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Plant Genome Editing Technology for Sustainable Agriculture- Policies and Regulations

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INTRODUCTION

Our agricultural system is highly subjected to climate changes uncertainties. With the increase in the global population, chronic malnutrition has become a great concern. It has been projected that by 2050 global population will exceed 9 billion. Thus, our agricultural system will require crops with a higher yield, better quality, and low input use. In short, an approach for sustainable agriculture is an urgent need. The present crop improvement approach, i.e; the conventional breeding approach takes a long time from the selection of plant varieties to first crosses into commercial varieties. Moreover, conventional breeding is a more laborious and tedious technique. (Foley et al., 2011, & Tilman et al., 2011) Biotechnological techniques that are used to modify and develop the existing plant varieties by transfer of gene/genes of known function to produce genetically modified (GM) crops are popular these days. GM crops are supposed to contribute to global food security but their commercial cultivation is highly threatened by unproven health hazards and environmental safety concerns. Several government policies and regulations act as a barrier to the adoption and commercialization of these GM crops. Thus, the advantages of GM crops are restricted to only a few crop species (Prado et al., 2014).

To safeguard the food security of the global population, Genome editing techniques have come to the rescue. Genome editing (GE) is defined as a precise and efficient method of modifications of the genome at genomic loci (Gao, 2015). GE is preferred over GM because GE involves genome edits that include few nucleotides only. Segregation of genome-edited population renders no clue to distinguish between a natural mutant and a gene edit. Various genome editing techniques have been developed to date and many more are on their way.

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Techniques like ZFN (Zinc Finger Nuclease) (Kim et al., 1996) and TALEN (Transcription activator-like effector nuclease) (Christian et al., 2010) have been used for two decades. Recently CRISPR/Cas system, a genome editing technique has come under the spotlight due to its simplicity and easy targeted gene editing (Jinek et al., 2012).

ZFN includes zinc finger-based DNA recognition modules and DNA cleavage domain of the Fok1 restriction enzyme. This technique has been widely used to edit maize, rice, soybean, Arabidopsis, apple, Nicotiana. Nevertheless, this technique is comparatively complicated and has low efficacy. TALEN is a combination of transcription activator-like effector (TALE) repeats and the Fok1 restriction enzyme. It allows a more flexible target design thus increasing the number of potential target sites. TALEN was first implicated in rice to combat bacterial blight disease. This technique has been extensively used to prevent diseases in wheat, maize, sugarcane. It has also been used to modify nutritional levels in soybean, potato, and many more. Thus, this technology has a great potential for crop trait improvement. However, the designing of TALE repeats is somewhat exigent and the efficiency of the technique is variable. CRISPR/Cas system is a fusion of small guide RNA (sgRNA) and Cas enzyme. It is vastly used due to its ease in handling, simplicity, higher efficiency, and low cost. It is mostly used for gene knockouts and the production of null alleles. This genome editing technique has been largely used in cultivated crops like rice, soybean, maize, potato, wheat to increase yield, nutritional value, disease protection, herbicide resistance, increase shelf life, and so on. But the drawback of this system is that it can only recognize DNA sequence upstream of the appropriate 5'-NGG-3' PAMs, thus limiting potential target sites. Therefore, to overcome this limitation, the CRISPR/Cpf1 system has come into play. (Zhang et al., 2018).

As seen above, every gene-editing technique is associated with one or more limitations; innovations are regularly added to the existing genome editing techniques to combat this limitation. DNA-free genome editing system and Base editing technique are recently added to the genome editing toolkit. DNA-free genome editing system produces genetically edited crops with undesirable off-target effects and meeting the present and future agricultural demands from both scientific and regulatory viewpoints. It is achieved by protoplast–mediated transformation as well as by particle bombardment (Woo et al., 2015). On the other hand, the base editing technique uses Cas9 nickase or dead Cas9 fused to an enzyme with base conversion activity (Komor et al., 2016). Recently, this technique has been employed to develop herbicide resistance plants (Zong et al., 2018). Especially for CRISPR/Cas-systems many varieties and modifications are already known and new variants are being steadily developed. Thus, genome-editing by using SDNs can be categorized into three types (Shimatani et al., 2017, 2018; Li et al., 2018; Molla & Yang, 2019; & Zhang et al., 2019).

1. the induction of single point mutations or InDels (SDN-1),
2. short insertions or editing of a few base-pairs by an external DNA-template sequence (SDN-2) and,
3. the insertion of longer strands (SDN-3) of allochtonous (transgenes) or autochtonous sequences (cisgenes).

The increasing diversity of genome editing methods and approaches thus leads to a broad spectrum of applications in plants that are progressively applied commercially. The advent of genome editing systems has led to the speeding up of crop breeding techniques and to meet up the increased global food demand. However, it has created a huge controversy regarding the regulatory and governance challenges. In the USA, products obtained from biotechnology are not completely considered risky because of the technological and societal uncertainties regarding the applications of genome editing.

Societal uncertainties arise due to biosecurity and biosafety concerns.

The United States regulatory system has not been changed with the emergence of genome editing and products thereof. Just like in the United States, Canada's regulatory system has not been changed with the emergence of genome editing, but due to its product-oriented policy, the system is flexible and able to cope with all plants, irrespective of their breeding method (Smyth, 2017). Israel's Ministry of Agriculture announced to invest approximately 17 Million US-Dollar to establish a national genome editing center (Minister of Agriculture & Rural Development, 2019). Israel strongly promotes the research and development of new and innovative agricultural products in the plant and livestock fields.

In the Indian Ministry of Science and Technology (2020) the Indian Department of Biotechnology drafted the rules to propose a layer regulative approval method categorization regulatory groups depending on genome editing type. Group one combine’s plants whose genomes harbor one or a couple of nucleotide edits or deletions supported SDN-1 or ODM, whereas group two harbors a few or several base pair edits based on SDN-2 using a template. The third group is for plants with large DNA changes and the insertion of foreign DNA. therein case, a similar stringent risk assessment as for traditional transgenic plants applies (Schiemann et al., 2020). The regulation of breeding technologies mostly differs between countries and depends in most cases on whether or not modifications appeared as natural mutations, untargeted because of the radiation-based or chemical cause, or targeted by the utilization of transgenesis or genome editing technologies. The world "regulatory mixture" sets high hurdles for the global to unharness however additionally for import (and export) of genome-edited plants.

The scientific community must elaborate and share and indulge healthy follow in self-regulation. Exchanging information, sharing views, and prioritizing necessary aspects for future analysis in biosecurity and safety square measure advised for biosecurity and scientific communities. The extent to which genome-edited crops fall beneath specific regulative provisions depends on the genetic compose of the edited crops and whether or not the changes brought within the crop happen naturally or not. several jurisdictions have their safety regulative provisions. Bechtold refers to food labeling and consumer choice as an institution where one can support the communication of values and widen the viewpoint on genome editing in agricultural products (Schiemann et al., 2020).

CONCLUSION

Agriculture faces a serious challenge because of environmental condition uncertainties, increase in world population, and environmental pollution because of modernization. Sustainable production of high organic process crops and increase in yield is that the immediate want. Genome editing (GEd) system in agriculture and food is resulting in the development of new, improved crops and different merchandise. Genome editing techniques are quickly being developed and applied to serve agricultural and food production objectives. To profit absolutely, the product developed using GEd should face affordable, science-based safety rules and regulations. Moreover, rapid progress in policies and governance is needed for acceptance and exploitation of the ordering genome-edited crops.

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