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Prospects of Advanced Genomics for Development of Climate Resilient Wheat Genotypes

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ABSTRACT

Wheat is one the most important cereal crops of the world. As it major crop commodity for food security, there is a need to increase wheat production by developing new high yielding and climate resilient varieties,to meet the projected demand of increasing population and with changing climate. In the present review we have discussed the prospects of the advanced genomics approaches for development of climate resilient wheat genotypes and role of advanced technologies like High-throughput phenotyping, next generation sequencing, genomics-assisted breeding, and CRISPR/Cas9 genome-editing have been emphasized for management of abiotic stressors in wheat.

Keywords: wheat, genomics, abiotic stress, genome editing

Introduction

Crop production is mainly affected by the climate changes hindering the growth and development of the plants due to unfavourable environmental factors, which is the main challenge to the agriculture. Major abiotic stresses to plants include the temperature either heat or cold, drought and salinity, which are causing a huge productivity loss and are the main concern for the agricultural scientists to combat climate change for food security. Plants have intrinsic molecular regulatory mechanisms to develop resilience and tolerance to these abiotic stresses, which are the focus to increase crop productivity. Since the green revolution, the scientists are working on enhancing and engineering plants mechanism against abiotic stresses to increase the productivity(Calanca, 2017; Mosa et al. 2017).

Wheat is the world's third largest cereal crop cultivated in 220.4 million hectare area with the production of 729 million tonnes, with an average yield of 3.3 tonnes/hectare (FAO, 2015).There is a need to increase wheat production by 1.6% annually by 2020 to meet the projected demand of 760 million tons (Calanca, 2017). New high yielding and climate resilient varieties must be developed to improve agricultural production of wheat.The conventional breeding approaches are slow and inaccurate to simultaneously select for and combine putative loci from different genetic backgrounds for such a huge improvement demand. There have been major genomic advancements for the wheat improvement in the recent years as follows.

1. High-throughput phenotyping tools and marker-assisted selection provided a new opportunity for improving the selection efficiency and pyramiding of genes conferring tolerance to abiotic stresses.

2. Recent advances in next generation sequencing have transformed molecular breeding to the genomics-assisted breeding. Functional genomics approaches are identifying genes and/or QTLs responsible for the abiotic stress tolerance in crop species as well as in wild relatives.

3. High-density marker arrays like SNP and InDels etc. from next generation sequencing facilitated the genotyping-by-sequencing; the genome wide association studies and the genomic selection approaches, which are superior to conventional phenotypic selection for discovering novel genes for abiotic stress tolerance.

4. Whole genome sequence assembly revolutionised the field with the genome of the reference hexaploid wheat line 'Chinese Spring' with assembled 21 constituent chromosomes. It will be possible to identify target genes, examine their expression pattern across hundreds of RNAseq samples, determine their haplotypes in diversity collections and order knockout mutants using targeted genome editing.

5. This extensive fundamental research of plant stress tolerance could improve commercial crop yields. In wheat, major QTLs have been identified for drought; heat and cold stress; salt tolerance, which will provide novel opportunities for abiotic stress tolerance and for a more targeted search for novel alleles in wild germplasm.

6. There are increasing number of germplasm resources including precise near isogenic lines as well as next-generation populations such as multi-founder populations (e.g., multi-parent advanced generation intercross populations), which have been developed to facilitate validation of climate-smart crops. New variation incorporated into elite backgrounds from landraces, ancestral or wild crop relatives also offers potential for discovery of functional variation.

7. The CRISPR/Cas9 genome-editing technology can be a useful integral component of functional genomics to study the genetic basis of abiotic stress response and/ or tolerance in the large and complex wheat genome by knocking out or silencing target genes or genomic regions. Further transgene free targeted gene editing has been demonstrated in wheat which could generate elite cultivars with durable climate resilience. Enhancing photosynthesis efficiency in wheat through modification of key enzymes (e.g. Rubisco) will be the key to increase wheat yield potential.

Conclusion

The difficult to predict climate impact on crops could be reduced with the advanced genomics technologies, but it requires a multidisciplinary and integrated approach to more effectively accumulate favourable alleles from different backgrounds to develop genotypes that are more resilient to climate change for food security in future.

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