

ACHIEVING CLIMATE RESILIENCE THROUGH GENOME EDITING TECHNOLOGIES

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ABSTRACT

This article underscores the urgent need for innovative strategies in agriculture to tackle global challenges like climate change and population growth. Traditional methods struggle with evolving conditions, and genome-engineering tools like ZFNs, TALENs, and CRISPR/Cas9 offer precision for developing climate-resilient crops. The focus is on mitigating climate change impacts through water management, conservation practices, and genome-edited cultivars. The urgency is emphasized in light of escalating abiotic and biotic stresses, ensuring food security amid a growing population and unpredictable weather patterns.



INTRODUCTION

In the backdrop of imminent threats posed by abiotic and biotic stresses to global agriculture, where abiotic stress alone is projected to annually reduce global crop yields by over 50%, there is a critical need for transformative approaches. Traditional methods have proven inadequate in effectively managing heightened crop yields amidst the dynamic backdrop of evolving climatic conditions. A recent paradigm shift in agricultural sciences has been witnessed with the emergence of genome-engineering strategies as promising tools for imparting desirable traits in a diverse array of eukaryotic species, prominently among them, plants.

The pressing concerns of food security and climate change gain heightened significance against the projected backdrop of a global human population reaching approximately 10 billion by 2050. These concerns stem from a convergence of factors, including unabated population growth, diminishing arable land, depleting agricultural resources, and the growing unpredictability of weather patterns. This intricate web of challenges paints a complex picture, foretelling an impending food crisis exacerbated by the adverse impacts of global warming on plant physiology, soil productivity, and microbial interactions.

Conventional breeding methodologies, although stalwart in their own right, now face the stark reality of proving inadequate to catapult crop production to the anticipated levels demanded by the growing

global population. This deficiency necessitates a shift towards innovative and sustainable approaches that can dynamically address the multifaceted challenges at play. Recognizing this imperative, researchers are actively engaged in the exploration of genome-editing technologies as proactive measures to bolster climate resilience in crops, operating within the framework of existing agricultural practices. This concerted effort seeks not only to enhance productivity but also to foster adaptability in the agricultural landscape, underscoring the pivotal role of genomic interventions in shaping the future of global agriculture.

NEGATIVE IMPACT OF CLIMATE CHANGE ON AGRICULTURE

1. Heat Waves:

- Induces desiccation and heightened photorespiration in crops.
- Climate change-related heat waves significantly reduce average crop yields.
- Global production of wheat, rice, and maize falls short of demand, necessitating stock releases.

2. Fluctuations in Monsoon:

- Droughts and floods contribute to decreased crop yields.
- Extreme weather events become more common, disrupting agriculture.

3. Hail Storms:

- Larger hail physically damages crop plants upon contact.
- Hail exceeding 1.6 inches causes substantial harm to crops.

4. Drought:

- Increasing frequency of droughts due to global warming.
- Results in crop failures and loss of vegetation.

5. Tropical Cyclones:

- Coastal cyclones adversely affect agriculture through direct damage from high-speed winds and flooding.
- High tides may introduce saline water, rendering fields unsuitable for cultivation.

6. Rise in Sea Level:

- Increased CO₂ concentration leads to rising temperatures, melting icebergs, and elevated sea levels.
- Elevated sea levels contribute to enhanced coastal salinity.

MITIGATING EFFECTS OF CLIMATE CHANGE ON AGRICULTURE

1. Efficient water and nutrient management through practices like sprinkler and drip irrigation.
2. Adoption of conservation agricultural practices such as no-tillage to prevent soil erosion and promote carbon sequestration.

3. Utilization of tolerant cultivars developed through genome editing technologies.

GENOME EDITING TECHNOLOGIES

Genome editing involves precise modifications in the genetic makeup of organisms, employing tools like zinc finger nucleases (ZFNs), transcription activator-like effector nucleases (TALENs), and CRISPR/Cas9. Among these, CRISPR/Cas9 stands out as the most effective for precise genome editing in major crops.

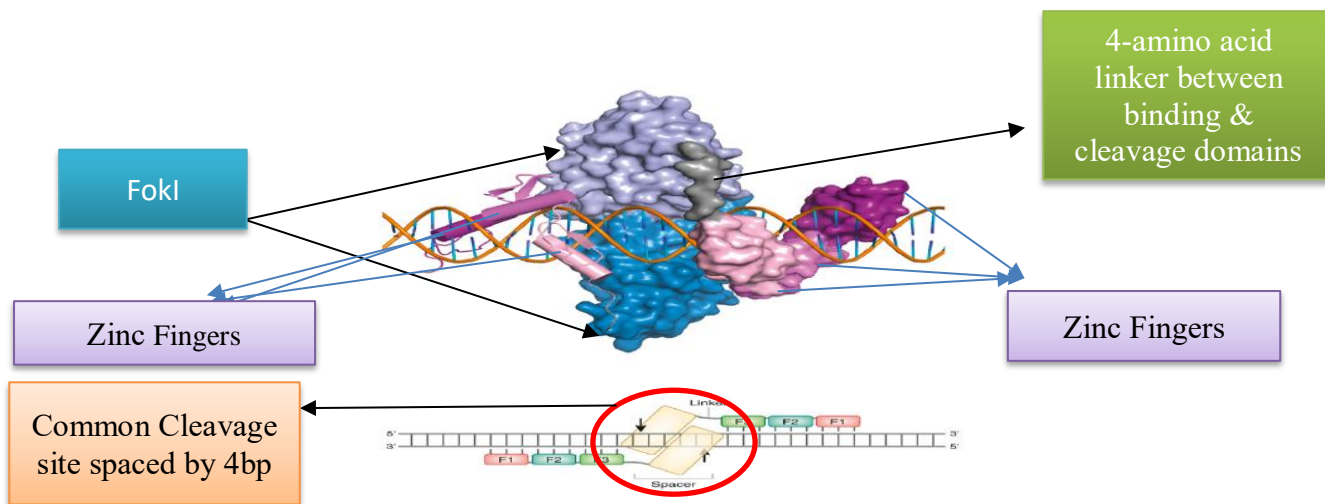
NEED FOR GENOME EDITING TECHNIQUES

1. Accelerated breeding periods facilitated by genome editing.
2. Enhanced accuracy and precision compared to conventional breeding methods.
3. Cost-effectiveness in development from an economic standpoint.
4. Increased public acceptability of genome editing techniques.
5. High frequency of application.

GENOME EDITING TECHNOLOGIES

1. ZFNs - Zinc Finger Nuclease:

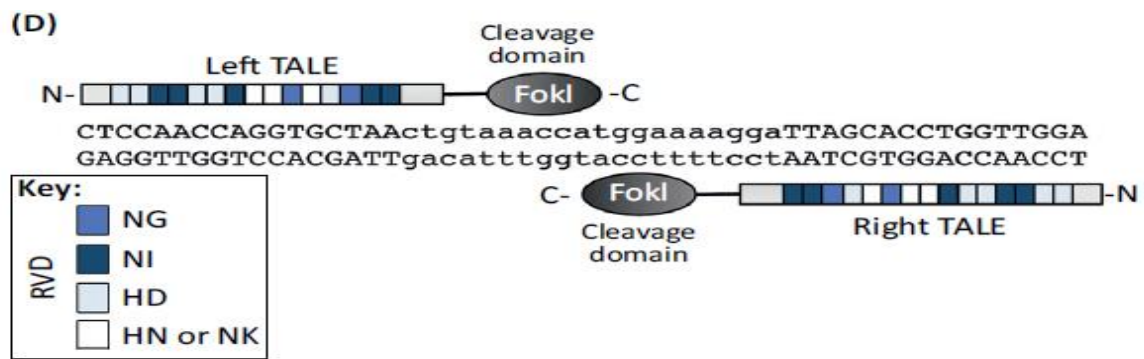
- Fusion of the FokI restriction endonuclease with zinc-finger proteins.
- Induces targeted DNA double-strand breaks (DSBs) via designed zinc-finger domains.



Structure of Zinc Fingers

2. TALENs - Transcription Activator Like Effector Nucleases:

- Fusion of FokI cleavage domain and DNA-binding domains derived from TALE proteins.
- Induces targeted DSBs, activating DNA damage response pathways.



3. CRISPR/Cas Systems:

- Utilizes clustered regularly interspaced short palindromic repeats (CRISPR) loci.
- Relies on crRNA and tracrRNA for sequence-specific silencing of foreign DNA.
- Type II systems, particularly CRISPR/Cas9, serve as effective RNA-guided DNA endonucleases for precise genome editing in major crops.

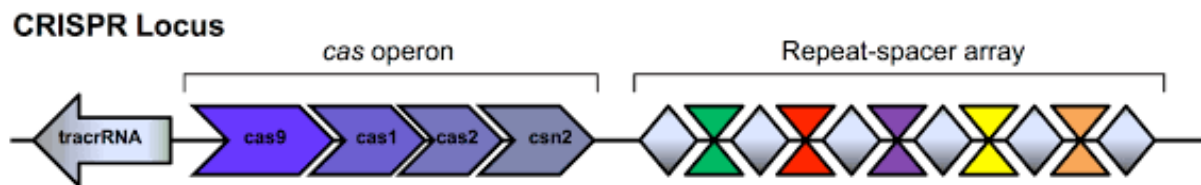


Figure1: CRISPR Locus structure

CONCLUSION

Navigating global challenges of climate change and population growth necessitates a paradigm shift in agricultural strategies, as conventional breeding proves inadequate for escalating crop demands. Genome editing technologies, exemplified by ZFNs, TALENs, and CRISPR/Cas9, emerge as transformative tools for developing climate-resilient crops. Adverse climate impacts—heat waves to rising sea levels—underscore the urgency of mitigation. Practical approaches include water and nutrient management, conservation practices, and the integration of genome-edited cultivars. The efficiency, precision, and cost-effectiveness of genome editing position it as indispensable in shaping the future of agriculture. Genome-edited crops promise increased yields, adaptability, and sustainability amidst the evolving landscape of global agriculture.
