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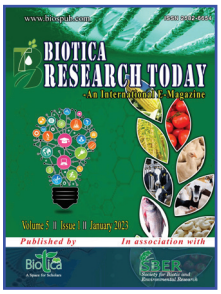

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Pre-Breeding: A Link between Gene Pool and Crop Improvement

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Abstract

Plant breeding focuses on the genetic enhancement of the plants which is hampering the limited availability of germplasm resources. Pre-breeding, being a multi-disciplinary approach, provides a special opportunity to lessen this genetic vulnerability and develop the new base population for enhanced crops and varieties, by introducing desirable genes from wild germplasm to agronomically suitable backgrounds. It has emphasized on the improvement of the core gene pool of several crops including rice, wheat, barley, chickpea and groundnut. Linkage drag poses a difficulty in pre-breeding that could be reduced using genomic approaches. The major requirements, objectives and approaches have been discussed in the following article.

Introduction

Genetically enhancing plants for human benefit through plant breeding is an art as well as science. Plant breeding is devoted to the development or enhancement of crop cultivars with economic advantages for both small-scale and commercial farmers. Professional plant breeders employ it all over the world by frequently crossing the elite varieties, cultivars, and lines. High-yielding varieties (HYVs) are uniformly cultivated nowadays, which has diminished crop genetic diversity and exposed crop plants to epidemics of diseases and insect pests. Global production and productivity are primarily hampered by this limited genetic diversity of cultivars and the inadequate utilization of genetic resources.

Plant breeders must consciously work to diversify their crop's gene pool in order to offset these impacts and lessen genetic vulnerability. Pre-breeding presents a special opportunity to reap the benefits of this genetic diversity by introducing desirable genes from wild germplasm into cultivated backgrounds that may be employed quickly and with the least amount of linkage drag. Pre-breeding uses a larger pool of genetic resources to create a new base population that offers the potential to develop enhanced crops and varieties that are resilient to current and foreseeable problems and better suited to shifting environmental conditions as presented in Figure 1.

What is Pre-Breeding?

In 1984, Rick came up with the term "pre-breeding", an alternative term for genetic enhancement. Pre-breeding includes all activities meant to identify materials not suitable for direct use in breeding programmes and to transfer these traits to a set of intermediate materials that breeders can utilise to create new cultivars for farmers (Abebe and Tafa, 2021). It is an essential initial step in creating genetic variability to its utilization by the germplasm curator and the plant breeder who collaborate, in order to comprehend

the extent and importance of germplasm collections as well as how new traits from these collections might be bred into new varieties. It is the practice of introducing desirable genes into agronomically suitable background or breeding material from exotic or wild sources. Pre-breeding has been used to successfully improve many cultivated varieties for various qualitative and quantitative traits in several crops, including rice, tomato, soybean, maize, cotton, wheat, barley, chickpea, pigeon pea, groundnut, sorghum, and pearl millet.

Need of Pre-Breeding

The potential of any crop improvement program to be successful depends on the availability of enough genetic diversity, but this diversity must exist in a form that can be applied in conventional agriculture. Breeding progress is impeded due to the lack of variability and limited genetic base, making it a clear concern to food security. Pre-breeding acts as the most promising alternative to link the gene pool and breeding programmes, having at least three well-defined aspects (Jain and Omprakash, 2019). The first is to avoid genetic uniformity and the ensuing genetic susceptibility. The second crucial goal of genetic enhancement is to increase yield to unprecedented levels, as it is known that majority of breakthrough cultivars have highly heterogenous parentage; although, this goal is more frequently sought for than achieved. The third, being the introduction of quality traits that are not present in the native cultivars. Pre-breeding is chosen based on the anticipated effectiveness, efficiency, and reliability of eventually transferring the desired traits into cultivars for farmers and source of desired genes. Pre-breeding is required when desired genes are present in accessions not well adapted to the target environment, and in more distant species that are difficult to cross with. Some of the major achievements include semi dwarf wheat, high yielding dwarf rice, and hybrid sorghums.

Requirements of Pre-Breeding

Pre-breeding, serving as a link between breeding and PGR (Plant Genetics Resources) conservation, requires multiple disciplines. Under-represented diversity is collected for the purpose of preserving the range of diversity present in wild species and enabling predictive trait mining based on eco-geographic data and comprehensive passport data. Along with this, sharing of improved information and feedback, co-ordination of evaluation, improved collaboration between basic and applied research to better understand the genotype-environment interactions are required (Sukumaran *et al*., 2022).

Objectives of Pre-Breeding

1. Enhanced genetic resources and complementary germplasm that increase the diversity and expression of resistance.

2. Utilization of wider pool of genetic resources to boost the crop output, incorporate pest and disease resistance and other desirable quality traits.

3. Better selection techniques and enhanced parental stocks to be easily used in breeding programmes.

4. Identifying desirable characteristics/ genes and then transferring them to an appropriate group of parents to be used for future selection.

5. Developing strategies that result in the creation of enhanced germplasm that is ready for use in varietal development.

6. Seek potentially helpful genes in a gene bank that is well-maintained and documented.

Pre-Breeding Approaches

Some of the significant approaches used in Pre-breeding are:

Wide Crosses

Wide cross is the term used to describe the cross between two individuals of different species or genera. It is possible for such a cross to occur in nature, leading to the creation of new species and base populations, but it must first overcome obstacles that prevent either the creation of fertile offspring or the possibility of such a cross occurring on its own. Wide crosses are frequently used to practically expand a crop's gene pool. The wide crossing has been successfully utilized with great success in some crops, such as rust-resistant wheat, insect-resistant rice, and blight-resistant potato.

Introgression

Dr. Edgar Anderson developed the idea of Introgression by backcross in cotton, and Knight was the first to conceptualise it (1945). Introgressive hybridization, is the repeated backcrossing of an interspecific hybrid with one of its parent species that transfers a one or more genes from exotic, unadapted, or wild stock to breeding stock that has undergone selective breeding.

Participatory Plant Breeding

The plant breeding programmes, being different in various aspects, share some key phases such as creation of variability, selection and testing of experimental cultivars. A participatory plant breeding programme operates along the same line, but with a few differences *viz.,* majority of the process takes place in farmers' fields, decisions are made jointly by the farmers and the breeder, and the process can be implemented at various locations with numerous farmers evaluating various breeding materials.

Marker Assisted Breeding

Breeding techniques based on molecular markers co-segregating with the candidate genes is a tool that can make the selection process for crop traits, more effective for plant breeders.

Problems Encountered while Pre-Breeding

Pre-breeding does, on the one hand, prevent many of the issues that arise in a regular breeding programme, but on the other hand, it also encounters some issues.

1. Barriers to chromosome pairing in hybrids, reducing the capacity to introduce genes from wild species.

2. Linkage drag.

3. Hybrid inviability and sterility.

4. Constrained genetic recombination.

5. Limited donors for specific traits like disease resistance.

6. Small size of sample population.

7. Challenges in exchange of genetic material due to legal limitations such as IPR (Intellectual Property Rights).

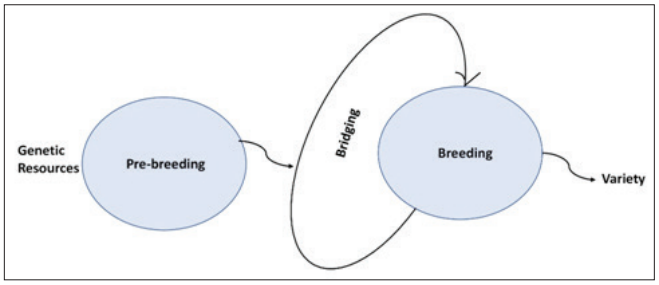

Figure 1: Positioning of Pre-Breeding, Bridging and Breeding from genetic resources to Variety

Future Prospects of Pre-Breeding

Lack of characterization, assessment of evolutionary divergence, documentation of data, inter-species relationships, a robust breeding programme, and liquidity requirements are the main obstacles to pre-breeding. Due to the elevated risk of extinction for endemic and narrowly adapted species, the aforementioned issues highlight the urgent need for the collection, characterisation, and documenting of wild species, especially crop wild relatives. Gene decoding, genome mapping and gene synteny could be applied for crop improvement, to develop crops resilient to biotic and abiotic challenges. New breeding techniques with genetic transformation and bioinformatics tools are needed to use the information from genome analysis to deal with the complex traits and tertiary gene pool and beyond.

Conclusion

Crop improvement requires sufficient genetic variability, existing in the form of wild relatives and landraces, to be utilized in the breeding programmes. However, these require a lot of resources and time. Pre-breeding overcomes these obstacles by emphasizing on the supply of beneficial variability to the breeding pipeline. Although being essential for enhancing the core gene pool of crop improvement, pre-breeding is a challenging process. Additionally, linkage drag makes the processes more difficult but it is reduced by genomic-assisted pre-breeding, making it easier to transfer the genes for genetic improvement.

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