Genetic engineering of crops

A ray of hope for enhanced food security

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Crop improvement has been a basic and essential chase since organized cultivation of crops began thousands of years ago. Abiotic stresses as a whole are regarded as the crucial factors restricting the plant species to reach their full genetic potential to deliver desired productivity. The changing global climatic conditions are making them worse and pointing toward food insecurity. Agriculture biotechnology or genetic engineering has allowed us to look into and understand the complex nature of abiotic stresses and measures to improve the crop productivity under adverse conditions. Various candidate genes have been identified and transformed in model plants as well as agriculturally important crop plants to develop abiotic stress-tolerant plants for crop improvement. The views presented here are an attempt toward realizing the potential of genetic engineering for improving crops to better tolerate abiotic stresses in the era of climate change, which is now essential for global food security. There is great urgency in speeding up crop improvement programs that can use modern biotechnological tools in addition to current breeding practices for providing enhanced food security.

According to the belief of Dr MS Swaminathan, the future belongs to nations with grains, not guns. Global agricultural land, the water for irrigation, and other natural resources are limited. Additionally, maximum food supply for mankind basically comes from a very small number of food crops, and total number is also decreasing steadily.¹ Furthermore, the rapidly increasing world

population requires adequate food supply to feed billions of new mouths. Therefore, the agricultural security in terms of enough grain production is fundamental to the global food security. So the global crop production must be enhanced several-fold to maintain the livelihood of nations, and this needs to be done sustainably with reduced inputs keeping pace with global climate change. The World Summit on Food Security declaration demands approximately 70% more food by 2050, which means about 44 million metric tons of annual increase in crop production is required every year. On the other hand, the World Bank projects that the climate change will decrease the crop yields by 20% or more by the year 2050. Furthermore, the State of Food Insecurity in the World (2013) reported that a total of 842 million people in 2011–13, or around 1 in 8 people in the world, were estimated to be suffering from chronic hunger, regularly not getting enough food to sustain an active life.² Therefore, agriculturally important countries require vibrant and productive agricultural produce to fight food insecurity. The changing climatic conditions are a major challenge for scientists to protect the crop plants from a variety of environmental attacks in the form of various biotic and abiotic stresses. Crop plants frequently encounter a variety of abiotic stresses among which water availability (drought, flooding), extreme temperatures (freezing, cold, heat), and ion toxicity (salinity, heavy metals) are major causes of crop failure worldwide. It has been estimated that the relative decreases in potential maximum yields

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associated with abiotic stress factors vary between 54–80%.³ The gap between potential yield and actual yield is principally because of the adverse effects of various abiotic stresses on crop production. Thus, it is necessary to improve our understanding of the molecular and physiological aspects of plant functions under stress to maintain or boost crop production in suboptimal conditions like less water or nutrient supplies or under high salt conditions, etc. The adaptation of crop plants to abiotic stresses requires the activation of cascades of molecular networks that involve stress perception, signal transduction, and the expression of specific stress-related genes and metabolites. The development of abiotic stress tolerant crops is very important for food production in many parts of the world today.⁴ The advancement of our understanding of abiotic stress resistance mechanisms and the application of genetic engineering technology have allowed the scientists to develop the plants, which can tolerate various abiotic stresses efficiently. Therefore, the application of genetic engineering for abiotic stress tolerance is vital for improving and escalating agricultural productivity. Climate resilient agriculture and modern biotechnological tools hold great potential.

The crop improvement through genetic engineering is a very promising, powerful, and efficient technology for low-input, high-output agriculture where conventional breeding tools have not been as effective. Through this technology, crop improvement can be speed up for enhanced tolerance to stresses, better

productivity, nutritional value, and nutrient and water use efficiency. The genetic engineering approaches could be one of the fastest ways to produce genetically modified or improved varieties that can tolerate the stresses and can produce good yield under continuous stress conditions. Several genetically engineered crops such as cotton, soya, maize, potato, sugar beet, alfalfa, and canola are grown across the world. The US, Brazil, Argentina, and China are massive producers. Genetic engineering of crop plants with novel candidate genes, e.g., overexpression of transcription factors (OrbHLH001, ZNF24, OsNAC10, HOMEODOMAIN GLABROUS11),^{5–8} ion transport proteins,⁹ compatible solutes,¹⁰ ROS scavenging machinery,^{11,12} glyoxalase (Gly I and Gly II),¹³ heatshock proteins,¹⁴ late embryogenesis abundant (LEA) proteins,¹⁵ and plant helicases,^{16–19} etc., which protect and maintain the function and structure of cellular components can provide a rapid way to develop multi-stress tolerant crop varieties and to improve yields. Furthermore, translation of genes conferring an advantage to the plant under various stresses needs to be transformed into high-yielding varieties to make a reasonable impact.

It is imperative that the use of genetic engineering has high expectations and great prospective to improve plant stress tolerance potential and crop productivity to harness the full genetic potential of crop species, but large biosafety issues related to genetically engineered crops must be ensured for sustainable crop production. In the future, efforts should also be taken more in developing the marker/

reporter-free genetically engineered crops with plant-derived promoter(s) rather than virus-derived promoter(s). Production of marker-free transgenic crops to avoid the risk of horizontal gene transfer, e.g., antibiotic resistance genes from genetically engineered crops to soil- and plant-related microorganisms or escape of herbicide resistant genes to wild relatives also needs the attention of plant scientists.^{20,21}

Furthermore, stress-inducible promoters, which only express when exposed to stresses, have also been identified with minimum negative effects on the plant growth. Genetic engineering of plants for abiotic stress tolerance with stress-inducible promoters has uncovered the way ahead for abiotic stress tolerance without yield penalty. Heat and abiotic stress-inducible expression in transgenic *Arabidopsis* plants has been reported with wheat chloroplast targeted sHSP26 promoter.²² A few more stress-inducible promoters like OsNCED3,²³ Wsi18,²⁴ APX, PGD1, and R1G1B²⁵ have also been found to be predominantly active in rice plants under stress.

Keeping in mind feeding the increasing world population in the era of climate change, there must not be unscientific prejudices against genetically engineered crops. Therefore, there is an urgent need of a transparent biosafety system so that issues like transgenic food safety are considered rationally and scientifically for the betterment of the world population.²¹

Disclosure of Potential Conflicts of Interest

No potential conflicts of interest have been disclosed.

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