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Application of MAS in Rice Crop Improvement

(*Gangishetti Ranjithkumar[1] and Madhana Keerthana S[2])
[1]Department of Genetics & Plant Breeding, SKCHS, Ananthapuramu
[2]Department of Plant Physiology, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur
*Corresponding Author's email: email2grk@gmail.com

Rice (2n=24) is one of the oldest cultivated crops. Genus Oryza includes approx 20 speies and out of these two species are cultivated diploids (*Oryza sativa* and *Oryza glaberimma*). Almost half of the world's population depends on rice (*Oryza sativa*) as a staple grain, making it one of the most important crops in global agriculture. Two wild species namely, *Oryza perennis* and *Oryza nivara* widely used in breeding programmes to develop improved rice cultivars

Rice is a staple food and a source of income for millions of people, so improving rice types through breeding is vital. The science and art of creating novel varieties of rice with superior characteristics is known as rice breeding, and it is essential for fulfilling the needs of an expanding world population, adjusting to environmental changes, and improving agricultural production.

The objective of rice breeding is to create new varieties with desirable qualities in an effort to increase rice productivity and quality. These characteristics could be increased yield of grains, disease and insect resistance, enhanced tolerance to abiotic stresses including salinity and drought, and increased grain quality. The ability to develop rice varieties that meet these criteria is essential for achieving food security and sustaining agricultural practices in diverse environments.

Developing new rice cultivars with enhanced characteristics including increased yield, tolerance to disease, and adaptability to different environments is known as rice breeding. This involves selecting and cross-breeding plants with desirable characteristics.

Marker assisted selection in Rice

Traditional rice breeding takes a lot of time and is dependent on the environment. It takes eight to twelve years to develop a new variety, and even there is no assurance that an improved variety will be released. Because of this, breeders are very interested in emerging technologies that may improve the efficiency of breeding methods. This is made possible by molecular marker technology, which uses a variety of cutting-edge techniques to enhance the selection processes. Recent approaches which include genetic engineering & molecular markers which accelerate the identification and integration of useful traits. By continually advancing breeding methods, researchers work to ensure that rice can meet the growing global demand while adapting to changing environmental conditions.Molecular markers play a crucial role in rice crop improvement by aiding in the identification and selection of desirable traits.

These are unique DNA sequences associated with particular genes or traits, like grain quality, yield, and disease resistance. Through the application of molecular markers and marker-assisted selection (MAS), which improves the accuracy of selecting plants with desirable features, breeders can accelerate the production of novel rice cultivars.

It is possible to develop cultivars that are resistant to diseases like bacterial blight or blast by using markers associated with resistance genes. similarly, markers associated with traits like resistance to drought or superior grain quality allow breeders to concentrate on developing varieties that fulfil breeding objectives. The application of molecular markers also facilitates the mapping of quantitative trait loci (QTLs), which are regions of the genome associated with complex traits influenced by multiple genes. This information allows for the fine-tuning of breeding strategies and the introduction of beneficial traits into elite rice varieties more effectively. Overall, molecular markers enhance the efficiency and effectiveness of rice breeding programs, contributing to improved crop yields, resilience, and quality.

MAS is a combined product of traditional genetics and molecular biology. MAS allows for the selection of gene that control traits of interest. MAS has become a valuable tool in selecting organisms for traits of interest. It is a process where a marker is used for indirect selection of a trait of interest (i.e., productivity, disease resistance, a biotic stress tolerance, and/or quality). It is an indirect selection process where expression of a trait is selected not based on the expression itself but on a marker linked to It.

Requirements for Marker assisted breeding

Marker-assisted breeding requires several key components: high-quality genetic markers (e.g., SNPs, SSRs) for precise trait selection, a detailed genetic map and reference genome, and identified Quantitative Trait Loci (QTL) linked to target traits. Effective breeding programs need clear objectives and well-chosen parent varieties. Essential infrastructure includes genotyping facilities and data analysis tools, supported by robust data management systems. Expertise in molecular genetics and plant breeding is crucial, along with validation through field trials. Adherence to regulatory guidelines and collaboration with research institutions further supports successful implementation and advancement of marker-assisted breeding.

Some of rice varieties developed using marker assisted selection

1. IR64 Sub1: variety developed by International Rice Research Institute for flood tolerance.
2. Swarnadhan: this variety tolerant to drought.
3. IRRI 6: variety developed by International Rice Research Institute, resistant to blast and bacterial blight.
4. MTU1010 (Samba Mahsuri): It features improved resistance to diseases like bacterial blight and is known for its excellent cooking quality and aroma. MAS was used to incorporate resistance genes and enhance the grain's quality attributes.
5. Swarna Sub1 : The Swarna Sub1 variety was developed by incorporating the Sub1 gene, which provides resistance to submergence or flooding. This variety is a key advancement for regions prone to flooding during monsoons, particularly in eastern India. The use of MAS allowed for precise incorporation of the Sub1 gene into the high-yielding Swarna variety.
6. Pusa Basmati 1509: Developed by IARI, New Delhi. This variety is high-yielding, long-grain aromatic rice developed through MAS for better grain quality, yield stability, and resistance to diseases like bacterial blight and sheath blight. The incorporation of specific markers has enhanced its resistance to these diseases without compromising on the grain's fragrance and quality.
7. Kalanamak Sub1: it is a flood-tolerant version of the traditional Kalanamak rice, which is an aromatic variety. Through MAS, the Sub1 gene was introduced into Kalanamak, improving its flood tolerance while preserving its distinct aroma and quality.
8. Improved Pusa Basmati 1 : developed by Indian Agricultural Research Institute in collaboration with National Institute for Plant Biotechnology, New Delhi. Country's first MAS derived variety of rice resistant to bacterial blight disease.Š Similar grain quality to Pusa Basmati 1 with less than 5% chalky grains. Strong aroma with excellent cooking and eating quality
9. Improved Samba Mahsuri: *xa5*, *xa13* and *Xa21* genes were introgressed into sam mahsuri variety to deveop this variety developed by Indan Institute of Rice Research in

collaboration with Centre for Cellular and Molecular Biology, Hyderabad.Resistant to bacterial blight.

10. Pusa 44: Pusa 44 is developed by IARI, a short-duration rice variety that was developed with resistance to rice blast and bacterial blight. MAS played a role in identifying and selecting the appropriate markers for these disease-resistance traits.

Conclusion

Marker-Assisted Selection (MAS) has transformed rice breeding in India by enabling precise incorporation of traits like disease resistance, drought tolerance, and high yield. This technology accelerates the development of improved rice varieties, addressing challenges such as climate change and biotic stresses. MAS has helped enhance traditional varieties while boosting productivity and resilience. It plays a crucial role in ensuring food security and sustainability in rice production. As research progresses, MAS will continue to drive innovations in rice breeding for diverse agro-climatic conditions. Ultimately, it offers a pathway to more efficient and adaptable rice production globally.