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BIOTIC STRESS BREEDING IN CROPS: CONVENTIONAL VS MOLECULAR APPROACHES

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Abstract

Biotic stresses, caused by pests, pathogens and weeds, pose a significant threat to global crop production and food security. Over the years, breeding strategies have evolved from traditional methods to advanced molecular approaches to tackle these challenges. While conventional breeding relies on phenotypic selection and crossbreeding, molecular breeding leverages genomic tools to enhance precision and efficiency. This article compares the two approaches, highlighting their strengths, limitations, and roles in developing stress-resistant crops to meet the demands of a growing population.

Key words: Biotic stress, Stress breeding, Conventional methods and Molecular approaches.

Introduction

Agriculture faces numerous challenges, with biotic stresses being among the most detrimental. Pests, diseases, and invasive weeds can reduce crop yields by up to 30%, making resistance breeding a critical area of research. Traditional breeding methods have played a pivotal role in developing resistant crop varieties, yet they often face limitations like time-intensive processes and susceptibility to environmental variability.

Recent advancements in molecular biology have revolutionized breeding, offering tools such as marker-assisted selection (MAS), genetic engineering, and CRISPR-Cas9 genome editing. These techniques promise greater precision and faster development of resistant crops, providing an effective complement or alternative to conventional methods. Understanding the differences between these approaches is essential to harness their full potential.

Conventional Breeding Approach

Conventional breeding relies on traditional methods to develop crop varieties with desirable traits. This process is largely based on selecting phenotypes and crossbreeding.

Key Techniques in Conventional Breeding

- **Phenotypic Selection**: Observing and selecting plants with resistance traits over generations. Selection of rust-resistant wheat varieties in the early 20th century revolutionized wheat production.
- **Hybridization and Crossbreeding**: Combining resistant donor plants with high-yielding or desirable parent varieties. The Green Revolution's success relied on developing semi-dwarf wheat varieties resistant to rust diseases through hybridization (Awan *et al.,* 2022).
- **Backcrossing**: A resistant trait from a wild relative or donor plant is repeatedly crossed with an elite cultivar to retain the desired traits while adding resistance. Development of rice varieties resistant to blast disease (*Pyricularia oryzae*).

Selection in Segregating Generations for biotic stress resistance

Selection in segregating generations is a pivotal process in crop breeding that aims to identify and preserve the most promising plants from a genetically diverse population. This process occurs after a cross between two parent plants, during which their offspring (progeny) inherit a mix of traits. Segregating generations, such as the F2 (second filial) and later generations, are where these traits begin to vary significantly, allowing breeders to select plants with the desired characteristics.

Mutagenesis: Inducing random mutations using chemicals or radiation to generate novel resistant traits. Mutagenesis in barley led to the creation of *Golden Promise*, a drought-tolerant and disease-resistant variety (Manjaya and Gupta 2023).

Molecular Breeding Approach: Molecular breeding employs advanced genomic and biotechnological tools to improve crop resistance against biotic stresses. This approach relies on understanding the genetic basis of resistance and manipulating it with precision.

Key Techniques in Molecular Breeding

Marker-Assisted Selection (MAS): Genetic markers linked to resistance genes help breeders select plants with desired traits without the need for phenotypic evaluation. In rice, MAS has been used to introgress the *Xa21* gene, which confers resistance to bacterial blight, into high-yielding varieties like IR64 (Fiyaz *et al.,* 2022).

- **Genetic Engineering**: Genes from unrelated species are introduced into crops to provide resistance. Bt cotton, where a gene from *Bacillus thuringiensis* produces a toxin that is lethal to bollworms. Golden rice engineered with genes for vitamin A production also incorporates resistance traits for fungal infections (Conchita *et al*., 2023).
- **Genome Editing**: This revolutionary tool allows precise editing of genes to enhance resistance. CRISPR has been used in tomatoes to knock out the *SlMlo1* gene, conferring resistance to powdery mildew.
- **Genomic Selection:** Predicts the genetic potential of plants based on their DNA, enabling early selection even before traits are expressed. Wheat breeders use genomic selection to improve resistance to multiple fungal diseases.
- **Transcriptomics and RNA Interference (RNAi)**: These techniques target specific genes at the RNA level to silence the expression of disease-causing genes. RNAi-based maize varieties resistant to rootworm pests have been developed (Saddeeq *et al*., 2022).

Examples Highlighting the Differences

Aspect	Conventional Breeding	Molecular Breeding
Rice (Bacterial Blight)	Developed by phenotypic selection in *IR20*.	Introgression of *Xa21* gene using MAS in IR64.
Wheat (Rust Resistance)	Crossbreeding wild relatives with high-yield varieties.	CRISPR editing of *Lr34* gene for durable rust resistance.
Cotton (Pest Resistance)	Developed pest-resistant cotton by hybridization.	Bt cotton with *Bacillus thuringiensis* gene for bollworm resistance.
Tomato (Powdery Mildew)	Breeding resistant varieties using wild relatives.	CRISPR-based knockout of *SlMlo1* gene.

Both approaches have their unique advantages and applications. Conventional breeding provides a foundation, while molecular breeding pushes the boundaries of what's possible, addressing challenges more effectively and quickly. A combined approach often yields the best outcomes for crop improvement.

What's the Difference?

Aspect	Conventional Breeding	Molecular Breeding
Process	Selecting and crossing plants over several generations.	Using advanced tools to tweak DNA directly.
Speed	Slow (10–15 years to develop a new variety).	Fast (3–5 years for results).
Tools Needed	Fields and simple tools.	Labs, computers, and sophisticated equipment.
Examples	Rust-resistant wheat, hybrid rice.	Bt cotton, CRISPR-edited tomatoes.
Cost	Low-cost but labor-intensive.	Expensive upfront but saves time and effort.

Why Should You Care?

Farmers Save Money: Resistant crops reduce the need for pesticides, cutting costs and protecting the environment.

More Food for Everyone: These methods help ensure crops survive, even when diseases and pests attack.

Safer Foods: Crops like Golden Rice are enriched with nutrients and disease resistance, tackling hunger and malnutrition.

Protecting the Planet: Less pesticide use means healthier soils, water, and biodiversity.

A Blend of Old and New

In the end, both approaches are essential. Conventional breeding is like the steady, hardworking farmer - it takes time but gets the job done. Molecular breeding is like a tech-savvy friend who uses gadgets to solve problems quickly. By combining these methods, we can create crops that are not only resilient but also sustainable for future generations. So, the next time you eat a slice of bread or a bowl of rice, remember: behind every grain is years of science and effort to ensure it's safe, nutritious, and sustainable.

Conclusion

Both conventional and molecular approaches are indispensable in the fight against biotic stresses in crops. Conventional breeding remains a vital tool, especially for smallholder farmers and regions with limited resources. However, the molecular approach offers unprecedented opportunities to address complex and evolving challenges, such as emerging pests and pathogens and climate-induced stresses. Future breeding programs should integrate both methods, leveraging the strengths of each to ensure sustainable crop production and global food security. The fusion of traditional wisdom with cutting-edge technology holds the key to agricultural resilience in the face of biotic threats.

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