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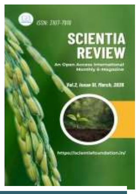

POPULAR SCIENCE ARTICLE

From Gene to Green: CRISPR-Cas9 Shaping the Future of Vegetables

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Abstract

Modern farming faces many major challenges, it needs to grow enough healthy food for a population that is growing quickly while also dealing with climate change, pests, diseases and limited resources traditional breeding methods in vegetables take a long time and are slow. Scientists are using more advanced technologies, like CRISPR/Cas9 genome editing, to make vegetable crops better in order to get around these problems. CRISPR/Cas9 is a powerful tool for editing genomes that lets you make exact changes to the DNA of living organisms and increase yield, enhance nutritional quality and increase shelf-life in crops. This technology can assist in developing the crops which are more resilient to pests, diseases and climate variability, while being more productive and nutritious. Many varieties of genome-edited vegetables are already preparing for market, demonstrating the practical applications of this technology.

Keywords: CRISPR, Genome editing, Vegetable crops, Food security

Introduction

Modern farming faces many major challenges: it needs to grow enough healthy food for a population that is growing quickly while also dealing with climate change, pests, diseases and limited resources. Vegetables are an important part of a healthy diet because they provide us vitamins, minerals and antioxidants that we need, but traditional breeding methods in vegetables take a long time and are slow. Scientists are using more advanced technologies, like CRISPR/Cas9 genome editing, to make vegetable crops better in order to get around these problems (Aishwarya and Singh, 2025).

What is CRISPR/Cas9?

CRISPR/Cas9 is a powerful tool for editing genomes that lets you make exact changes to the DNA of living organisms. It works like a pair of molecular scissors that can cut DNA at certain points, which lets scientists modify genes. The 2 primary components of CRISPR/Cas9 are Cas9 and sgRNA (Negi *et al*., 2022, Martín- Pizarro and Posé, 2018).

- The Cas9 enzyme, which cuts the DNA
- Single- stranded guide RNA (sgRNA) tells Cas9 where to go to find the target gene.

After the DNA is cut, the cell repairs the break through using natural processes like non-homologous end joining (NHEJ) or homology-directed repair (HDR). Scientists can delete, add or replace certain DNA sequences with the help of these repair processes.

Originally found in bacteria as a way to protect themselves from viruses, CRISPR technology is now one of the most common tools for genome editing in plant biotechnology.

The significance of CRISPR in vegetable breeding:

Cross-pollination and selection are used in traditional breeding, which can take a long time to create better varieties. CRISPR technology speeds this up by directly changing the genes that control important traits.

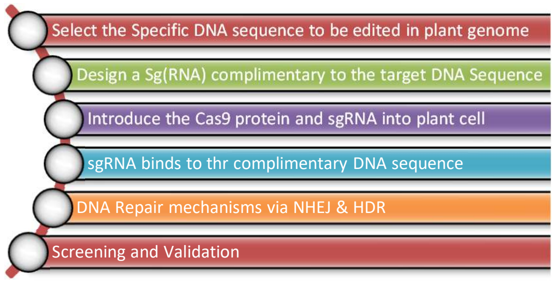

Fig. 1. Steps Involved in plant genome editing

CRISPR/Cas9 has these benefits:

- Increases the crop yields
- Enhances the nutritional quality
- Increases resistance to pests and diseases
- Improvement in tolerance to environmental stresses like salt, drought and extreme heat
- Increase in shelf-life

This technology makes it easier and faster to create better vegetable varieties.

Uses of CRISPR/Cas9 in Vegetable Crops

1. Stress tolerant devolvement

Vegetable productivity goes down when the environment is stressed by abiotic factors like drought, salt and very hot or cold temperatures. CRISPR technology lets you modify genes that can help plants live in these conditions. For instance, changing genes like SlHyPRP1 and SlARF4 in tomatoes has made them more tolerant to salt and drought. These changes help plants grow better even when the conditions aren't right.

2. Improvement in Disease Resistance

Fungi, bacteria and viruses are some of the pathogens that often attack vegetable crops. By changing susceptibility genes, CRISPR/Cas9 can be used to make disease-resistant plants.

For example, scientists changed the SlMlo1 gene to make a tomato that was resistant to diseases. This gene made the tomato resistant to fungal pathogens. Editing other genes has also made plants more resistant to pathogens like *Pseudomonas syringae* and *Phytophthora capsici*

3. Resistant to herbicides

Weeds compete with crops for nutrients, water and sunlight. CRISPR technology can help plants tolerate certain herbicides, which makes it easier for farmers to keep weeds under control.

Scientists have used CRISPR to change the ALS gene, which has developed herbicide-resistant in crops like watermelon and tomatoes.

4. Control Ripening

Ripening significantly influences the storage and transportation of vegetables. By modifying ripening-associated genes like RIN and SlDML2 in tomatoes, researchers can slow down ripening and prolong shelf life

5. Improving the quality and nutritional value

CRISPR technology can also enhance the nutritional and commercial quality of vegetables. As an example:

- Increasing main compounds like amino acids
- Improving starch content in potatoes
- Reducing browning in vegetables
- Enhancing nutrient content in vegetable crops

These changes make food healthier with better quality.

6. Developing fruits without seeds

CRISPR has also been used for developing parthenocarpy, which makes fruits without seeds. Editing the IAA9 gene in tomatoes made fruits without seeds that had good agricultural traits.

Challenges in Using CRISPR Technology

CRISPR/Cas9 has a lot of potential, but there are still some problems that need to be fixed.

1. Effective delivery systems - Introducing CRISPR components into plant cells may be difficult and sometime it may lead to failure.

2. Off-target mutations - sometimes changes happen in other parts of the genome that weren't meant to happen.

3. Genome instability- DNA breaks can lead to changes in the structure of chromosomes.

4. Concerns regarding ethics and regulations- Biosafety standards and societal acceptance vary across countries

To get rid of these problems, scientists are trying to make CRISPR technology more accurate and efficient.

Future Prospects

Over the coming decades, CRISPR/Cas9 is expected to transform vegetable breeding methods. This technology can assist in developing the crops which are more resilient to pests, diseases and climate variability, while being more productive and nutritious. Many varieties of genome-edited vegetables are already preparing for market, demonstrating the practical applications of this technology

Conclusion

CRISPR/Cas9 genome editing is a game-changing tool for modern farming because it lets you make precise changes to genes. This opens up new ways to make vegetable crops better in terms of yield, quality, stress tolerance and disease resistance. There are still problems to solve, like regulatory issues and off-target effects, but more research and responsible use of this technology could be very important for making sure that everyone has enough food in the future.

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