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Breeding Strategies for Climate Resilient Rapeseed-Mustard Improvement

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Abstract

Modern advancement in crop breeding techniques make easier for accelerated climate-resilient yield enhancement. Consequently, advanced new breeding techniques can be a capable approach to tackle changing climate and develop highly adaptable crop varieties. Rapeseed and Mustard is the most significant segment in edible oil economy of the country, and creates a vibrant group of oilseed crops around the world. The primary objectives of breeding are to increase seed yield, increase oil content and canola quality, and withstand biotic and abiotic stresses. Although hybrids based on cytoplasmic male sterility, or CMS, have been created, the level of yield heterosis in these hybrids must be increased rapidly. By combining the genes for insect and disease resistance in agronomically superior varieties, genomics and biotechnological tools such as DH (doubled haploid), soma-clonal variation marker assisted selection (MAS), recombinant DNA technology, and genome editing are expected to accelerate crop improvement and increase productivity over time.

Keywords: Resistance, double haploid, marker assisted breeding, genome editing, speed breeding

Introduction:

Brassica oilseed is the third most popular oilseed worldwide, behind soybean and oil palm. The production, and productivity of mustard and rapeseed in the world in 2021 were 1921 kg/ha, 71.86 mt, and 37.40 mha, respectively (FAOSTAT, 2023). India ranks fourth in the edible oil industry, contributing 17.91% and 14.20% of the total area and production, respectively, after the USA, China, and Brazil (FAOSTAT, 2023). India's main winter oilseed crop is Indian mustard, or *Brassica juncea*. About 75–80% of the 8.06 million hectares planted to rapeseed and mustard crops in 2021–2022 come from this area. India's average productivity for the rapeseed-mustard crop is 1458 kg/ha, which is less than the global productivity levels recorded in B. *napus*. Currently, the goal of the crop improvement program is to acquire superior alleles for disease resistance, yield, and insect and pest resistance from primary and secondary gene pools in order to strengthen the crop's genetic base.

Breeding objectives in Rapeseed-Mustard Improvement:

- **High oil & seed yield:**Achieving high oil content and seed yield stands as paramount breeding objectives within *Brassica juncea*. These objectives have been pursued through strategies such as broadening the genetic base through hybridization programs, resynthesis B. *juncea*, and developing hybrid varieties based on cytoplasmic male sterility (CMS).
- **Maturity duration:** In crop breeding, early maturity, or short duration, is essential because it permits crop rotation and several cropping sequences. Considering the unique agro-ecological conditions and crop sequences common in the northeastern and eastern parts of the country, the creation of early maturing varieties of Indian mustard, toria, yellow, and brown sarson is especially important.
- **Oil & meal quality:** Long-chain fatty acids like erucic acid and eicosenic acid can be found in mustard seed oil. Oils from Brassica species are suited for industrial and consumable uses due to their fatty acid makeup. The fatty acid content of oil determines its quality, whereas the presence of high-quality seed protein and low amounts of anti-nutritional elements determines the quality of seed meal. Internationally recognized quality standards state that it is preferable to limit the amount of glucosinolate in seed meal below 30 micro moles/g of defatted seed meal and to minimize the amount of erucic acid to less than 2%.

Breeding for biotic and abiotic stress resistant varieties:

Current cultivars of mustard are susceptible to a range of biotic and abiotic stressors. Abiotic challenges include heat, salinity, and drought; biotic stresses include Alternaria blight, white rust, stem rot, powdery mildew, and downy mildew. The broad host range of the disease makes the development of resistant cultivars more challenging. The mustard aphid (*Lipaphis erysimi*) is a serious pest. The production of mustard from rapeseed has considerable obstacles from heat, cold, drought, and salt. Water stress occurs often in rain-fed locations during different phenological phases, contingent on the amount of moisture present in the root zone. Significant yield decreases are also brought about by high temperatures during the terminal and

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crop establishment stages. By influencing seedling emergence and impeding physiological or metabolic processes, salinity further lowers oilseed Brassica yields.

Breeding methods used in Rapeseed-Mustard Improvement

The goal of advanced breeding is to create climate-smart cultivars with great yield potential by combining modern molecular, genomic, and phenomic technologies with traditional breeding techniques. To speed up the breeding cycle and improve screening for particular biotic and abiotic stresses, new breeding techniques have been implemented, including DH (doubled haploid), MABC (marker-assisted backcrossing), MARS (marker-assisted recurrent selection), and GS (genomic selection). Genetic advances will be aided and expedited by biotechnology-driven breeding methods such as genetic alterations and marker-assisted breeding.

However, further research into the genetic characterization and phenotyping of complex adaptive characteristics used in climate-resilient breeding will be necessary for their successful deployment. While cross-pollination of up to 18% has been seen, Indian mustard primarily self-pollinates (Labana and Banga 1984 and Bhajan et al. 1991). Numerous methods of selection have been employed, including pure line selection and mass selection. Assuming that a new variety arises from a single, self-fertilized homozygous plant, a progeny test is used in pure line selection to assess the genetic quality of the chosen plant. In mass selection, which mustard also utilizes with some modifications, does not involve progeny evaluation; rather, it involves harvesting and bulk collection of phenotypically superior plants.

Pedigree Method

Pedigree selection is the most prevalent approach for developing cultivars of Indian mustard. This method needs hybridizing two or more parents and selecting superior plants from the F_2 generation based on plant phenotypes. In segregating generations, selected plants progress to the plant to progeny rows (F3-F5). The best progenies are bulked in F_6-F_7 and tested in multilocation replicated yield trials. Delaying the first backcross until the F2 generation typically helps because it permits a recombination cycle that facilitates the breaking of undesirable connections (Robbelen and Nitsch 1975). It worked better to manipulate basic characters, combine characters, or delay selection until F3 or subsequent generations.

Recurrent selection

In Indian mustard, recurrent selection is rarely utilized because it cannot guarantee random mating. Recurrent selection, however, has been introduced by GMS (Genetic Male

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Sterility) and can be employed. Using this technique, the GMS line and bulked seed with chosen genotypes are sown separately to promote random mating. Only a limited number of male-sterile plants are eligible for seed harvesting. In order to improve the population and raise the frequencies of desired alleles, this cycle is repeated two or three times. The male-sterile gene eventually disappears from the population. After that, the enhanced population can be used to create new inbred lines or as a cultivar.

Backcross breeding

Backcross breeding is used to introduce a specific gene or genes into an agronomically superior cultivar that is lacking in one or more characteristics. It mostly entails selecting for the particular character or characters being transmitted from the donor parent after repeatedly backcrossing to the hybrid's recurrent parent. Backcrossing is used in Brassica species to integrate fertility restorer and male sterility genes, reduce erucic and glucosinolate levels, and provide disease resistance.

Mutation Breeding

Mutations, both induced and spontaneous, cause chromosomal and nucleotide changes. Chemical mutagens alter nucleotide sequences, whereas physical mutagens, such as ionizing radiation, produce chromosomal abnormalities such as breakages and deletions. Numerous qualitative and quantitative benefits of mutations have been reported for brassicas (Choudhery and Jambulkar 2016). The process of changing the fatty acid composition of oil in Brassica species has advanced dramatically. The discovery of mutants in B. *napus* is one of the notable findings, that is low C18:3 and high C18:1. Thirteen mutant cultivars have been created globally, of which eight have come from India, five each from Bangladesh, China, and Sweden.

Biotechnology assisted methods

- **Marker assisted breeding:** Marker-assisted selection (MAS) has emerged as a crucial tool in enhancing genotype and germplasm improvement by combining all significant features into a single variety. Breeding systems now use a combination of genotype and phenotype-based selection, which has significant advantages over phenotype-based breeding. MAS methods used in breeding programs include (i) stacking numerous genes from different sources into elite breeding lines through marker-assisted gene pyramiding (MAGP) and (ii) marker-assisted backcrossing (MABC), which involves incorporating advantageous alleles into elite germplasm. Genetic markers associated with agro-morphological traits can be included into elite crop genetic backgrounds through marker-assisted breeding (MAB), which makes it possible to integrate desirable features into elite varieties and improves their capacity to adjust to climate fluctuations.

- **Genomics-assisted breeding and DNA sequencing:**Techniques like reduced representation sequencing (RRS) and whole genome resequencing (WGR) are frequently used in genetic research. Variants relevant for both contemporary methods such as genome-wide association studies (GWAS) and conventional QTL analysis can be found by genotyping by sequencing (GBS) technology. GWAS uses recombination events in a variety of association panels to find genes linked to phenotypic features. The increasing use of GWAS is enhancing our comprehension of the genetic basis of crucial climate-specific traits such as drought and heat tolerance. In order to improve significant traits, it is possible to create new alleles or investigate beneficial alleles from Crop Wild Relatives with a thorough understanding of the molecular mechanisms behind these traits.
- **Genome editing:** Climate change is increasing the need for early maturing cultivars, which enable plants to complete critical developmental phases prior to the beginning of stress. The process of genome editing enables the faster domestication of new crops that are obtained from Crop Wild Relatives (CWR) or small crops that have important characteristics that let them endure harsh conditions. In order to improve crops' ability to adapt to changing climatic circumstances, functional genomics and genome editing are used to help identify potential genes linked to agronomic, physiological, and phenological aspects connected to climate change. the integration of genome editing with conventional plant breeding practices facilitates the development and deployment of climate-smart crop varieties tailored to farmers' needs.
- **Somaclonal variation:** The genetic variety seen in somatic cells as a result of chromosomal rearrangements and the regeneration of various plants from callus through plant tissue culture is known as somaclonal variation. Tissue culture techniques have led to significant genetic diversity in B. *juncea* through induced somaclonal variation, chemical mutagenesis, and gamma ray-induced mutations. In India, the first somaclonally derived variety, Pusa Jai Kisan (Bio-902), introduced in 1993, developed

from Varuna as a parent, resulting in a 17.4% increase in yield compared to the parent variety.

- **Speed breeding:** Crops' prolonged generation cycles, which usually allow for just one or two generations year, are a major barrier to plant breeding. Breeders have been able to produce up to six generations year, essentially reducing the generation time. In order to hasten the identification and use of allelic diversity in landraces and Crop Wild Relatives and promote the creation of crop varieties that are climate-resilient, speed breeding is a viable strategy. Furthermore, plant genes can be precisely modified through speed breeding in conjunction with cutting-edge techniques like gene editing to increase resilience to a range of biotic and abiotic challenges brought on by catastrophic climate change.

Speed breeding has the potential to accelerate re-domestication through several selection steps following diploid crossing and colchicine treatment. Ultimately, this approach enables access to novel plant characteristics, facilitating the development of disease-resistant and stress-tolerant crop varieties. Furthermore, combining targeted mutagenesis and gene editing with rapid breeding may improve the efficiency of biofortification in the production of healthier meals. Combining these technologies with speed breeding allows for rapid access to desired alleles and unique variations found in crop wild relatives, thereby expediting breeding pipelines for the development of climate-adapted cultivars.

Future prospects

Indeed, rapeseed-mustard has a very bright future. Improved genotypes that can withstand pests and diseases while efficiently using fewer resources and demonstrating consistent yields in the face of a challenging environment in the near future may only aid in achieving the goal of climate resilient mustard and rapeseed. For achieving the goal of climate-resilient rapeseed-mustard, it's crucial to develop better genotypes capable of withstanding diseases and pests while utilizing fewer resources and maintaining consistent yields in challenging climates. This requires research focus on untapped species with potential for resilience. Large breeding populations, effective phenotyping, data management systems, and molecular approaches are critical to addressing crop sensitivity to climate change in rapeseed-mustard breeding. Preserving plant genetic resources is essential for this breeding effort. Utilizing cutting-edge techniques like gene editing, novel variety may be obtained by introducing advantageous genes from wild plants into domesticated types. Understanding the underlying physiological and genetic processes of stress tolerance is essential to developing novel cultivars that can withstand numerous pressures. Future development and use of climate-smart cultivars are made possible by technical, digital, and phenotypic and genotypic analytical advancements.

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