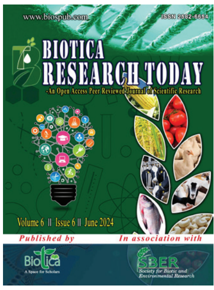

Bio. Res. Today 2024, 6(6):353-354

Biotica Research Today

e-ISSN: 2582-6654

June, 2024

Article ID: RT1681 **Popular Article**

Smart Breeding Revolutionizes Climate-Resilient Agriculture

Divya Chaudhary[1*] and Sivendra Joshi[2]

[1]ICAR-National Bureau of Plant Genetic Resources, New Delhi (110 012), India
[2]Central Institute of Medicinal and Aromatic Plants, Research Center, Pantnagar, Uttarakhand (263 145), India

Open Access

Corresponding Author

Divya Chaudhary
✉: divyachaudhary6767@gmail.com

Conflict of interests: The author has declared that no conflict of interest exists.

How to cite this article?

Chaudhary, D., Joshi, S., 2024. Smart Breeding Revolutionizes Climate-Resilient Agriculture. *Biotica Research Today* 6(6), 353-354.

Abstract

Climate change presents immense challenges to global agriculture, threatening food security through rising temperatures, erratic weather and evolving pests. Traditional agricultural practices are insufficient to address these issues, necessitating advanced plant breeding techniques. Unlocking genetic diversity, especially through wild germplasm, is critical for crop improvement. Advances in phenomics, sequencing and genome editing, alongside artificial intelligence, provide new avenues for developing climate-resilient crops. Plant breeding has historically revolutionized agriculture and continues to do so by enhancing crop varieties for higher production and resilience. Pre-breeding integrates desirable traits from wild relatives into modern cultivars, while marker-assisted selection and speed breeding accelerate genetic gain. Genome editing technologies like CRISPR/Cas9 enable precise modifications for improved stress tolerance. Integrating AI with phenomics enhances the efficiency of selecting better-performing breeding lines. Smart breeding approaches promise to address food security challenges, ensuring sustainable agriculture amidst climate change.

Keywords: Climate change, CRISPR/Cas9, Marker-assisted selection, Pre-breeding

Introduction

Human society stands at a critical juncture as climate change becomes increasingly real and unavoidable. Increasing temperatures undermine food production, while melting glaciers lead to catastrophic flooding and soil erosion. The worldwide effects of climate change are unparalleled and traditional agricultural practices are no longer sufficient to meet these challenges. Fortunately, plant breeding, which has historically revolutionized agriculture, offers a solution to protect humanity from the imminent threats of climate variability, rapidly evolving pests and resource scarcity.

Accessing the reservoir of genetic diversity and utilizing wild germplasm are essential for improved cultivar development. Recent advancements in genomics, various sequencing techniques, high-throughput phenomics, accompanied by genome-editing tools and artificial intelligence, are unlocking new possibilities for accelerating the development of climate-resilient crops (Figure 1). Integrated smart breeding techniques can efficiently combat climate change and create crop varieties that are better suited to their environments.

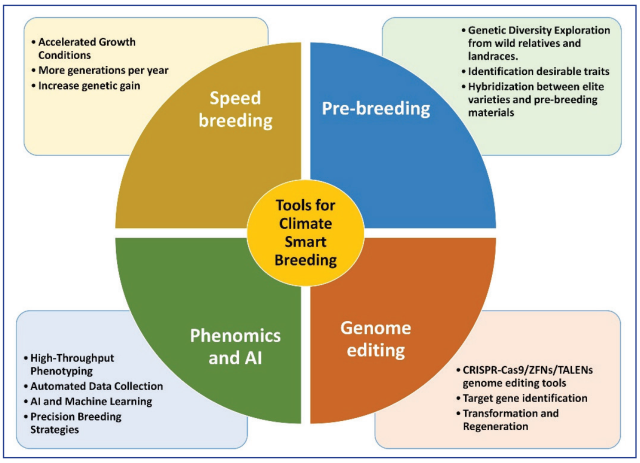

Figure 1: Tools for climate-smart crop breeding

Contribution of Plant Breeding to Agriculture

Across history, plant breeding has been pivotal in revolutionizing agriculture to sustainably feed an increasing global population. The main objective of plant breeding is to

Article History

RECEIVED on 20th June 2024 RECEIVED in revised form 25th June 2024 ACCEPTED in final form 26th June 2024

develop improved varieties tailored to specific environments, aiming for increased production. The inclusion of advanced molecular biology and biotechnology has generated extensive genetic data on genes and Quantitative Trait Loci (QTLs), crucial for accelerating breeding programs. Accurate phenotyping and genotyping present substantial opportunities for developing crop varieties that are well-suited to changing climatic conditions, thereby promoting the growth of resilient cultivars.

Pre-Breeding: Bridging Wild and Modern Cultivars

Severe weather fluctuations, pests and plant diseases that are emerging and increased exposure of crops to biotic and abiotic stresses are all consequences of climate change. Crop Wild Relatives (CWR) and ancestral species retain wider adaptation to environments, making them valuable in breeding program. Pre-breeding serves as a bridge to transfer desirable genes from CWR to modern crop varieties. By introgressing desirable genes from wild species into elite breeding lines, pre-breeding helps enhances crop resilience along with minimize linage drag. This approach has been successfully applied in various crops, including rice, wheat, maize, chickpea, pigeonpea, sugarcane, cotton, potato, tobacco and tomato.

Marker-Assisted Selection: Precision in Breeding

Advances in biotechnology tools have revolutionized plant genetics, facilitating molecular crop breeding. By combining phenotypic and genotypic selection, marker assisted selection strategies enhance the efficiency of transferring desirable genes or QTLs to the plant genome (Cobb *et al*., 2019). This approach is particularly effective for traits of simple inheritance and has been successfully applied to improve yield and other important traits in crops like rice, maize, wheat, barley, sorghum, groundnut, cassava, chickpea, beans, cowpea and potato. In India, notable examples of marker-assisted breeding include the development of improved varieties such as “Swarna Sub-1”, “Improved Pusa Basmati 1”, “Improved Samba Mahsuri” and “IR 64 Sub-1”. “CR Dhan 801” and “CR Dhan 802” are drought and submergence-tolerant rice varieties developed in the background of popular variety “Swarna”. These two rice varieties were released by NRRI, Cuttack, in 2019.

Speed Breeding: Accelerating Crop Improvement

The existing rate of yield improvement in staple food crops such as wheat, rice and maize is inadequate to meet the requirements in future. Speed breeding protocols, which utilizing prolonged exposure to light and precise temperature control, enable to harvest up to six generations year^{-1}, greatly shortening the overall generation period. Such practices have been applied to important crops like spring wheat, rice, barley, chickpea and canola, accelerating crop improvement and enhancing climate resilience. In 2017, the University of Queensland in Australia developed the first speed-bred spring wheat variety, called ‘DS Faraday’.

Genome Editing: Precision Tools for Crop Improvement

Genome editing has allowed breeders to manipulate DNA sequences within the genome with precision, revolutionizing crop improvement. Techniques like TALENs, ZFNs and CRISPR/Cas9 have shown enormous potential in introducing desirable traits and accelerating the development of climate-smart crop varieties. CRISPR/Cas9, specifically, has been employed to alter genes associated with susceptibility to diseases and tackle abiotic stresses in staple crops. For instance, knocking out the *SWEET11* gene in rice has increased resistance to bacterial leaf blight. By targeting the *RAV2* gene in rice and the *ARGOS8* gene in maize, improved tolerance to salinity and drought stress, respectively, has been achieved (Kaur *et al*., 2022).

Phenomics and Artificial Intelligence (AI)

Integrating phenomics and genomics with AI tools can expedite the development of crop varieties that can withstand climate challenges (Shakoor *et al*., 2019). Advanced field-level phenotyping with high resolution and high throughput effectively identifies superior breeding lines from larger populations across various environments. New sensors, high-resolution imaging and advanced platforms have elevated phenotypic data collection. AI technologies, particularly deep learning, have been widely employed to analyze and interpret large-scale phenomic data, thereby advancing the analysis of plant images and phenotyping for environmental stress.

Conclusion

Smart breeding technologies hold significant promise in enhancing crop yields and developing novel varieties. These advanced techniques have expedited plant breeding programs, resulting in varieties capable of tolerating both biological and environmental stresses while exhibiting high productivity. By addressing the rising demands of the growing global population, these improved varieties present a valuable opportunity to ensure global food security amid climate change challenges. The integration of genomics, phenomics, AI and genome-editing tools in smart breeding approaches is crucial for developing climate-resilient crops, securing a sustainable future for agriculture.

References

Cobb, J.N., Biswas, P.S., Platten, J.D., 2019. Back to the future: Revisiting MAS as a tool for modern plant breeding. *Theoretical and Applied Genetics* 132, 647-667. DOI: https://doi.org/10.1007/s00122-018-3266-4.

Kaur, N., Sharma, S., Hasanuzzaman, M., Pati, P.K., 2022. Genome editing: A promising approach for achieving abiotic stress tolerance in plants. *International Journal of Genomics* 2022(1), 5547231. DOI: https://doi.org/10.1155/2022/5547231.

Shakoor, N., Northrup, D., Murray, S., Mockler, T.C., 2019. Big data driven agriculture: Big data analytics in plant breeding, genomics and the use of remote sensing technologies to advance crop productivity. *The Plant Phenome Journal* 2(1), 1-8. DOI: https://doi.org/10.2135/tppj2018.12.0009.