Ecofarming
e-Magazine for Agriculture and Allied Sciences
http://www.rdagriculture.in
e-ISSN: 2583-0791
Ecofarming Vol. 03(03): 275-280, 2023

Plant breeding

in the era of climate change

Kavita[1], Naresh[1] and Shivani[2]

[1]Department of Genetics and Plant Breeding, CCSHAU, Hisar
[2]Department of Seed science and Technology, CCSHAU, Hisar

Email: kavitadhaka127@gmail.com

Received: **April, 2023;** ***Revised:*** **May, 2023** ***Accepted:*** **June, 2023**

Introduction

At the present time, some of the worldwide major production constraints of crop plants are recognised as climate change, rapid population growth, loss of biodiversity, rising demand for food, growing demand for better agricultural inputs and many other variables simultaneously affect production and productivity of crop plant. Among them, climate change, rising population and improved agricultural inputs are the major production restrictions worldwide. The difficulty of feeding enormous population is growing formidable due to the imbalance between the population increase and crop productivity, which is increasing geometrically while crop productivity is increasing arithmetically. The severe impact of climate change and its associated adverse effects is one of the main causes of this imbalance. Climate change is the study of how weather patterns vary throughout decades or longer and how both natural and human forces can modify the climate.

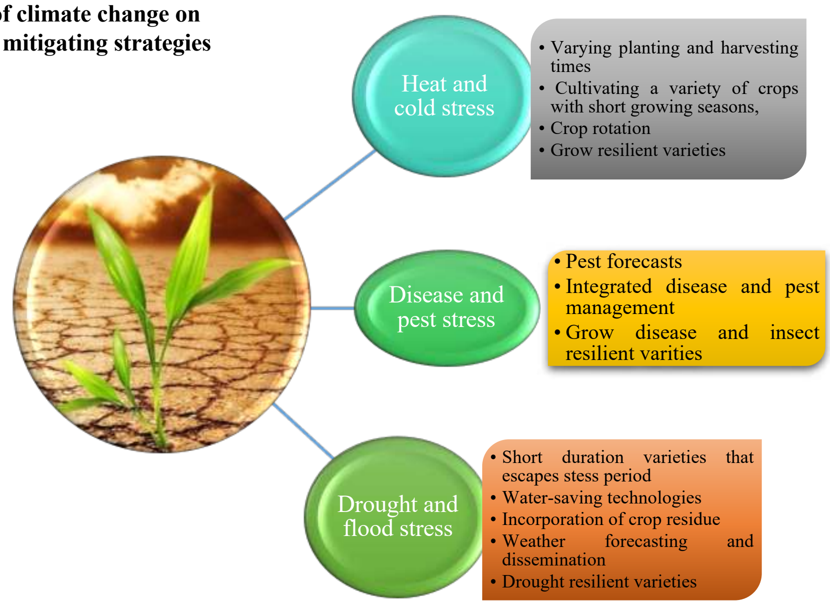
Climate change and agriculture are interconnected processes. Global climate change projections have the potential to negatively impact agriculture in a variety of ways, including through changes in average temperatures (heat and cold stress), rainfall patterns (drought and floods), and an increase in biotic stresses (pest and diseases), which will result in millions of people being starved throughout the world. It has become increasingly obvious recently as several areas of the country encountered droughts, excessive rain, floods, cyclones, frost, heat waves, and other climate disasters. And Agriculture is considered to be a sector that is expected to be most vulnerable to climatic fluctuation, because agriculture depends extensively on weather and climate to produce food and fibre (Yohannes, 2016). Sudden environmental and climate change may have a negative impact on the food production system, which will increase the number of people suffering from hunger (Lenaerts *et al.,* 2019).

Impacts of Climate change on agriculture

Under field conditions, heat and drought are the most prevalent stress factors and have a large impact on plants. As heat stress affects cereal production and yield, cold stress results in sterility, and drought stress has a negative effect on the morpho-physiology of plants. These climatic issues have an adverse effect on plant growth and yield, generating major molecular, physiological, biochemical and morphological responses. Fluctuations in rainfall patterns intensify the possibility of short-term crop failures and long-term drops in production. Seasonal shifts, increase in temperature and changes in precipitation patterns have already been observed. Climate change has both direct and indirect effects on crop yields. Changes in crop duration have a direct impact on reproductive processes such as pollination and fertilisation. While the indirect effect is primarily the result of changes in water availability, disease, pest and weed dynamics have also been altered. Clearly, the effects of climate change on all crops are not identical. Studies found that rain-fed crops are more susceptible to climate change because they have fewer options for coping with rainfall and temperature variability. There can be early-season, mid-season, and late-season droughts that are detrimental to agricultural production. Water stress has a negative effect on yield at any stage of its crop growth cycle, but terminal droughts are particularly harmful because the reproductive phase is especially vulnerable. Drought and heat stress at the terminal stage of crop are prevalent in the northern, western, and central regions of India, resulting in significant yield losses for important food crops such as wheat.

Strategies to mitigate climate change: Major climate change adaptation strategies (Fig 1) are

Fig. 1 Impact of climate change on agriculture and mitigating strategies



Source: https://geneticliteracyproject.org/2019/06/25/

- **Cultural Methodologies:** Farmers utilise a variety of beneficial techniques, such as varying planting and harvesting times, cultivating a variety of crops with short growing seasons, crop rotation, irrigation techniques, and diverse cropping schemes. All these are essential cultural strategies for reducing the potential threat of climate variability and enhancing adaptability of crop plants in order to ensure food safety and security.
- **Water-saving technologies**
- **Incorporation of crop residue**
- **Sustainable agriculture**
- **Site specific nutrient management practices**
- **Integrated farming systems**
- **Pest forecasts**
- **Weather forecasting and dissemination**
- **Growing climate resilient varieties:** Climate resilience is the capacity of a plant or crop to withstand and replenish from the adverse effects of climate change. Climate-resilient crop varieties are those that consistently produce greater yields under various abiotic stresses. Understanding thermo tolerance mechanisms, photoperiod sensitivity and genetic variation for transpiration efficiency will aid in the development and identification of climate-resilient crop varieties with enhanced tolerance to drought, heat, salinity, flooding, and chilling stresses which are essential for maintaining and enhancing crop yields in the face of climate change. It is essential to narrow yield gaps, boost productivity and profitability, reduce risk and increase the standard of living for millions of people whose livelihoods depend on agriculture.

Role of plant breeding to mitigate climate change in agriculture production:

To combat climate change, genetic diversity and plant breeding are crucial components, and integrating plant breeding with climate change strategies is one of the best ways to ensure sustainable food production. Plant Breeding has always played a crucial role in human history, from revolutionising agriculture to feeding a constantly expanding population. The primary function of plant breeding in agriculture is to assist in the development of new cultivars with enhanced traits that are more competent to adapt to climate change, using either traditional or genomic technologies (Habash *et al.,* 2009). Various techniques, ranging from simple selection of plants in farmer's fields with desirable characteristics for propagation to more classical or molecular techniques to combat climate change, can be used to develop distinct varieties.

1.) **Conventional plant breeding:** In conventional plant breeding, the development of a cultivar can take up to 10 years or even longer, depending on the plant's growth pattern, reproductive cycle, and trait complexity. In traditional breeding methods, plant breeders generate new cultivars by selecting directly or indirectly for yield and its components in specific environments, as most varieties are unable to perform consistently across environments. Hence, conventional plant breeding methods alone cannot solve the world's severe problems. Therefore, to cope with food security issues, conventional plant breeding should be supplemented and utilised with various biotechnology advancements in order to accelerate crop genetic improvements.

2.) **Advanced breeding techniques**: The rapid climate change necessitates the development of new varieties within a shortened time frame in order to adapt to the unpredictability of weather conditions. Accelerated Plant Breeding is the concept of combining conventional breeding techniques with advanced molecular instruments to accelerate the breeding process. Recent advancements in genomics, coupled with high-throughput and accurate phenotyping, facilitate the identification of genes governing essential agronomic characteristics. The advancements in precise phenotyping and genotyping provide tremendous opportunities to develop crop varieties that are adapted to changing climatic conditions, thereby enhancing plant breeding activities for developing climate-resilient cultivars or varieties. New breeding techniques, such as shuttle breeding, mutation breeding, marker-assisted selection (MAS), genomic selection (GS), speed breeding, and genome editing etc. have been implemented to shorten the breeding cycle and provide efficient tools for developing new varieties in a shorter amount of time that are adapted to the current environment to mitigate the effects of climate change (Atlin *et al.,* 2017). Some of these are:

A. **Marker assisted selection (MAS):** Marker-assisted selection (MAS) is indirect gene/QTL selection based on molecular markers associated with gene. Negative selection with molecular markers is used for elimination of the effect of undesirable genes, environmental stress on plant physiology and biochemical processes. MAS is essential for disease resistance breeding which is sometimes caused by climate change. Molecular markers assist in selection of resistant plants at seedling stage. MAS helps elite germplasm lines acquire favourable alleles at target loci. Indirect selection of MAS improves the efficiency of selection as it evades the influence of the environmental stress and climate change.

B. **Mutation breeding:** Chemically induced mutagenesis and DNA screening techniques resulted in Targeting Induced Local Lesions in Genome (TILLING). Mutation breeding has been demonstrated to be a valuable technique for the identification of allelic variants that contribute to crop adaptation to abiotic and biotic stresses resulting from climate change (Mousavi-Derazmahalleh *et al.,* 2019).

C. **Speed breeding:** Speed breeding is a promising breeding technology that can significantly shorten breeding cycles and increase selection efficiency, regardless of seasonal changes in day length, temperature, and precipitation. Speed breeding is about two to three times more efficient than conventional breeding. With the aid of speed breeding, climate-resilient varieties can be developed rapidly in order to effectively sustain the world's growing population in the face of changing climates.

D. **Gene editing**: Genome editing plays a significant role in the transmission, insertion, and deletion of new sequences at the target genome's desired location. Using genome editing technologies, particularly CRISPR/Cas9, it is possible to manipulate phenotypes by modifying the known genes that regulate important traits. In addition to drought- and salt-tolerant varieties, commercial markets in many developed nations, such as the United States, now consist of a number of genome-edited crops (Begna *et al.,* 2021).

Conclusion

In the present climate change scenario, plant breeding methods appear to be the most successful method for mitigating the effects of climate change on agricultural production. As future food production depends on synthesis of new crop varieties as well as novel crops, breeders has been developing new methods, technologies to combat with climate change. The plant breeding approaches like: QTLs mapping enables evaluation of elite germplasm in the stressed climate, molecular markers that adds to crop improvement through resistant breeding, speed up the breeding advancement, genomic editing tool CRISPR/Cas9 tools can be used to develop edited non transgenic plant to combat climate change stress confirming food security. Molecular plant breeding techniques are prospective and effective methods for enhancing food security and crop improvement under a range of climatic conditions through the development of stress-resilient varieties.

References

1. Adhikari, S., Suwal, G., Suwal, B., Bashyal, N., and Pandey, R. (2021). Plant breeding approaches for combating impact of climate change in agriculture production: A Review. *Tropical Agroecosystems (TAEC)*, **2**(1): 1-5.

2. Atlin, G. N., Cairns, J. E., and Das, B. (2017). Rapid breeding and varietal replacement are critical to adaptation of cropping systems in the developing world to climate change. *Global food security*, **12:** 31-37.

3. Begna, T. (2021). Global role of plant breeding in tackling climate change. *International Journal of Agricultural. Science and Food Technology* **7:** 223-229.

4. Habash, D. Z., Kehel, Z., and Nachit, M. (2009). Genomic approaches for designing durum wheat ready for climate change with a focus on drought. *Journal of experimental botany*, **60**(10): 2805-2815.

5. Lenaerts, J. T., Medley, B., van den Broeke, M. R., and Wouters, B. (2019). Observing and modeling ice sheet surface mass balance. *Reviews of Geophysics*, **57**(2): 376-420.

6. Mousavi-Derazmahalleh, M., Bayer, P. E., Hane, J. K., Valliyodan, B., Nguyen, H. T., Nelson, M. N. and Edwards, D.

(2019). Adapting legume crops to climate change using genomic approaches. *Plant, Cell & Environment*, **42**(1): 6-19.

7. Raza, A., Razzaq, A., Mehmood, S. S., Zou, X., Zhang, X., Lv, Y., and Xu, J. (2019). Impact of climate change on crops adaptation and strategies to tackle its outcome: A review. *Plants*, **8**(2): 34.

8. Yohannes, H. (2016). A review on relationship between climate change and agriculture. *Journal of Earth Science & Climatic Change*, **7**(2).