CRISPR-Cas Genome Editing

Subjects: Biotechnology & Applied Microbiology
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The adaptive immune system CRISPR (clustered regularly interspaced short palindromic repeats)-Cas (CRISPR-associated) in prokaryotes has led to a revolution in targeted genome editing with high precision and accuracy. This technology allows the manipulation or modification of crop plant genome in several ways. The CRISPR-Cas technology is faster, cheaper, precise, and highly efficient in editing genomes even at the multiplex level. Application of CRISPR-Cas in editing the crop plant genome is emerging rapidly for the increased yield, quality, domestication, and stress tolerance. More importantly, this technology is becoming a user-friendly tool for the development of non-transgenic genome-edited crop plants.

Keywords: Gene editing ; Genome ; CRISPR-Cas ; Food security

1. Introduction

The population in the world is expected to increase from 7.3 to 9.7 billion by 2050 (Clarke and Zhang 2013). To feed the estimated increased population in the world, food production will need to be increased by 70–110% by 2050 for a well-fed world population (Goodfray et al. 2010; Jones et al. 2014). To meet this demand, crop varieties with higher yield and better adaptability to the changing climate will need to be developed in the coming decades on an urgent basis. Although classical breeding methods helped to feed billions of people in the last century, this classical technology seems unable to face future challenges due to its time-consuming nature, fitness penalties, and loss of genetic diversities. The recently developed, the clustered regularly interspaced short palindromic repeats (CRISPR)-CRISPR-associated protein (Cas) genome-editing technology (CRISPR-Cas) has so far been shown the greatest promise (Jinek et al. 2012; Shan et al. 2013; Nekrasov et al. 2013; Li et al. 2013; Islam 2019). Genome editing can be defined as the precise alteration of genetic sequences in the living cells including those of humans at much higher accuracy than ever before. The CRISPR-Cas genome editing is a revolutionary technique that targets a specific section of DNA to make a precise cut/break at the target site, and can do at least one of two things - (i) makes a gene nonfunctional, and (ii) replace one version of a gene with another.

2. Application

This system relies on the ability of a short sequence called guide RNA (gRNA) to guide CRISPR-Cas nuclease to cleave target sites and produces site-specific DNA double-strand breaks (DSBs), leading to genome modifications during the repair process (Jinek et al. 2012; Xing et al. 2014; Haque et a. 2018; Adli 2018; Islam et al. 2019). The CRISPR-Cas system has already been successfully used for the improvement of a large number of plant traits in almost all major food crop plants including rice, wheat, maize, cassava, soybeans, and many other crop plants. It is expected that the CRISPR-Cas genome editing in various crop plants may revolutionize food production, which should lead to the second green revolution to ensure food and nutritional security of the ever-increasing population of the world (Islam 2019). A good number of CRISPR edited non-transgenic plants have received a green pass in the USA for commercial cultivation. Although Canda and Japan also consider CRISPR edited non-transgenic plants outside the requirements for rigorous biosafety protocols for release to cultivate in the practical fields, many countries have not yet formulated any regulatory framework for the CRISPR edited plants. However, improvement in protocols, higher access to CRISPR-Cas technology, and necessary changes in the global regulatory environments and their harmonization are badly needed for the wider application of this frontier technology for sustainable food production in the changing climatic conditions of the world [1][2][3][4][5][6][7][8][9][10][11]. Developing countries should ensure training and infrastructural facilities to get the highest benefit from this frontier technology to ensure food and nutritional security of their increasing population under the threat of climate change to agriculture.

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