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EDITORIAL

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Plant genome editing to achieve food and nutrient security

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Abstract

Genome editing enables precise genetic manipulation in plants, offering hope for tackling global food insecurity and malnutrition by enhancing crop traits and nutritional content. The *BMC Methods* Collection 'Genome Editing in Plants' will showcase advancements in the field, including target selection, delivery systems, off-target effects, and efficiency optimization.

Main text

Genome editing is a versatile technology for precise manipulation of genetic material in different organisms, including plants. Originally, homologous recombination (HR) was employed for gene knockout, but its practical application was limited by low editing efficiency and labour-intensive procedures [1]. Following this, RNA-mediated interference (RNAi) was adopted for gene knockdown studies; however, it frequently resulted in incomplete and non-specific effects [2]. Subsequently, site-directed nucleases, including meganucleases (MNs), zinc finger nucleases (ZFNs), and transcription activator-like effector nucleases (TALENs), were introduced to enable targeted knockout or knockdown studies by inducing double-strand breaks (DSBs) at specific loci. However, these methods remain expensive and require extensive plasmid construction alongside labor-intensive protocols [3]. To address these limitations, the discovery of the CRISPR-Cas9 genome editing tool in 2012 emerged as a transformative breakthrough [4]. In this system, a single guide RNA (sgRNA) directs Cas9 to precisely target and cut the genome. Due to its simplicity, cost-effectiveness, and ease of use, the scientific community rapidly embraced the CRISPR/Cas9 system as a reliable and user-friendly tool for editing genomes across various organisms. While Cas9 remains the most widely used nuclease, alternative programmable Cas variants, including Cas12, Cas13 and Cas14 have been discovered to enhance the precision of CRISPR/Cas-mediated genome editing [3]. Following the developments of CRISPR/Cas9/12/13/14 tools, base editing was introduced in 2016, a CRISPR-Cas9-based genome editing technology that allows the introduction of point mutations in the DNA without generating DSBs. Two major classes of base editors have been developed: cytidine base editors or CBEs allowing C > T conversions and adenine base editors or ABEs allowing A > G conversions [5]. Finally, the ground-breaking prime editing system, introduced in 2019, represents a significant advancement in genome editing. Unlike conventional CRISPR methods, prime editing utilizes a longer guide RNA called pegRNA, along with a fusion protein comprising Cas9 H840 nickase and reverse transcriptase (RT). This innovative approach enables precise targeting of specific genomic loci minimizing off-target effects and offers the remarkable capability to delete or insert DNA sequences of substantial size, even up to kilobases, at predetermined locations in the genome [6].

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Most of these tools have successfully been applied in diverse plants for various trait improvements during the past decade.

Application of genome editing in plants: prospects to achieve food and nutrient security

According to the Food and Agriculture Organization's (FAO's) 2022 statistics, approximately 735 million people worldwide experience acute food shortages, and 3.1 billion people are unable to afford a healthy diet. Projections indicate that by 2030, nearly 600 million people will suffer from chronic undernourishment [7].

An effective strategy to address the challenges posed by a growing population and hunger is to enhance crop production and engage in agricultural activities in marginal areas. Over the past century, significant advancements in agricultural production and innovations have played a pivotal role in the success of the Green Revolution. During this period, efforts were focused on enhancing the genetic traits of traditional crops. These included selecting for higher yield potential, adaptability to diverse environments, shorter growth duration, improved grain quality, and resistance to biotic and abiotic stresses such as pests, diseases, drought, and flooding. As a result of these initiatives, cereal crop production tripled while the cultivated land area increased by only 30%. The Green Revolution led to significant reductions in poverty and food prices, underscoring its profound impact on global food security and socioeconomic well-being [8].

However, modern agricultural production faces unprecedented challenges such as global warming, rapidly changing climate conditions, soil salinization, and the accumulation of pollutants in the soil, resulting in toxic effects. These challenges require faster responses and more effective solutions that cannot be addressed by traditional agricultural methods [9].

Expanding upon the increasing availability of complete DNA sequences for numerous crops, genome editing technologies, especially CRISPR-Cas-mediated genome editing, provide a faster and more precise way to enhance crop improvement compared to traditional breeding methods [10].

Genome editing is now being applied to a wide range of crops in several countries, primarily focusing on enhancing crop yield and related traits such as tolerance to biotic and abiotic stresses. This aims to increase agricultural productivity, thus mitigating hunger, while also addressing nutritional deficiencies by enhancing the nutrient content of crops [11]. In rice, a staple for a large portion of the world's population, numerous genome editing studies target improving quality and resistance to diseases and pathogens [12, 13]. Similarly, genome editing efforts in wheat, another vital crop in human nutrition, aim to enhance its nutritional profile by modifying the levels of amylose and gliadin well [14]. Interestingly, genome edited crops such as waxy corn, anti-browning fungi, high-oleic soybeans, and γ-aminobutyric acid-rich tomatoes are already commercially available [15].

As genome editing technologies become more accessible and cost-effective, they hold significant promise for a wide array of benefits. For consumers, these advantages encompass improved nutrition, enhanced food safety, and reduced food waste. Farmers will benefit from increased resistance to diseases, weeds, and pests, as well as more affordable seeds due to lower production costs. Additionally, genome editing offers opportunities to bolster climate resilience and enhance biodiversity within cropping systems.

However, it is important to acknowledge the potential risks associated with genome edited crop varieties. These include non-target edits that may compromise safety or agronomic performance, as well as concerns regarding transparency, equity in technology spread and regulatory oversight. Therefore, it is crucial to consider scientific, political, and social factors when determining how to sustainably regulate and promote the safe use of genome-edited plants.

Acknowledging the importance of this field, we are pleased to announce that we are now accepting submissions to our Collection titled "Genome Editing in Plants." For more information, please visit: https://www.biomedcentral.com/collections/gep. We believe that this collection will serve as a valuable platform for sharing novel protocols and methods to drive advancements in this area.

Abbreviations

HR	Homologous recombination
RNAi	RNA-mediated interference
DSB	Double-strand break
MN	Meganucleases
ZFN	Zinc finger nucleases
TALEN	Transcription activator-like effector nucleases
sgRNA	Single guide RNA
CRISPR	Clustered Regularly Interspaced Short Palindromic Repeats
CBE	Cytidine base editors
ABE	Adenine base editors
RT	Reverse transcriptase
FAO	Food and Agriculture Organization

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SAC and MK conceived and drafted the Editorial. All authors read and approved the final manuscript.

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