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CRISPR/Cas9 based Genome Editing for Improved Nutritional Security and Climate Resilient Crops

Dr. Akarsh Parihar[1] and Dr. Shiwani[2]

[1]*Department of Genetics & Plant Breeding, BACA, AAU, Anand-388110 (Gujarat)*
[2]*Department of Agricultural Biotechnology, Centre of Excellence in Biotechnology, AAU, Anand-388110 (Gujarat).*
E-mail: hodgpb@aau.in

Abstract: In order to attain global food security by 2030, one of the sustainable development objectives set by the UN in 2015 is to end hunger. In order to feed the world's population and achieve the aim of eradicating hunger by 2030, a greater and more reliable crop supply will be necessary. To end hunger, new technologies are needed, and the most promising one is genome editing technology. Meeting these problems and ensuring sustainable food production depend on ongoing innovation in crop breeding. Recent developments in gene editing technology, particularly those based on the CRISPR/Cas systems, make targeted and precise genetic manipulation of crops more practical and hasten the shift to precision breeding for crop enhancement.Given its effectiveness and strength over transgenics, this technology can be thought of as a promising technique for accomplishing world hunger eradication.

INTRODUCTION

The world's ever-increasing population and changing climate are putting heavy pressure on global food security. According to a United Nations (UN) report, the world population and food demand will rise to 8.5 billion and 11.6 billion tons, respectively by 2030. If recent trends continue, the number of people affected by hunger could surpass 840 million by 2030 (United Nations, 2019). To achieve zero hunger goal, the world needs to produce 15-20% more food than yields predicted from recent trends. Human efforts have resulted in increased crop yields in the past. From the period of green revolution (1940s to the late 1960s) to advances in biotechnology, hybridization, mutation and transgenic technologies (late twentieth century) paved the way toward developing improved crop varieties. Many transgenic crop varieties have been released and commercialized in the different part of the world but they need vigilant supervision to limit the natural selection of insect pests and weeds with tolerance to the engineered traits. In addition, issues related to cost, efficiency, bioethics, regulation and public acceptability of genetically modified plants have limited applying these techniques in crops.

Novel plant breeding methods provide practical, adaptable, economical, and time-saving strategies to achieve precision in plant breeding. These methods include advancements in genome editing, speed breeding, and the integration of omics technology. Thanks to modern genome editing methods, it is now possible to modify genes that are important for agriculture. These range from random (physical and chemical mutagens) to non-random meganucleases (MegaN), zinc finger nucleases (ZFNs), transcription activator-like effector nucleases (TALENs), clustered regularly interspaced short palindromic repeats (CRISPR)/ associated protein system 9 (CRISPR/Cas9), the CRISPR system from Prevotella and Francisella1 (Cpf1), base editing (BE), and prime editing (PE). These nucleases system create a double-stranded cut in the host genome at a specific site, then the cell's endogenous DNA repair machinery repairs the sequence by nonhomologous end joining

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(NHEJ) or homologous recombination (HR). Repair by NHEJ canknockout gene function by producing small deletions andrepair by HR using a template can introduce specific changesto the DNA sequence at the desired region. Rather thancreating double-stranded DNA breaks, novel applications ofthe CRISPR-Cas system can create other modifications at thetarget site, such as changing the DNA sequence by base editingor altering the chromatin structure to cause epigeneticchanges. Genome editing techniques that promote crop improvement through hybrid seed production, induced apomixis, and resistance to biotic and abiotic stress are prioritized when selecting for genetic gain in a restricted timeframe. The novel Cas 9 variants, namely BE and PE, can generate transgene-free plants with more frequency and are therefore being used for knocking out of genes of interest. Moreover, CRISPR/Cas system helps in the generation of transgene free plants which make it more efficient, economical and adaptable. The generation of transgene-free plants is helpfulin categorizing genome editing of plants developed through classical breeding methods.

CRISPR/CAS TECHNOLOGY TO ACHIEVE ZERO HUNGER

Different strategies have been deployed via the CRISPR-Cas system for crop improvement to show its potential in achieving zero hunger.

Improvement of biotic stresses: Targeting susceptibility (Su) genes in plant genome using CRISPR/Cas system is an alternative strategy against introducing dominant resistance (R) genes through breeding or transgenic technology for the improvement of biotic stress tolerance in crop plants.*SWEET*genes are famous Su genes for bacterial blight disease, as they facilitate the proliferation of bacteria in plant tissues.Olivia*et al.* (2019) developed rice line by disrupting the linkage between TALEs and *SWEET* genes resulted in broad-spectrum resistance to bacterial blight. Similarly, resistance to powdery mildew disease in wheat improved by targeting the *Mildew Locus O (MLO)* gene via CRISPR-Cas (Wang *et al.*, 2014).

Improvement of abiotic stresses: In addition to biotic stress, plant face different abiotic stresses. Some plants genes known as sensitivity genes (Se genes) enhance the deleterious effects of abiotic stresses. CRISPR/Cas genome editing strategy have been used in several plant species including grain, vegetable and fruit crops to improve abiotic stress tolerance by disrupting these Se genes (Ahmad *et al.*, 2021). In maize, disruption of *Auxin-Regulated Gene Involved in Organ Size 8 (ARGO8)* by CRISPR/Cas9 improved drought tolerance (Shi *et al.*, 2017).

Improvement of grain yield: CRISPR/Cas strategy can also be used for the improvement of grain yield and plant architecture by controlling the QTLs that affect 1000-grain weight, number of grains per panicle, number of florets per panicle and number of panicles per plant. CRISPR-based editing of *OsGS3*and *OsGL3.1* improved grain size, which ultimately increasedthe 1000-grain weight and overall yield per plant in rice(Yuyu*et al.*, 2020).

Improvement of photosynthesis and nutrient use efficiency: Photosynthesis plays a key role in plant growth and development, grain and fruit yield and biomass production. It has also been improved via CRISPR based gene editing. Sheng *et al.* 2020 disrupted *Negative Regulator of Photosynthesis 1 (NRP1)* results in improved rice photosynthetic efficiency, grain yield and biomass production.The development of crops with greater nutrient use efficiency (NUE) will reduce the fertilizers' consumption and improve farmers' profit and decrease pollution. Some genes downregulate nutrient uptake and thus negatively impact NUE in plants. Lu *et al.* 2017 edited the rice nitrate transporter gene *NRT1.1B*using CRISPR based cytosine base editing system (CBE) and resulting mutant showed improved NUE compared with wild type rice.

CONCLUSION AND FUTURE PERSPECTIVE

CRISPR based genome editing system have revolutionized plant breeding. The development of material has become more efficient and robust with CRISPR/Cas system in several ways. The development of two-linehybrids via CRISPR will not only save time but could alsoincrease yield several folds. The costs associated with growing asegregating F_2 population are very high. To fix this problem,hybrid vigor can be maintained via CRISPR, which willtransform the development of hybrids and their breedingprograms. CRISPR's role as a breeding tool in the developmentof smart and efficient crops, i.e., development of climateresilientcrops, induction of self-compatibility in economicallyimportant food crops, and material preparation for developinghybrids between species, could save a substantial amount oftime, money, and energy and ultimately allow us to meet theglobal challenge of food security.

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