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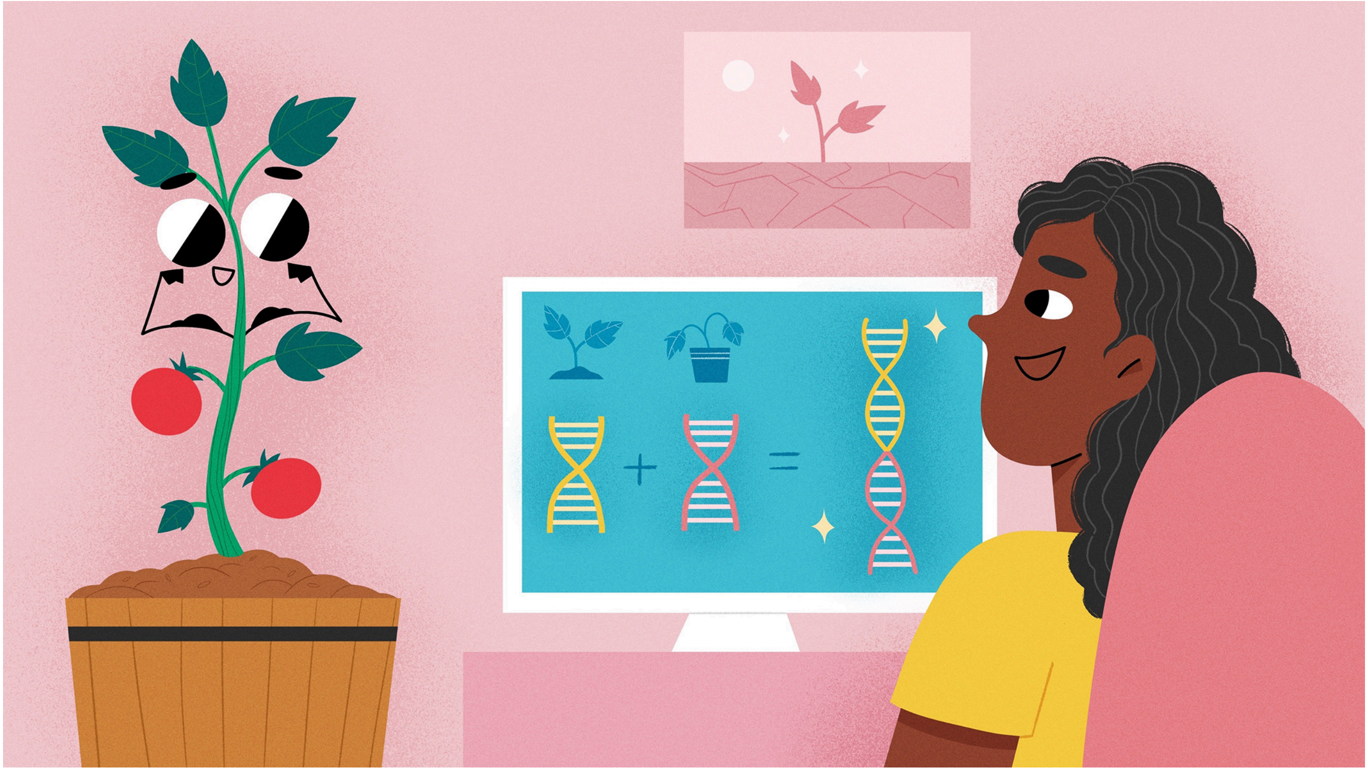

GROWING STRONGER CROPS FOR A CHANGING WORLD

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The crops that we grow for food are sensitive to the effects of climate change, including drought, flooding, poor soil conditions, and increasing temperatures. This is a major problem because the demand for food continues to grow as Earth's population increases—and we cannot keep turning land into farmland. Instead, we could try to develop crop plants that can survive the stresses of a changing climate. The wild relatives of many crop plants can thrive in challenging environments, but those survival traits were often lost as farmers bred those plants to become good food producers. How can science help crop plants to regain important survival traits? In this article, we will describe two possible ways: either giving existing crop plants the survival genes from wild plants, or giving wild plants (that already have survival genes) the genes that can make them good

food producers. Both options are challenging, so plant scientists have plenty of work to do!

FARMERS AND THEIR CROPS ARE FEELING THE HEAT!

Farming has always been a difficult job. Growing crops can require exhausting physical labor, long hours spent outdoors in all kinds of conditions, and constant worry about pests, diseases, and bad weather that can spoil harvests. While some advances in technology, like GPS-guided tractors and computerized watering systems, have made farming easier over the years, in some ways the job of growing food is becoming *even more* challenging. Earth's climate is warming, and the changing conditions are decreasing the amount of food some farmers can produce on their lands [1].

ABIOTIC STRESSES

Environmental factors like drought, extreme temperatures, or poor soil conditions that negatively affect plant growth and survival but are not caused by living organisms like pests or diseases.

While some plants grow best at warm temperatures, many crops like wheat, rice, potatoes, and soybeans prefer slightly cooler conditions. Even heat-loving crops like corn and sugarcane cannot tolerate the high temperatures projected for the coming decades. Non-living factors that make it difficult for plants to grow, such as high temperatures, too much or too little water, and poor soil conditions, are called **abiotic stresses**.

DROUGHT

A prolonged period with little or no rainfall, leading to a shortage of water that can harm crops, animals, and ecosystems.

SALINITY

The amount of salt present in soil or water. High salinity can make it difficult for plants to absorb water and nutrients, affecting their growth and survival.

Climate change is increasing other abiotic stresses in addition to high temperatures. Some areas are experiencing more (and more severe) **droughts** and floods. Droughts occur when there is not enough water, making it challenging for plants to absorb the necessary nutrients from the soil. Droughts have been getting more frequent and severe since the 1970s (Figure 1A). At the other extreme, when there is too much water during heavy rains or floods, plants experience waterlogging, which drowns their roots and deprives them of oxygen. Increasing soil **salinity**, which is the amount of salt in the soil, is another abiotic stress that is worsening as the climate changes [2]. In some places, hot, dry conditions increase the need for farmers to water their crops (Figure 1B), and shortages of freshwater can force farmers to use brackish (slightly salty) water, taken from sources where freshwater mixes with seawater. After a while, salt builds up in the soil and makes it difficult for plants to take up water and nutrients, leading to limited growth and poor yields. All these abiotic stresses, which are getting worse under climate change, are decreasing the amount of food farmers can grow.

CAN WE MAKE PLANTS STRONGER IN THE FACE OF STRESS?

Meanwhile, as climate change is worsening and decreasing the amount of food farmers can produce, the number of people on the planet keeps increasing—so the demand for food is growing.

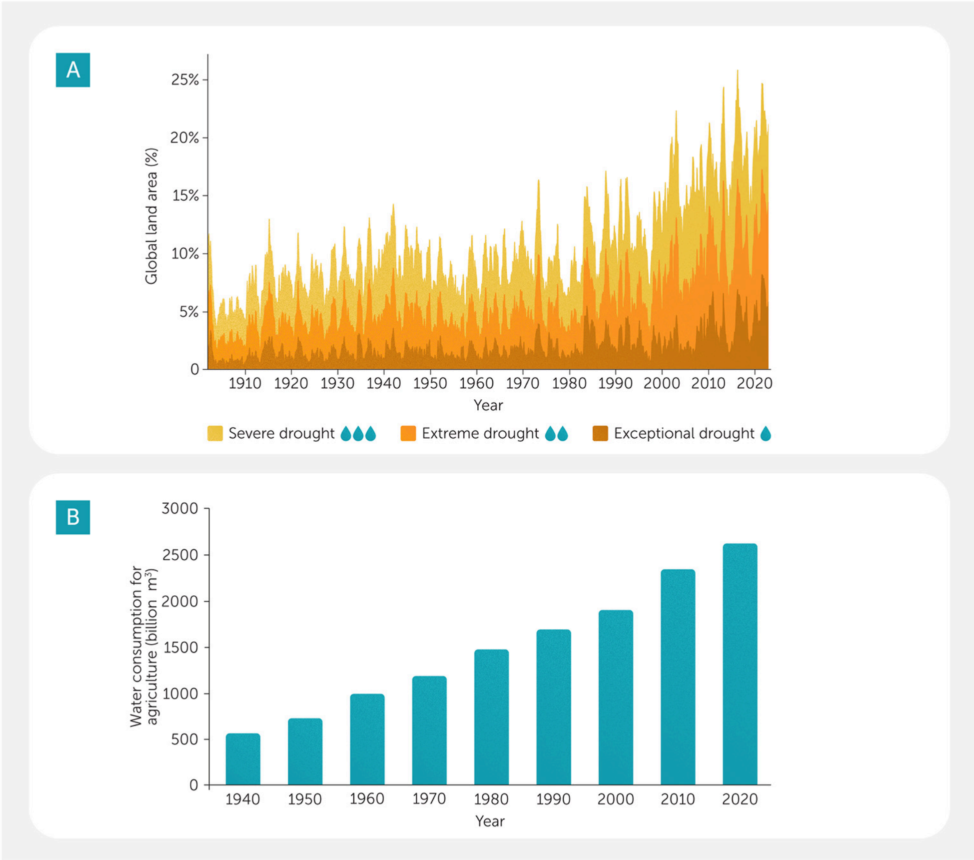

Figure 1

Figure 1

(A) Percent of the Earth affected by droughts in the last 100 years. Droughts have been getting more severe since the 1970s, and dry conditions are a type of abiotic stress that makes it difficult for crop plants to grow. **(B)** As hot, dry conditions and droughts increase, farmers need to use more water to irrigate their crops. If this water is slightly salty, salt can build up in the soil. High soil salinity is another source of abiotic stress.

While farmers could solve this problem by making their farms bigger, that is not a good long-term solution. Instead, scientists need to find ways to make crops stronger in the face of abiotic stresses, so farmers can continue to grow as much food as possible on their current farmland.

How do we get strong plants that can survive stresses like high temperatures, drought, waterlogging, and increasing salinity? The answer might be found by looking at crop plants' wild relatives. Most of today's crops come from wild plants that early farmers "tamed", by generations of breeding, to become efficient food producers. Some wild relatives still exist and are stronger than crop plants when it comes to withstanding abiotic stresses—these wild plants have important genes that give them the **traits** needed to survive in harsh conditions. The survival traits of wild plants were often lost over generations, as early farmers focused on breeding plants that produced lots of food. This is similar to what happened when humans tamed wild dogs to become cute pets. While pet dogs are great companions, many of them no longer have the toughness that helped wild dogs survive without humans.

TRAITS

Characteristics or features of an organism, such as color, size, or resistance to disease, that are passed down from generation to generation through genes.

What if scientists could combine the strength of wild plants with the desirable food-production traits of common crops? Could they produce new plants that could survive the challenges of a changing climate while still producing lots of food?

ADDING WILD "TOUGHNESS" GENES TO MODERN CROPS

One way to make crop plants stronger is to figure out which "toughness" genes were lost and put those genes back into modern crops—a process called **rewilding** [3]. For example, wild tomatoes have a gene called *SlHAK20* that makes them more tolerant to salty soil, but this gene is no longer present in modern tomatoes. Scientists put *SlHAK20* back into modern tomato plants and found that their ability to tolerate salt increased [4].

REWILDING

The process of reintroducing natural survival traits, like resistance to drought or pests, back into modern crop plants by using the traits of their wild ancestors.

There are two main ways that scientists can put genes from wild plants back into crop plants (Figure 2). First, they can breed crop plants with their wild relatives, carefully selecting the "baby" plants that have the toughness trait and then breeding those, over several generations. This can take a long time! The second method involves **genetic engineering**, which is a laboratory technique by which scientists can insert, remove, or change an organism's genes, often giving it new traits. If a desired toughness gene can be identified, scientists can use genetic engineering to precisely add that gene into the DNA of the crop plant.

GENETIC ENGINEERING

A method of directly modifying an organism's DNA using biotechnology to add, remove, or change specific traits, like making crops more resistant to pests or improving nutritional content.

CHALLENGES TO REWILDING

While genetic engineering methods can be faster and more precise than plant breeding, rewilding is not as easy as it might sound. First, scientists must make sure the crop plant's wild relatives have the toughness trait they are interested in. Then, they must pinpoint which of the many thousands of genes in the wild plant are responsible for that trait—like finding a needle in a haystack! To make this even more complicated, most toughness traits come from a combination of multiple genes, not just one gene, and sometimes complex networks of many genes are involved. The more genes, the more difficult it is to find them all and transfer them into crop plants. Another challenge is to make sure these genes are inserted into the right place inside the plant, for proper operation.

TURNING WILD PLANTS INTO CROP PLANTS

Instead of trying to find "toughness" genes in wild plants and add them back to crop plants, what if scientists *started* with wild relatives that already have those genes? If scientists could change strong, wild plants

Figure 2

Rewilding crop plants to restore the "toughness" traits of their wild ancestors can be done by two main methods. **(A)** Scientists can breed crop plants with their wild relatives and select the "baby" plants that have the toughness trait. Reestablishing the trait can take multiple generations. **(B)** Through genetic engineering, scientists can insert toughness genes from the wild ancestors (if they can find them) into the DNA of the crop plant, which reintroduces the toughness trait.

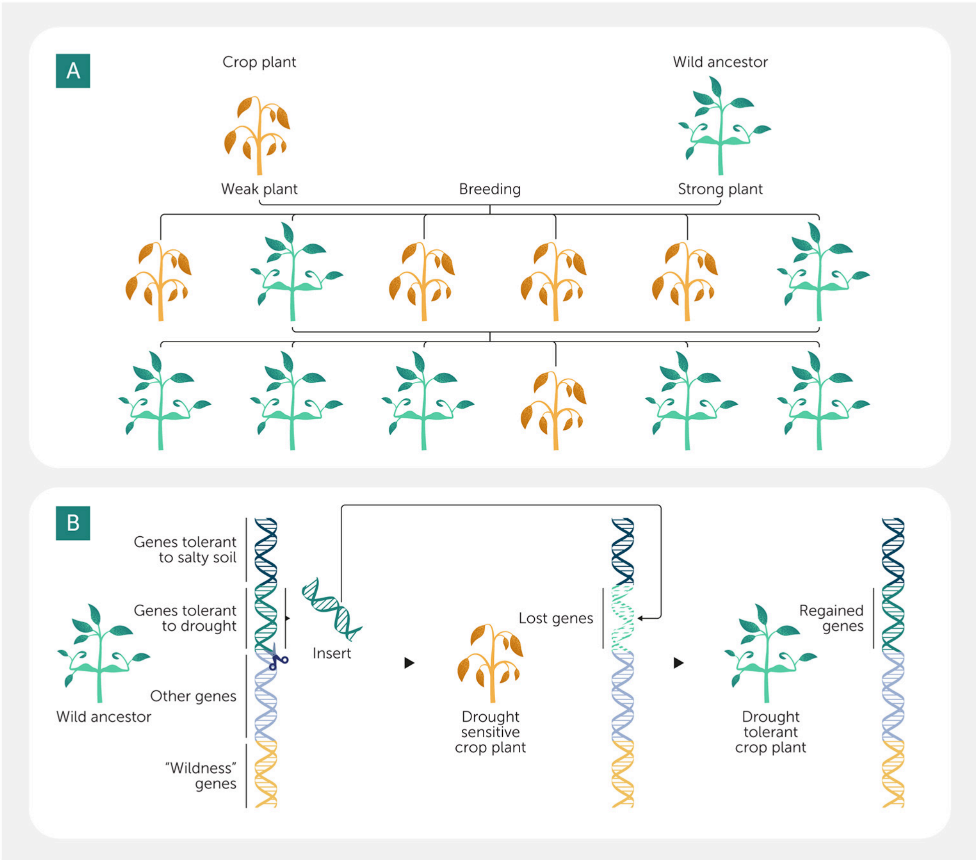

Figure 2

into crop plants while being careful to keep the "toughness" traits, this might be an easier way create crops that can tolerate abiotic stresses [5]. For example, maybe scientists could change wild rice plants, which do not produce much rice but can tolerate drought, into a variety that is both drought resistant *and* a good rice producer. Turning wild plants into crop plants this way is called ***de novo* domestication**.

De novo domestication can also be accomplished by genetic engineering, and it might be easier than rewilding. For one thing, domestication does not require adding any new genes. Instead, it typically only requires minor changes that "shut off" or change the strength of a wild plant's existing genes in some way. So, scientists can use a type of genetic engineering called **gene editing** to make these gene changes in wild plants, giving them the traits of good crop plants (Figure 3). However, scientists still need to figure out which genes to edit and sometimes, as with rewilding, multiple genes can be involved. Also, the crop plants created by *de novo* domestication might produce more food than their wild relatives, but still not as much as the high-yielding varieties that most farmers grow today.

***DE NOVO* DOMESTICATION**

The process of selectively breeding wild plants or animals from scratch to create new domesticated species with traits desirable for agriculture, like improved yield or easier harvesting.

GENE EDITING

A precise form of genetic engineering that involves making targeted changes to an organism's DNA, like adding, deleting, or altering specific genes, to achieve desired traits without introducing foreign DNA.

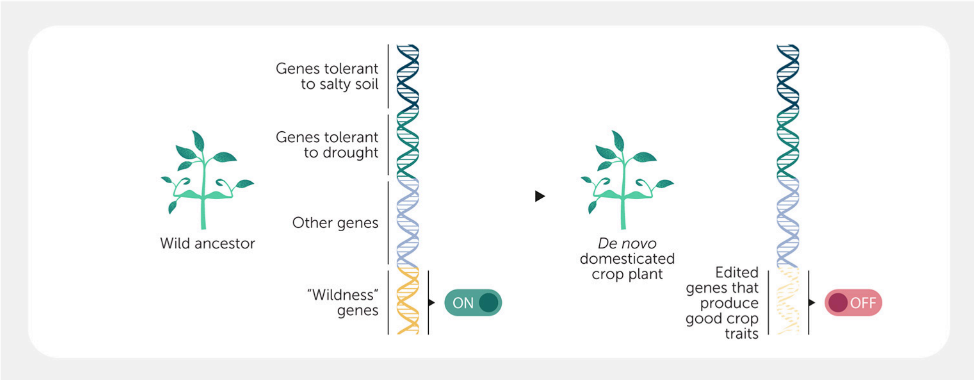

Figure 3

Figure 3

De novo domestication—turning wild plants that can tolerate abiotic stresses into crop plants with good food-production traits—can be accomplished by a type of genetic engineering called gene editing. In this technique, scientists can change or "shut off" certain genes in the wild plant to give it the traits of a good crop plant while keeping the "toughness" genes.

AND THE FINAL ANSWER IS...SCIENCE!

While climate change is making it harder for farmers to grow enough food for everyone, harnessing the power of science can help create stronger crops that can handle difficult changes in weather and soil conditions. As you have seen, both rewilding of crop plants and *de novo* domestication of wild plants show promise for helping crops handle stressful conditions like high temperatures, drought, flooding, and poor soil—but it is still too early to know which strategy is best. What we *do* know is that more research is urgently needed on both methods, to give farmers the best chance of success.

Developing stronger crops is not just a scientific challenge—it is a societal one. One challenge is that many people are skeptical about genetically engineered plants. Some worry about whether those plants are safe to eat or if they might damage the environment. Strict laws limiting the use of genetically engineered plants can make it harder for farmers to try out these crops in their fields.

To combat people's fears, scientists and safety experts are doing lots of testing to make sure genetically engineered plants do not pose any risks to human health or the environment. Teaching the public about genetic engineering is also important, and so is the prevention of false information often spread by the media. Educating people about this issue and teaching them that genetically engineered plants might help farmers to produce enough food for the world's growing population is critical for getting the public to accept these approaches. As people everywhere face the challenges of a changing world, we need to support research and embrace new technologies that will help farmers succeed at the difficult job of growing enough healthy food.

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I am 12 years old and a passionate elementary school student. I love sketching and painting, especially when inspired by my adventures in nature. My favorite books include "Amari" and "The Magicians of Paris", along with any fantasy stories that ignite my imagination. I enjoy cycling, playing chess, and badminton, and I frequently hike to explore the wonders of nature. I take notes and create detailed sketches of the plants and animals I discover along the way!

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