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# An Analysis on the Benefits of Gene editing in Agricultural Biotechnology

TCN 705 Whitepaper



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## Executive Summary

This white paper will analyze the benefits and drawbacks of gene editing in agriculture. It will explain the process of gene editing, the benefits, and statics provided by experts. This type of technology is important to consider as our populations rise, and we need solutions to solve food scarcity. This white paper will create a convincing stance for companies to consider using more gene editing in the agriculture industry.

### Problem Statement

Food scarcity is a lasting issue, and many countries experience this problem to differing degrees of seriousness. It is key to find modern technologies and methods to increase the production of food and crops. One of these solutions include gene editing, as this technology can include adding, removing, or changing the DNA in the plant. This research will focus on the benefits of gene editing in agriculture and could improve the issue of food scarcity and nutrition.

## Introduction To the White Paper

The first section of this white paper will explain the process of gene editing and the types of technology currently used by plant breeders, scientists, and companies. Next, I will focus on the benefits using gene editing and how it will affect stakeholder groups. This will also include statistics and case studies of popular technologies. Finally, I will summarize my findings and explain why companies should invest in gene editing to aid in agriculture.

### Definition Of Food Scarcity

Food scarcity is the shortage of food. This may occur when factors such as droughts, floods, or pests prevent crops from growing. Other factors that may affect food scarcity include food distribution, transportation, government, and politics. However, for the purposes of this white paper, we will focus on the agricultural impacts on food scarcity.

## The Basic Process of Gene editing

There are challenges that come with growing and keeping plants. For example, floods, droughts, heat, pests, and other factors affect the growth of plants. Gene editing is the process of making very precise changes to the DNA structures of plants to target traits. In agricultural settings, this type of technology is common. For example, scientists and plant breeders can guarantee a certain level of survivability of crops or increase a plant's nutrition. This can include editing the genome of crops, so they become more durable against droughts, floods, or other major weather changes.

### Example Of the Gene editing Process

Figure 1 shows how the background mutation of selected ancestral crops turn into a modern crop. For example, there could be a spontaneous mutation of a gene that increases resistance against floods. Gene editing can turn the ancestral crop into a modern crop that has higher yield, better taste, and is easier to grow. Therefore, with gene editing technologies, the wild crop can become a modern crop.

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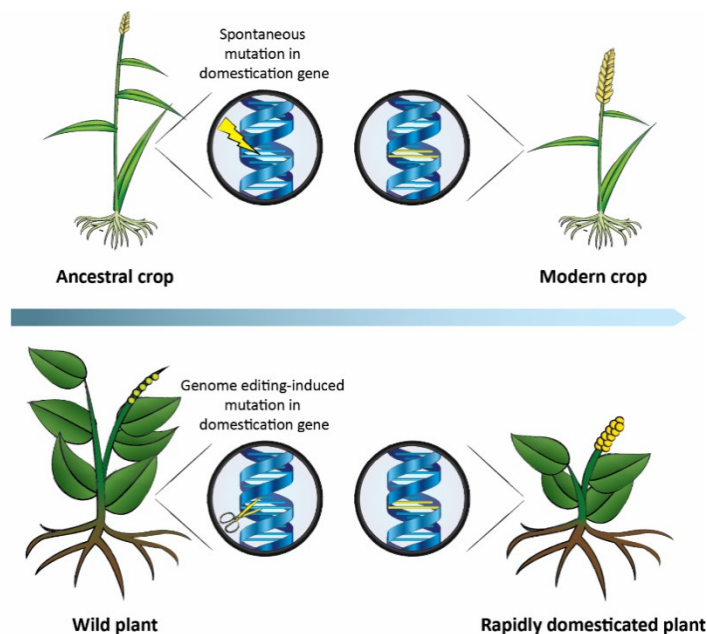


Figure 1. Example of impact of gene editing in crops

### Specific Types of Gene editing Technology

CRISPR/Cas-9 (Clustered Regularly Interspaced Short Palindromic Repeats) and TALEN (Transcription Activator Like Effector Nucleases) are the two most common gene editing technologies. Companies can compare the benefits of both technologies to decide which one to use.

#### Changes of plant traits because of gene editing

- Cold resistance.
- Heat resistance.
- Pesticide and herbicide tolerance.
- Drought resistance.
- Viral, bacterial, and fungal resistance.
- Flood resistance.
- Increase in size and weight of crops.

#### Summary Of CRISPR Technology

CRISPR is part of bacterial immune systems that can cut DNA and can be repurposed as a gene editing tool. The CRISPR technology research won the 2020 Nobel Peace Prize in chemistry and is a well-known tool.

#### The major components that allow for gene editing

- A CRISPR-associated (Cas9) nuclease. This protein finds and binds to any target sequence.
- A guide RNA sequence (gRNA) helps guide the Cas9 to the target. Figure 2 shows the basic process of how the CRISPR technology works.

### The Basic Procedure Of CRISPR

The Cas9 protein will attach to a cell with a piece of gRNA. The Cas9 protein will combine with the gRNA and move along the DNA structure. It will bind to the sequence that matches with the RNA sequence. Then, the Cas9 protein will cut the DNA at the target location. Scientists will add new sections of DNA to the sequence. Finally, the cut will repair and introduce new mutations to the genome.

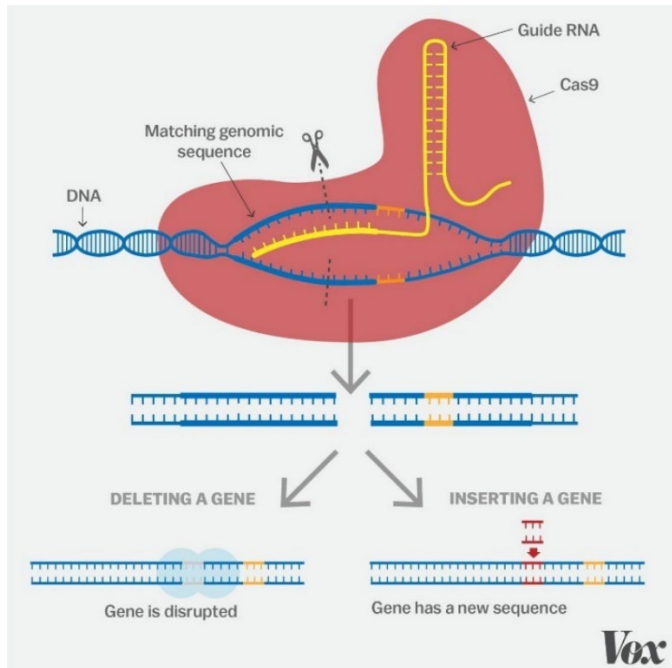


Figure 2. CRISPR Diagram

### Introduction To TALEN Technology

Like CRISPR, TALEN technology can attach to DNA and change gene expression, cut patterns of DNA, repair genes, or insert mutations. TALEs (transcription activator like effector) are from a bacterial plant pathogen that bind to DNA and activates genes. Figure 2 shows an image of TALEN and how it edits genes.

### Basic Procedure of TALEN

The TALE binds to the DNA at a specific nucleotide and fused to a Fok1 nuclease. Each repeat in the Fok1 binding domain can include different amino acids that decide which nucleotide it can bind to in the DNA sequence of the genome. The Fok1 nuclease domain binds to another stretch of the TALE and the pattern repeats in the DNA sequence. The two Fok1 subunits combine to create a double-strand DNA break. A process called nonhomologous end joining (NHEJ) repairs these breaks in the DNA. However, this can also result in deletion, insertion, or rearrangement of the chromosome. Figure 3 shows a visual of the process of TALEN technology.

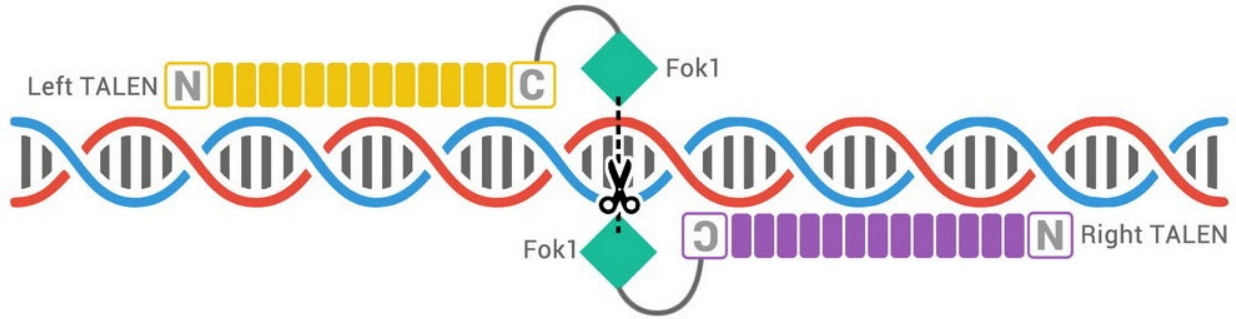


Figure 3. TALEN Diagram

### Comparison of Gene editing Technologies

This section shows the differences between CRISPR and TALEN. Each type has benefits and drawbacks that companies should consider.

	CRISPR	TALEN
<b>Advantages</b>	<ul style="list-style-type: none"> <li>• Can insert multiple gene mutations with only one injection.</li> <li>• More efficient when inserting genetic material</li> <li>• More cost effective compared to other technologies.</li> <li>• Higher yield of crops.</li> <li>• Is very versatile.</li> </ul>	<ul style="list-style-type: none"> <li>• Can insert simple gene mutations.</li> <li>• Can target any genome sequence.</li> <li>• Designing TALENs is straightforward.</li> </ul>
<b>Disadvantages</b>	<ul style="list-style-type: none"> <li>• There is concern about the effects if CRISPR cuts the DNA at a different location. It could result in harmful mutations.</li> <li>• Experts need to research more to develop crops and regulatory policies.</li> <li>• Public concerns about GMOs.</li> </ul>	<ul style="list-style-type: none"> <li>• Not as efficient as CRISPR as it only targets one site at a time.</li> <li>• Public concerns about GMOs.</li> </ul>

Table 1. Advantages and disadvantages of CRISPR and TALEN technologies

### The Benefits of Implementation

There are many ways in which gene editing can improve agriculture. These benefits are important for companies to consider as it can decrease environmental harm and production costs.

#### Environmental Sustainability

Gene editing can increase crop yield using the same or smaller plots of land. In addition, using less plots of land would result in less resources used for plant maintenance. This decreases the environmental harm and increases crop yield.

#### Examples of environmental sustainability improvement

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- Decreases water use.
- Improving drought tolerance of plants.
- Decreases nitrogen use.
- Decreases insecticide use by improving resistance to pests.

### Adapting To Climate Change

The consequences of climate change can affect the growth and output of crops. Global declines in crop yield are a direct result of climate change. The extreme weather will decrease global food supply and drive up the prices, which will further contribute to food scarcity. Therefore, gene editing can allow plants to adapt to changing climates. This increases the durability and yield of crops.

### Improving Nutrition

Gene editing can also decrease unhealthy elements such as saturated or trans fats and high starch foods and add elements with higher nutrition. The efforts to change global dietary habits can result in a decrease in health concerns worldwide. This will help create healthier foods for people to consume.

### Examples of implementation

- Using TALEN to launch a new soybean with high levels of healthy fatty acids and lower levels of harmful types of fatty acids.
- Using CRISPR to increase content of resistant starch in rice.
- Using CRISPR to increase digestibility and proteins in sorghum.

### Increasing Crop Yield and Crop Resistance

Gene editing can help plants become resistant to disease and change physical structures of plants that allow for a high crop yield. In addition, changing genes within plants can also help in pesticide resistance.

### CRISPR-mediated resistance methods

- Directly targets virus genome within the crop.
- Targets crop genes responsible for development of disease.
- Targets against RNA viruses by interfering in the RNA genome.

### Reducing Food Costs

Gene editing can help lower food prices for consumers. All these elements would result in the reduction of food costs and increase food accessibility for lower-income families, therefore creating solutions to food scarcity.

## Case Studies

Case studies are important to analyze as they are examples of how companies are using gene editing. The statistics from these studies will also show that gene editing is making change to the agriculture industry.

### Pairwise

Pairwise is a health-focused food and agriculture company that uses CRISPR to insert traits into plants. They find the relationship between DNA and the different plant traits before deciding to target certain

traits. Then, they use CRISPR proteins to edit DNA either by removing unwanted traits or replicating traits.

### Inari

Inari is a company that creates new seed technology that will improve efficiency, and yield. They use CRISPR technology for their research, and they focus on the need for developing modern technologies that address the concept of sustainability.

#### **Predicted statistics because of gene editing**

- 10-20% increase in crop yield. This would mean growing more crops for less land.
- 40% reduction in nitrogen. This would improve the resource use of crops.
- 40% reduction in water. This would reduce the need for a precious resource.

### Calyxt

Calyxt is a company that uses TALEN to create stronger and higher-yielding crops. By choosing certain types of genes, the company tries to increase the unique traits that exist naturally within each crop. Therefore, the company mostly focuses on improving nutrition of crops.

#### **Crop enhancement projects by Calyxt**

- Improve digestibility of alfalfa.
- High fiber wheat.
- Increase in protein favoured soybeans.
- High oleic and low linolenic soybeans.

## Conclusion

Gene editing technology is creating changes in the agriculture field. I have summarized the benefits of gene editing in plants and how it can affect businesses and consumers in the future. The two most well-known technologies, CRISPR and TALEN, have the potential to make big changes in the agricultural field.

### Summary Of Findings

CRISPR and TALEN technologies are very versatile. Research by agricultural companies shows that there are methods for improving the issue of food scarcity and creating more sustainable practices as the technology continues to evolve.



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