



## The Journey of a Crop: From Lab to Land

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Agriculture today is no longer based solely on traditional practices but is strongly supported by scientific advancements in plant breeding. The crops grown in farmers' fields are the result of continuous efforts to improve yield, quality and adaptability. Scientific innovations have made it possible to develop crop varieties that can perform better under changing environmental conditions and increased food demand. The journey of a better crop begins in the laboratory, where scientists identify useful traits and develop improved varieties using various breeding approaches. However, developing a variety alone is not enough. Ensuring that these improvements reach farmers in the form of high-quality seeds is equally important. In recent years, the need for improved crops has become even more important due to challenges such as climate change, population growth and limited natural resources. Bridging the gap between laboratory research and farmers' fields is essential to ensure food security and sustainable agriculture.

### The science of better crops

The development of better crops starts with understanding plant genetics. Breeders identify important traits such as high yield, resistance to biotic and abiotic stresses with improved nutritional quality. These traits are combined through plant breeding techniques to develop improved varieties. Traditional breeding methods such as selection and hybridization have been used for many years to improve crops. In recent times, modern approaches including molecular breeding and genomics have made the process faster and more precise. These advanced tools help breeders identify useful genes and incorporate them into new varieties more efficiently, reducing the time required for crop improvement. The development of improved varieties is essential for meeting the increasing demand for food and ensuring agricultural sustainability. By combining desirable traits into a single variety, plant breeding plays a key role in enhancing productivity and resilience forming the foundation of the journey from lab to land.

### Different approaches for crop trait improvement.

**Selection:** it is one of the oldest and simplest approaches used in crop improvement. In this method, plants with desirable traits such as higher yield, better quality and adaptability are identified from a population and propagated over successive generations. By continuously selecting superior plants, breeders can gradually improve the overall performance of a crop. This method forms the basic foundation of plant breeding and is still widely used in many crops.

**Hybridization:** it involves crossing two genetically different plants to combine their desirable traits into a single variety. The resulting offspring, known as hybrids, often exhibit improved performance due to hybrid vigour or heterosis.

**Mutation breeding:** it used to create genetic variation by exposing seeds or plant materials to physical or chemical mutagens. These mutations can lead to the development of new traits that are not present in the original population. This method is particularly useful for improving specific characteristics such as disease resistance or plant architecture, thereby expanding the genetic base of crops.

**Marker-assisted selection:** a modern approach that uses molecular markers to identify desirable genes in plants. Instead of relying only on visible traits, breeders can select plants based on their genetic makeup, making the selection process faster and more accurate. This method reduces the time required to develop new varieties and improves the efficiency of breeding programs. Marker-assisted selection enables breeders to identify and select desirable traits at the DNA level, thereby increasing the efficiency and precision of crop improvement (Collard & Mackill, 2008).

**Genomics-assisted breeding:** the use of advanced genomic tools to understand and utilize genetic information for crop improvement. It helps in identifying important genes and their functions, allowing breeders to develop improved varieties more precisely and efficiently. This approach has significantly accelerated the pace of crop improvement in recent years.

**Biotechnological approaches:** it includes techniques such as tissue culture and genetic engineering. Tissue culture is used to produce disease-free and uniform planting material, while genetic engineering allows the introduction of specific genes into crops for desirable traits. Genome editing technologies such as CRISPR/Cas9 have revolutionized crop improvement by enabling precise and targeted genetic modifications (Doudna & Charpentier, 2014). These methods play an important role in addressing modern agricultural challenges and enhancing crop productivity.

**Table:1 Different approaches for crop improvement**

S.No.	Approach	Application
1	Conventional Breeding	Selection and hybridization of superior parents to combine desirable traits
2	Marker-Assisted Selection	Use of DNA markers to identify and select plants with target genes/QTLs
3	Genomic Selection	Prediction of breeding values using genome-wide markers for faster selection
4	Tissue Culture	In vitro propagation for rapid multiplication and production of disease-free plants
5	Genetic Engineering	Introduction of specific genes for traits like pest and disease resistance
6	Genome Editing	Precise modification of genes to improve traits without introducing foreign DNA
7	Mutation Breeding	Induction of genetic variation using chemicals or radiation
8	Doubled Haploids	Development of completely homozygous lines in a single generation

The above approaches highlight how modern plant breeding integrates conventional and advanced molecular techniques to accelerate crop improvement. While laboratory-based innovations such as marker-assisted selection and genome editing enhance precision and speed.

### Seeds that make the difference

Once a better crop variety is developed, the next important step is to ensure that farmers receive it in the form of high-quality seeds. A seed may look small and simple, but it carries

the full genetic potential of the crop. The quality of seed used by farmers directly affects germination, plant growth and ultimately the yield of the crop. The quality parameters such as genetic purity, physical purity, germination percentage and seed vigor were crucial for seed growth and development. Proper seed production practices, including isolation, rouging and careful handling are essential to preserve these qualities. In addition, seed testing ensures that only seeds meeting quality standards reach the farmers, improving reliability and performance in the field (Singh *et al.*, 2020). Good seed management also includes appropriate processing, storage and seed treatment. These practices help in protecting seeds from pests and diseases and maintaining their viability over time. The use of certified seeds ensures that farmers get uniform and healthy crops, which ultimately leads to better productivity and profitability.

### Reaching the farmer's field

Developing improved crop varieties and producing quality seeds are important steps, but their true value is realized only when they reach the farmers' fields. Bridging the gap between research and practical farming is essential for ensuring that scientific advancements benefit agriculture. This is achieved through strong extension services, demonstration of field trials and awareness programs that might help farmers understand and adopt new technologies. Field demonstrations play a key role in showing farmers the advantages of improved varieties and quality seeds under real farming conditions. When farmers observe better germination, uniform crop growth and higher yields they are more likely to adopt these innovations. Agricultural universities, research institutions and extension workers work together to ensure that reliable information and quality seeds are made available to farmers in a timely manner. In recent years, improved seed systems, better distribution networks and the use of digital tools have helped in faster dissemination of new varieties. These advancements are reducing the gap between laboratory research and field application ensuring the benefits of scientific progress reach farmers more effectively.

**Table: 2 crop varieties developed using laboratory techniques**

Crop	Crop Variety	Approach	Year	Characteristics
DRR Dhan 100 (Kamala)	Rice	Genome Editing (CRISPR/Cas)	2025	Higher yield (~19%), drought tolerance, climate-resilient
Pusa DST Rice 1	Rice	Genome Editing (CRISPR/Cas)	2025	Salinity & alkalinity tolerance, improved productivity
DBW 187	Wheat	Molecular Breeding	2022	Heat tolerance + high productivity under late sowing
HD 3385	Wheat	Marker-Assisted Breeding	2021	High yield + resistance to rust diseases
Bt Cotton	Cotton	Genetic Engineering	2002	Resistance to bollworm, reduced pesticide use, higher yield
Flavr Savr	Tomato	Genetic Engineering	1994	Delayed ripening, extended shelf life
Ganga Kaveri hybrids	Maize	Genomic Selection	2020	High yield + climate resilience

Recent advancements in Indian crop improvement clearly demonstrate the successful translation of laboratory techniques into field-ready varieties. The release of genome-edited rice varieties such as DRR Dhan 100 and Pusa DST Rice 1 marks a major milestone in precision breeding, while marker-assisted breeding has enabled the development of biofortified and disease-resistant varieties like DRR Dhan 45 and Improved Samba Mahsuri. These innovations highlight how modern biotechnology is enhancing yield, nutritional

quality and climate resilience, thereby strengthening the “lab to land” pathway in Indian agriculture.

### The way forward

The journey from lab to land clearly shows how science plays a vital role in improving agriculture. From developing better crop varieties through plant breeding to ensuring their quality through seed science, each step is important in delivering reliable and high-performing crops to farmers. As agriculture faces new challenges such as climate change, increasing population and limited natural resources, the need for continuous innovation becomes even more important. Strengthening the link between research, seed systems and farmers will help in faster adoption of improved technologies and better crop management practices. By combining scientific knowledge with practical application, it is possible to create a more sustainable and productive agricultural system.

### References

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