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Breeding Strategies for Radish Improvement

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Abstract

Radish is a popular root vegetable in tropical and subtropical regions. Rather from being spherical, elliptic, bulbous, or cylindrical, the early radish varieties were long and tapering. Radishes were originally black, then turned white in the 1500s, and finally round and red in the 1700s. These are radishes, *R. sativus* L. var. niger or *R. sativus* L. var. radicula (sativus). This paper examines the role of radish as a model crop in research on how plants respond to environmental stresses, focusing on the impacts of varying stress tolerances. Radish crosses easily due to its open architecture, self-incompatibility, biannual bolting, and protogyny. The three main strategies for utilizing heterotic breeding potential are doubled haploids (DH), CMS, and SI. The different breeding strategies are covered in this article, including the use of self-incompatibility to develop inbred lines and hybrid development, which not only benefits growers but also gives researchers relevant information to support stress resistance through breeding innovations and biotechnological tools.

Keywords: Brassicaceae, Breeding, Radish, Stresses, Strategies

Introduction

The overutilization of natural resources and their environmentally detrimental applications persist as significant challenges to global agricultural development. This practice increases the probability of the occurrence of stressors, which could potentially lead to a reduction in radish yield and productivity. Climate change and the increasing global population pose significant challenges to agricultural production on a global scale. The UN's Department of Economic and Social Affairs stated that the world's population will reach 9.6 billion people by 2050. In the last few decades, high temperatures, severe droughts, very powerful rainstorms, and deadly floods have become the new "normal" weather. These constraints had several negative effects on plants at the physiological, metabolic, and molecular levels. This has caused plants to grow less, produce less, and have less nutritional value, which is a major threat to global food security.

The Brassicaceae family's chemical components and high nutritional value have greatly enhanced human health and well-being. An herbaceous annual plant, radishes have two sets of nine chromosomes. It belongs to the family Cruciferae and is used in cuisines all over the world as shredded radish, garnish, and raw ingredients in salads. The wild *R. sativus* features a fragile, moderately thick pod composed of spongy parenchyma and a white or purple bloom on a white background (Singh et al., 2001).

Radish cultivation is significantly influenced by various and enhancing stress tolerance in radish has become a crucial breeding objective. In India, extensive breeding efforts have been dedicated to developing lines, cultivars, and hybrids resistant to heat stress, including varieties like Pusa Chetki, Kashi Mooli-40, VRRAD-200, Chetki Group, VRRADH-41, and VRRADH-42. In recent years, the primary method for genetically improving radish has been through varietal crossing. Local varieties, cultivated preferentially in their regions of origin, have preserved favourable characteristics. Alongside varietal crossing, there is potential for significant advancements in radish breeding through interspecific and intergeneric hybridization methods, even though genetic analysis remains incomplete. Breeding within the Cruciferae family through interspecific and intergeneric hybridization employs two approaches: the artificial synthesis of new species (amphidiploids) and transduction. In both methods, maximizing the production of F1 hybrid plants and ensuring the reliable maintenance of subsequent progenies over several generations are essential. The efficacy of transferring desirable agronomic traits through hybrid plants is suggested by the restoration of either parental donor rather than direct utilization of synthesized amphidiploid forms (Selvakumar, 2022).

Certain offspring of a spontaneous backcross between cultivated radish and the wild type *R. sativus* exhibited a high seed setting rate and were devoid of quadrivalent chromosomes. Therefore, it was recommended to promote gene flow, or introgression, from *R. raphanistrum* into radish cultivars (Selvakumar, 2022). The development of improved radish cultivars suited for tropical and subtropical regions is prioritized. Important aspects of radish breeding include stress tolerance and a range of agronomic traits. Stress from high temperatures has emerged as a key issue for radish cultivation. A radish root's centre turns reddish brown when it is subjected to high temperatures, producing unmarketable products. Nonetheless, it ought to be able to create a cultivar that is robust because susceptibility to high temperatures varies.

Earlier, methods like bulk and repeated selections were used in radish breeding to guarantee uniformity and increase yield (Kaneko and Matsuzawa 1993). But the 1950s saw a paradigm shift as hybrid breeding was introduced, allowing for the exploration of heterotic vigour's possibilities. The use of biochemical, molecular, and biotechnological technologies has expanded and enhanced breeding strategies in the modern period, with a special emphasis on enhancing quality and stress tolerance. Innovative approaches to the study of vegetable crops are provided by the combination of advanced genomic strategies—transcriptomics and proteomics, for example—with genome-wide association studies, genomic selection, transgenic breeding, marker-assisted selection (MAS), quantitative trait locus (QTL) mapping, genomic selection, and genome editing. These strategies are further enhanced by the potential of next-generation sequencing. Biotechnological approaches, such as embryo rescue and cell engineering, are also recognized as potentially valuable strategies, especially in the context of a more diverse food supply and increased demand for heightened disease resistance.

According to the results of one study, radish has high cross-pollination because of its protogyny, self-incompatibility, open flower architecture, and beauty (Kaneko and Matsuzawa 1993). The key to maximizing heterotic potential is to make use of mechanisms like doubled haploids (DH), cytoplasmic male sterility (CMS), and sporophyte self-incompatibility (SI). Enhancing root yield, attaining uniformity in size, shape, color, and maturity, adjusting to high temperatures and high rainfall, extending field stay, postponing bolting, and creating strong SI, CMS, and DH lines for F1 hybrid production are the main goals of radish breeding (Singh, 2021). Similar to other crops, radish is also cultivated using a variety of population improvement techniques. These techniques include backcross breeding, mutation breeding, hybrid breeding, gamete selection, molecular and transgenic methods, line breeding, family selection, recurrent selection, and mass-pedigree breeding (Singh et al., 2017). These techniques underscore the multifaceted and dynamic nature of contemporary radish breeding, blending traditional morphological considerations with cutting-edge molecular and biotechnological advancements to achieve enhanced quality and stress resilience. Breeding in Cruciferae by interspecific and intergeneric hybridization is done through the artificial

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synthesis of new species (amphidiploids). In either method, it is necessary to obtain as many F1 hybrid plants as possible and to maintain the following progenies reliably for a few generations. The effectiveness was also suggested in transferring available agronomic traits through hybrid plants by restoring either parental donor or direct utilization of synthesized amphidiploid forms (Kaneko and Matsuzawa 1993).

When self-propagation via bud pollination is repeated or exposed to high concentrations of carbon dioxide, the allogamous radish plant exhibits a high degree of self-incompatibility and displays inbreeding depression, allowing the generation of self-compatible progeny. They do, however, show signs of inbreeding depression, which makes obtaining inbred lines challenging. S-receptor kinase (SRK) is the recognition molecule of the stigma, while SP11, also known as SCR, is the recognition molecule of the pollen. This recognition molecule is similar to the self-incompatibility of *Brassica* species. These multiallelic recognition molecule genes (SP11/SCR and SRK) are inherited as the S haplotype. The abundance of S haplotypes in radish and the similarity of some radish S haplotypes' nucleotide sequences to *Brassica rapa's* indicate that S haplotypes possessed by an ancient species were inherited by species in both without significant nucleotide sequence modification. Getting a lot of seeds is challenging, mostly due to the small quantity of seeds that each pod produces. F1 hybrids produce their seeds using three different techniques: single crossing, three-way crossing, and double-crossing.

A profound understanding of the genetics and mechanisms governing stress tolerance is pivotal for developing varieties adapted to stress conditions. The integration of traditional breeding methods with modern biotechnological tools holds promise for creating stress-resistant *Brassicas* with improved agronomic traits. Research indicates that microRNA (miRNA) entities play a pivotal role in stress regulation across various plant groups. Leveraging transgenic approaches becomes a promising tool for enhancing plant yield while conferring tolerance to various stresses. The utilization of Next-Generation Sequencing (NGS) platforms has been instrumental in unraveling the gene regulatory network associated with stress resistance in Brassicaceae crops (Saha et al., 2022). A powerful toolkit for researching vegetable crops is provided by the combination of next-generation sequencing with contemporary genomics techniques along with transcriptomics and proteomics (Mangal et al., 2023).

To increase production and homogeneity, mass and repetitive selections were used in today world. On the other hand, hybrid breeding was started in the 1950s to investigate the potential of heterotic vigor. Biochemical, molecular, and biotechnological techniques of the twenty-first century enabled and varied quality breeding strategies. Important chromosomal genetic data and inheritance information for many genes important for agronomic, biochemical, and stresses need to be gathered for a successful radish breeding process (Selvakumar, 2022).

Conclusion and Future Prospects

The demand for vegetables and their production is rising in tandem with the world's population growth. However, radish cultivation poses various unsolved genetic problems. Before radish breeding, it is necessary to first determine the general analysis of each chromosome, the manner of inheritance for different resistance genes, traits in the cytoplasm, and the transduction of traits through extensive crossing. The development of more sophisticated breeding methods, including chromosomal or gene editing, is crucial for these investigations. Since field-grown radish is typically less sensitive to atmospheric stressors, there is limited significance to the findings of several research conducted in controlled environments to determine dose-response relationships. Another essential component of radish breeding projects is the gathering and preservation of genetic material. The goals of modern radish breeding are to create superior varieties that are suited to tropical and subtropical climates, to utilize types that are suited to Europe and America, and to enhance variations that are resistant to specific stresses.

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