide spraying by up to 90%, and is likely to be successful because the potato selected for the trials is already widely cultivated and consumed. If approved, it'll just have the added blight-tolerance trait.

Scientists in Uganda have also created a genetically engineered blight-resistant potato. Five years of field trials have shown the variety is "virtually 100 percent resistant to late blight disease and requires no chemical spraying," the International Potato Center said of the research. Farmers allowed to observe the trials were impressed by the results, which is significant since lack of grower interest halted the production of Monsanto's insect-resistant potato in 2001.

Saving Cavendish bananas and orange juice with biotech

Onerous regulations and activist opposition often slow the introduction of genetically engineered crops. In some cases, however, these two factors can actually keep disease-resistant crops off the market, although there may be no scientific justification for doing so.

For example, a GM solution may be the only means of saving the Cavendish banana from the ravishes of Panama disease, which threatens to devastate the crop in a similar manner to how a soil-dwelling fungus destroyed the Gros Michel, once the most popular banana variety. Scientists in Australia have developed such a disease-resistant banana by inserting a gene from a wild banana variety into the Cavendish. The biggest threat to progress in this case isn't technical, according to plant pathologist Steve Savage. Consumer concern, fueled by activist agitation against GMOs, has made the banana industry skittish about embracing a biotech solution to Panama disease.

A similar story could be told about America's citrus industry. Growers are struggling to control citrus greening disease, which is devastating orange groves in Florida and becoming a major problem in other orange growing states such as California, Texas and Arizona. The disease is caused by a lethal bacterial infection spread by a tiny insect, the Asian citrus psyllid. The infection blocks the flow of nutrients throughout the tree and causes leaves to turn yellow and fruit to become green, bitter and inedible. Left alone, infected trees usually die in five to seven years.

Scientist have discovered a biotech solution that involves transferring a gene from the Arabidopsis plant, a member of the mustard family. The GMO trees are not only resistant to citrus greening but to canker and black spot as well. Like banana growers, however, many citrus farmers are reluctant to utilize such a solution because of the controversy surrounding GM crops. Even if such a controversy did not exist, achieving regulatory approval would take many years given the heightened regulatory barriers GM crops must surmount before they can be commercially cultivated.

CRISPR to the rescue?

Since the US government has indicated it will not regulate gene-edited crops if they don't contain DNA from other species, there may be a gene-editing solution to citrus greening and diseases threatening banana production that can circumvent the heavy regulatory procedures that slow the approval of GMO crops.

> file a qi p
>
> Image not found or type unknown
>
> HLB yellow dragon citrus greening disease has infected orchards in Florida and around the world devastating the citrus crops. By Edgloris Marys/shutterstock.com

Researchers at the Universities of Florida and Connecticut are utilizing CRISPR gene editing to breed citrus greening-resistant oranges. Scientists have discovered that the bacterium that causes citrus greening secretes a protein that helps infect orange trees. It is believed that gene editing can be used to suppress or modify the protein so that it no longer damages the trees. University of Florida's Professor Fred Gmitter explained the significance of the research in December 2018:

> [T]here's no cure for citrus greening, and no citrus species is known to have complete resistance. However there are different sensitivity to the disease and gene editing offers hope that plant breeders and geneticists may be able to devise strategies that can lead to the development of very tolerant, or perhaps even resistant, citrus trees.

Researchers are similarly exploring how CRISPR could be used to immunize the Cavendish banana against a variety of diseases. These solutions have yet to make it out of the laboratory, but the early results are promising, as the authors of a 2019 review pointed out:

> Genome editing, an emerging powerful tool, can be applied for developing sustainable solutions to adapt to climate change by resisting biotic and abiotic stresses. CRISPR/Cas9 based genome editing has been lately established for banana, paving the way for functional genomics allowing identification of genes associated with stress?tolerant traits, which could be

> used for the improvement of banana for adaptation to a changing climate.

Added benefit: Cutting pesticide use

Currently, plant diseases are combated primarily by spraying pesticides that help control pathogens. Although most of these chemicals are generally safe when used as directed by the EPA and have low to moderate toxicity, they can still irritate the eyes, skin and respiratory system. And some of these products can have very detrimental health impacts if people are chronically exposed to high enough doses. This is true even of pesticides used in organic agriculture. The fungicide copper sulfate, for example, may damage the eyes and vital organs and is possibly carcinogenic as well.

Genetic engineering technologies, fortunately, offer the prospect of either eliminating the use of pesticides in some cases or sharply reducing their use by altering the genome of plants and thus making them less susceptible to plant diseases. This has been demonstrated in GMO strawberries (though they have not been commercialized), as well as several gene-edited plant varieties, as the GLP has previously reported:

> This trend has continued with the introduction of crops and pesticides developed through new breeding techniques (NBTs), such as CRISPR and RNA interference, which can edit and silence genes to produce desired effects. Plant scientists, for instance, can now protect apples from diseases that are difficult to treat with chemicals and control many different pests without adding even trace amounts of pesticide to the environment, as the EPA has pointed out.

Genetic engineering techniques have the potential to entirely prevent many plant diseases that are responsible for billions of dollars of crop losses every year, and which are quite expensive to control through disease management techniques that include the spraying of pesticides. Farmers and consumers will benefit immensely if these breeding solutions are successful. They could effectively immunize our major staple crops in the same manner that vaccinations have largely eliminated the scourge of childhood diseases.

Steven E. Cerier is an international economist and a frequent contributor to the Genetic Literacy Project