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Enhancing Horticulture through CRISPR-Cas9 Technology

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Abstract

Horticultural crops comprise a wide variety of fruits, vegetables, nuts, flowers, fragrant and medicinal plants. They provide nutritional, medical, and aesthetic advantages to humans. However, these crops face several biotic and abiotic stress. Thus, now a days conventional breeding and biotechnology methods are being used to generate improved cultivars. Recent novel plant breeding techniques, such as the Clustered Regularly Interspaced Short Palindromic Repeats/CRISPR associated 9 (CRISPR/Cas9) system, have gained popularity owing to their efficiency, accuracy and simplicity when compared to older genome editing methods. Increased understanding of the efficacy and efficiency of biotechnology techniques may inform the usage of CRISPR gene-editing technology. In this review article, we look at CRISPR/Cas9 technology, including its history, categorization, general applications, particular usage in horticulture crops, obstacles, current resources, regulatory implications, and the way ahead. We also highlighted the use of CRISPR technology in horticulture plants to increase stress responses, fruit quality, and cultivation features. This complete analysis was created to assist construct a full knowledge of the CRISPR/Cas9 systems and to serve as a reference for future development of this technology to efficiently control horticultural plant features.

Keywords: CRISPR; Horticulture; Gene-Editing; Biotechnology

Introduction

Horticulture crops provide valuable food and nourishment to people. *Solanum lycopersicum* (tomato), Musa spp. (bananas and plantains), *Citrullus lanatus* (watermelon), *Malus x domestica* (domestic apple), and Citrus spp. (citrus) are among the most important horticultural crops [1]. The present global population is 7.7 billion, which is expected to rise to 8.5 billion by 2030, 9.7 billion in 2050, and 10.9 billion by 2100 [2]. Food consumption has increased and continues to rise in tandem with the growing human population, necessitating agricultural output to keep up [3]. However, additional hurdles to agricultural output have evolved in recent years, including the creation of new pest and disease races, greater drought, heatwaves, climate change, and other abiotic pressures. Plant breeders have used a variety of strategies, including hybridization, selection, and genetic modification, to improve horticultural products [4]. These techniques have helped to boost yield, disease resistance, and other desirable characteristics [5].

CRISPR is an abbreviation of Clustered Regularly Interspaced Short Palindromic Repeats is a family of DNA sequences in bacteria. The sequences contain snippets of DNA from viruses that have attacked the bacterium. These snippets are used by the bacterium to detect and destroy DNA from similar viruses during subsequent attacks. The sequences play a key role in a bacterial defence system and form the basis of a technology known as CRISPR/Cas9 that effectively and specifically changes genes within organisms. The CRISPR-Cas9 system is extensively utilized as a genome editing tool, with guide RNA directing the Cas9 enzyme for precise DNA breakage and changes [6]. CRISPR-Cas9 has been shown to effectively improve critical features in a variety of agricultural crops via targeted alterations [7]. CRISPR/Cas9 technique is regarded as the most ideal option for obtaining genome-edited crops due to its reduced cost, more flexibility, and high dependability. However, there is still room for development in CRISPR/Cas9 technology when employed in horticulture crops. As a result, we will examine the evolution of gene-editing technologies, the creation of the CRISPR/Cas9 system, its optimization, and its application in horticulture crops, giving a reference for future technological development in horticultural crop trait improvement.

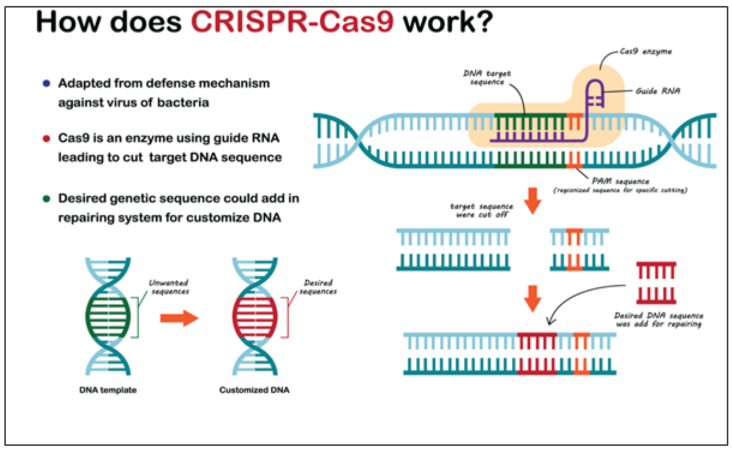

Figure 1: CRISPR-Cas9 work.

Application of CRISPR/Cas9 in Horticultural Crops

The Cas9 nuclease and the guide RNA (gRNA) are both necessary components of the CRISPR-Cas9 system. They work together to make precise genome editing possible in horticulture crops. CRISPR/Cas9 has the potential to be a valuable plant breeding tool, as shown by the degree of interest among the breeding community. Its applications include the following.

Trait Modification: The CRISPR-Cas9 method allows for precise manipulation of genes linked with desirable features in horticultural crops, such as disease resistance, abiotic stress tolerance, fruit quality, nutritional content, fragrance, colour, and post-harvest shelf life. Its use has effectively increased disease resistance in crops such as tomato, offering better protection against pathogens such as powdery mildew and bacterial spot [8].

Gene Activation/Suppression: The CRISPR-Cas9 technology allows for precise control of gene expression by targeting gene promoters or regulatory regions. This skill enables the selective activation or repression of certain genes. This method permits targeted crop phenotypic changes by altering key genes linked with various biological processes. Researchers successfully used CRISPR-Cas9 to increase lettuce output by activating key growth-related genes, demonstrating the technique's promise for precise gene control in horticulture crops [9].

Genome Engineering for Crop Domestication: The use of CRISPR-Cas9 is a powerful technique for crop domestication, allowing for quick alteration of wild or neglected plant species in order to turn them into prospective horticulture crops. This novel strategy allows researchers to incorporate specific genetic changes linked with desired agronomic features, such as reduced bitterness, improved nutritional content, and greater yield potential. Notably, the use of CRISPR/Cas9 technology has been studied in crops such as watermelon, where targeted mutagenesis of the ClBG1 gene using CRISPR/Cas9 led in a decrease in seed size and an increase in seed germination [10].

Genome Editing for Quality Improvement: CRISPR-Cas9 has the ability to improve the quality qualities of horticultural crops by changing genes involved in taste, nutritional content, texture, fragrance, and color. Researchers have successfully used this technique to target genes involved in anthocyanin biosynthesis, leading in the production of new hues in flowers and fruits, which improves their sensory and nutritional characteristics.

Potential Challenges Associated with CRISPR-Cas9 in Horticultural Crops

Off-Target Effects: These effects occur when the Cas9 nuclease accidentally cleaves DNA sequences that are similar, but not identical, to the intended target site. Such off-target effects may lead to unwanted genetic alterations, which can have unanticipated ramifications for the crop's phenotypic and genome stability. To discover and analyze the off-target impacts of CRISPR-Cas9 gene editing, many approaches are used, including whole-genome sequencing, focused deep sequencing, and computational analysis.

Delivery and Transformation Efficiency: Efficient transport of CRISPR-Cas9 components into plant cells is required for effective genome editing. However, the transformation process for horticulture crops may be extremely difficult, especially in refractory species with complicated genomes. Ongoing research aims on optimizing delivery mechanisms and increasing transformation efficiency to permit larger applications of CRISPR-Cas9 across varied horticulture crops. Certain horticultural crop genotypes provide intrinsic obstacles for transformation owing to their limited regeneration capacity or high levels of tissue browning or necrosis [11].

Conclusion

The original use of CRISPR-Cas9 in horticulture crop genome editing faced hurdles due to off-target effects, which resulted in unexpected genetic alterations. To overcome this issue, great progress has been made in generating enhanced Cas9 variations. High-fidelity Cas9 and Cas9 nickase have been designed to provide fewer off-target effects while preserving efficient on-target editing. Furthermore, enhanced computational methods have been used to improve off-target prediction, allowing for more accurate detection of probable off-target regions and directing target selection for safer genome editing. Improving specificity has been another key emphasis in CRISPR-Cas9 improvements for horticulture crop improvement. However, there is still room for development in CRISPR/Cas9 technology when employed in horticulture crops. As a result, we will examine the evolution of gene-editing technologies, the creation of the CRISPR/Cas9 system, its optimization, and its application in horticulture crops, giving a reference for future technological development in horticultural crop trait improvement.

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