Breeding for Biotic and Abiotic Stress Tolerance

Abstract

Breeding crop varieties with improved abiotic and biotic stress tolerance is critical for ensuring food security in the face of climate change and other environmental challenges. This can be achieved through various breeding approaches, including conventional breeding, marker-assisted selection, genetic engineering, genomic selection, mutagenesis, and participatory breeding. Each method has its advantages and limitations, and the choice of method will depend on the specific crop and stress condition being targeted. The literature suggests that a combination of different breeding approaches can be used to develop crops with enhanced stress tolerance. However, ethical and regulatory considerations must also be taken into account when using genetic engineering and genome editing technologies. Participatory breeding can also help to ensure that new varieties are well-suited to local conditions and farming practices. Overall, breeding for abiotic and biotic stress tolerance is crucial for ensuring food security and sustainable agriculture in the face of environmental challenges.

Authors

Deepak Rao
Ph.D. Research Scholar,
Division of Seed Science and Technology,
ICAR-IARI, New Delhi

Rahul Chandel
Ph.D. Research Scholar,
Division of Vegetable Science,
ICAR-IARI, New Delhi

C.P Sachan
Ex-Professore and Head DSST,
CSAUAT, Kanpur, UP

Ravish Choudhary
Senior Technical Assistant Division of seed Science and Technology,
ICAR-IARI, New Delhi
E-mail: ravianu1110@gmail.com

I. INTRODUCTION

Abiotic and biotic stresses are major factors that limit crop production and threaten global food security. Abiotic stresses such as drought, heat, salinity, and nutrient deficiency, as well as biotic stresses such as pests, diseases, and weeds, can cause significant yield losses in crops. As climate change and population growth continue to put pressure on agriculture, the development of crop varieties that can tolerate and adapt to these stresses has become increasingly important. Breeding for abiotic and biotic stress is a strategy that involves selecting plants with desirable traits and then using traditional breeding methods and modern genetic techniques to create new varieties that are better adapted to specific stress conditions. In this way, breeding for stress tolerance is a critical approach to increase agricultural productivity and food security, especially in areas prone to stress conditions. This approach has already shown promising results in developing stress-tolerant crops, such as drought-tolerant maize, rust-resistant wheat, and pest- resistant soybeans. Overall, breeding for abiotic and biotic stress is a crucial aspect of modern agriculture that can help to ensure food security and sustainable agriculture in the face of increasing environmental pressures.

II. METHOD OF BIOTIC AND ABIOTIC STRESS BREEDING

Conventional breeding this involves selecting plants with desirable traits and crossing them with other plants to create new hybrids. Conventional breeding can be used to create new varieties with improved stress tolerance by selecting plants that have natural tolerance to a specific stress and then crossing them with commercial varieties. Marker-assisted selection (MAS) this method involves identifying and selecting plants with desirable traits using molecular markers (Kumar *et al.*, 2024). MAS can help to speed up the breeding process by allowing breeders to select plants with specific genetic markers associated with stress tolerance. Genetic engineering this method involves introducing specific genes into the plant genome to confer stress tolerance. Mutagenesis this involves inducing mutations in the plant genome through chemical or radiation treatments. Mutagenesis can create new genetic variations that may confer stress tolerance.

Genomic selection this method involves selecting plants based on their entire genome, rather than just specific genes or markers. Genomic selection can be used to identify plants with desirable traits, such as stress tolerance, by analyzing large amounts of genetic data. Participatory breeding this method involves collaboration between farmers (Kumar *et al.*, 2017) and breeders, with the goal of developing crop varieties that are well-suited to the local environment and farming practices. Participatory breeding can help to ensure that new varieties are adopted by farmers and have a positive impact on their livelihoods.

Siddique *et al.* (2018) reviewed various breeding approaches for developing crop varieties with abiotic stress tolerance, including conventional breeding, marker-assisted selection, genetic engineering, and genomic selection. The authors highlighted the importance of combining different breeding methods to achieve the desired level of stress tolerance in crops. Kumar *et al.* (2019) conducted a review of biotic stress breeding in crops and highlighted various approaches, including conventional breeding, marker-assisted selection, genetic engineering, and genome editing. The authors emphasized the importance of considering ethical and regulatory issues when using genetic engineering and genome editing technologies.

Tovar *et al.*(2021) reviewed the use of genetic engineering to develop crops with enhanced abiotic stress tolerance. The authors discussed the use of various stress-responsive genes and regulatory elements, as well as the potential benefits and limitations of genetic engineering for stress breeding. Gholizadeh *et al.* (2021) reviewed the use of genomic tools for developing crops with enhanced biotic stress tolerance. The authors discussed the use of genomic selection, association mapping, and transcriptome analysis to identify genes and markers associated with biotic stress tolerance.

Dhanapal *et al.* (2019) reviewed the use of participatory breeding for developing stress- tolerant crops. The authors highlighted the importance of involving farmers in the breeding process to ensure that new varieties are well-suited to local conditions and farming practices. Overall, the literature suggests that a combination of different breeding approaches, including conventional breeding, marker-assisted selection, genetic engineering, and participatory breeding, can be used to develop crops with enhanced abiotic and biotic stress tolerance. However, the choice of method will depend on the specific crop and stress condition being targeted, as well as ethical and regulatory considerations.

Breeding for abiotic and biotic stress refers to the process of developing crop varieties that can withstand and adapt to environmental stresses caused by non-living (abiotic) and living (biotic) factors. Abiotic stress includes factors such as drought, extreme temperatures, salinity, and nutrient deficiency (Kumar *et al.*, 2018) while biotic stress includes pests, diseases, and weeds.

Breeding for abiotic stress involves selecting plants that are naturally more tolerant to specific environmental stresses and then cross breeding them with other plants to create new varieties with increased tolerance. One example is the development of drought-tolerant maize varieties using traditional breeding methods. The process involved selecting maize lines that had shown tolerance to drought in the field, and then crossing these lines with other maize lines to create a population of diverse hybrids. These hybrids were then tested in the field for their drought tolerance, and the most tolerant ones were selected for further breeding.

Breeding for biotic stress involves selecting plants that have resistance to pests and diseases and then incorporating these traits into new varieties. One example is the development of soybean varieties that are resistant to the soybean cyst nematode (SCN), a serious pest that can significantly reduce crop yields. The process involved identifying soybean lines that had natural resistance to SCN, and then crossing these lines with other soybean lines to create new varieties that were resistant to the pest.

Another example of breeding for biotic stress is the development of wheat varieties that are resistant to the fungal disease known as wheat rust. This was accomplished through a combination of traditional breeding methods and modern genetic techniques. Researchers identified genes in wild wheat varieties that conferred resistance to the disease and then used genetic engineering techniques to transfer these genes into commercial wheat varieties. In summary, breeding for abiotic and biotic stress is an important strategy for developing crop varieties that can withstand the challenges posed by environmental stresses. It involves selecting plants with desirable traits and then using traditional breeding methods and modern genetic techniques to create new varieties that are better adapted to specific stress conditions.

III. DIFFERENT TYPE OF ABIOTIC AND BIOTIC STRESS IN PLANTS

Abiotic and biotic stresses are major factors that limit plant growth, development, and productivity. Here are some of the different types of abiotic and biotic stresses in plants, along with references:

Abiotic Stress: Drought stress water scarcity is a major abiotic stress that affects plant growth and yield. (Farooq *et al.*, 2009). Salinity stress high soil salinity affects plant growth and metabolism by disrupting the balance of ions and nutrients in the plant (Muuns *et al.*, 2008). Heat stress high temperature stress affects plant growth and development by causing damage to cellular membranes, proteins, and other macromolecules. (Wahid *et al.*, 2007). Cold Stress low temperature stress affects plant growth and development by inhibiting enzymatic reactions and disrupting the plasma membrane. (Thomashow *et al.* ,1999; Kiran *et al.*, 2023)

Biotic Stress: Insect pests: Insects such as aphids, beetles, and caterpillars can cause significant damage to plant tissues and reduce crop yield (Karban *et al.*, 2011). Plant Pathogens bacterial, fungal, and viral pathogens can infect plants and cause diseases that can reduce yield and quality (Jones *et al.*, 2006; Patil *et al.*, 2021). Weeds can compete with crops for resources such as water, light, and nutrients, and reduce crop yield. (Chauhan *et al.*, 2010). Nematodes Plant-parasitic nematodes can feed on plant roots and cause significant damage to crops (Jones *et al.*, 2013). Overall, these different types of abiotic and biotic stresses pose significant challenges to plant growth and productivity, and researchers are working to develop crop varieties that are better able to tolerate these stresses.

Effect of Salinity Stress on Plants: When salinity stress increases in crops, it can lead to a range of negative effects that can reduce crop growth, yield, and quality. Salinity stress occurs when the concentration of soluble salts in the soil exceeds the level that the plant can tolerate, leading to an imbalance in the water and nutrient uptake of the plant.

Some of the effects of increasing salinity stress on crops include:

1. **Reduced Water Uptake:** High levels of salt in the soil can create a high osmotic potential, making it more difficult for plants to absorb water from the soil.
2. **Nutrient Deficiency:** As salinity increases, it can lead to a reduction in the uptake of essential nutrients such as nitrogen, phosphorus, and potassium, which can cause nutrient deficiencies in the plant.
3. **Ion Toxicity:** Excess salts in the soil can also lead to the accumulation of toxic ions such as sodium and chloride in the plant, which can cause damage to plant tissues and reduce crop growth and yield.
4. **Osmotic Stress:** As salinity stress increases, it can lead to a build-up of salt in the plant tissues, which can cause osmotic stress and damage to cell membranes.
5. **Reduced Photosynthesis:** High levels of salt can also reduce the efficiency of photosynthesis in plants, leading to a reduction in biomass accumulation and yield.

Overall, increasing salinity stress can have a range of negative effects on crops, highlighting the need for strategies to mitigate the impact of salinity stress on crop growth and yield, such as the breeding tools mentioned in the previous answer.

IV. MITIGATION OF SALINITY BY BREEDING TOOLS

Breeding crop varieties with improved salinity tolerance is essential for sustainable agriculture in regions where high soil salinity is a major problem. Mitigation of salinity can be achieved through various breeding tools. Here are some of the breeding tools used for mitigating salinity stress in crops, along with references:

1. **Conventional Breeding:** Conventional breeding has been used for developing salt-tolerant crops by selecting and crossing plants with desirable traits (Shabala *et al.,* 2013)
2. **Marker-Assisted Selection (MAS):** MAS is a breeding tool that uses molecular markers to identify and select plants with desirable traits, including salinity tolerance. (Ashraf *et al.,* 2009)
3. **Genetic Engineering:** Genetic engineering has been used to develop crops with improved salinity tolerance by introducing genes from salt-tolerant species into crops (Parida *et al.,* 2005)
4. **Participatory Breeding:** Participatory breeding involves collaboration between farmers, scientists, and other stakeholders to develop crop varieties that are well-suited to local conditions, including high soil salinity (Ceccarelli *et al.*, 2007)
5. **Mutagenesis:** Mutagenesis has been used to develop salt-tolerant crops by inducing mutations in plant genomes (Zeng *et al.,* 2001)

V. MERITS AND DEMERITS OF BREEDING TOOLS

Breeding tools offer several advantages and disadvantages when used for developing crops with improved abiotic and biotic stress tolerance. Here are some of the merits and demerits of breeding tools for abiotic and biotic stress:

Merits

1. **Precision:** Some breeding tools such as marker-assisted selection (MAS) and genetic engineering offer high precision and accuracy in selecting and introducing desirable traits into crops.

2. **Speed:** Breeding tools such as mutagenesis and genetic engineering can accelerate the development of stress-tolerant crop varieties compared to traditional breeding methods.
3. **Efficiency:** Breeding tools can help improve the efficiency of breeding programs by reducing the time and cost required to develop stress-tolerant crop varieties.
4. **Variety:** Breeding tools can help introduce new genetic diversity into crops, allowing for the development of a wider range of stress-tolerant crop varieties.

Demerits

1. **Risk of Unintended Effects:** Genetic engineering, in particular, can introduce unintended effects and unintended changes to the plant's genome.
2. **Regulatory Challenges:** Breeding tools such as genetic engineering can face regulatory challenges, including the need for approval by regulatory agencies before being released for commercial use.
3. **Technical Expertise:** Some breeding tools, such as genetic engineering, require specialized technical expertise and facilities, which may not be available to all breeding programs.
4. **Limited Impact:** While breeding tools can help develop stress-tolerant crop varieties, they may have limited impact if the underlying genetic basis of the stress tolerance is complex.

In conclusion, breeding tools offer several advantages and disadvantages when used for developing crops with improved abiotic and biotic stress tolerance. The choice of breeding tool will depend on the specific crop and stress condition being targeted, as well as the availability of technical expertise and regulatory approval.

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Self Assesment

1. The activated BT toxin bind to
   - **a. Surface of midgut epithelial cells**
   - b. Internal surface of hindgut epithelial cells
   - c. External Surface of foregut epithelial cells
   - d. Bind with surface of cuticle

2. Select the abiotic component in given options
   - a. Plants & Animals
   - b. Fungai and Virus
   - **c. Humus and Air**
   - d. Bacteria and Insect

3. Single, Self pollinated homozygous plant is called as
   - a. Multi-line
   - **b. Pure line**
   - c. Isogenic line
   - d. Inbred

4. ICRISAT Institute is situated at
   - **a. India**
   - b. Mexico
   - c. Philipines
   - d. Canada

5. Cytoplasmic male sterile gene in sorghum is
   - a. Tift-23 A
   - b. Milo
   - **c. Kafir-60**
   - d. CMS-T

6. Golden rice is rich in
   - a. Vitamin C
   - b. Protein
   - **c. Pro-vitamin A**
   - d. Antioxidant

7. Abiotic and biotic stresses are majorly affected the
   a. plant growth
   b. Development,
   c. Productivity
   d. All of the Above

8. Plant parasitic nematodes primarily affected by
   a. **Root**
   b. Shoot
   c. Equally root & shoot
   d. None of the above

9. What is the meaning of Participatory breeding
   a. Collaboration between farmers, scientists, and stakeholders
   b. Collaboration between scientists, and stakeholders
   c. Collaboration between farmers, and stakeholders
   d. Collaboration between farmers, scientists

10. A molecular diagnostic technique used for plant virus detection based on antigen antibody reaction is
   a. PCR
   b. DNA hybridization
   c. ELISA
   d. Serum analysis