

Breaking the Yield Barriers in Pulses: Challenges, Innovations and the Road Ahead

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ABSTRACT

Pulses occupy a central position in Indian agriculture and nutrition, serving as the primary source of dietary protein for millions while contributing substantially to soil health and sustainability. Despite India being the world's largest producer and consumer of pulses, their productivity has remained stagnant for decades, in sharp contrast to the yield gains achieved in cereals. This article examines the major constraints responsible for low and unstable pulse yields, including dependence on rainfed agriculture, sensitivity to abiotic stresses such as drought, heat, and waterlogging, heavy losses from insect pests and diseases, and the narrow genetic base of most cultivated pulse species. Crop-specific yield limitations in chickpea, pigeonpea, mungbean, and black gram are highlighted to illustrate the diverse and complex nature of these challenges. The article further discusses how modern breeding approaches ranging from pre-breeding and wild germplasm utilization to genomics-assisted breeding, genomic selection, mutation breeding, and speed breeding are transforming pulse improvement. By integrating classical breeding with advanced genomic tools and supportive policies, it is possible to break the long-standing yield barriers in pulses and usher in a new era of climate-resilient, high-yielding, and farmer-friendly varieties. Strengthening pulse productivity is essential not only for enhancing farmer incomes but also for ensuring national nutritional security and sustainable agricultural development.

INTRODUCTION

Pulses occupy a unique place in Indian agriculture. For centuries, crops such as chickpea, pigeonpea, mungbean and black gram have been integral to Indian diets, farming systems, and culture. Often described as the “*poor man’s protein*,” pulses are, in fact, nutritional powerhouses rich in protein, dietary fibre, essential vitamins and minerals. Beyond nutrition, pulses contribute to soil health, environmental sustainability, and farm resilience, making them indispensable for a sustainable food system.

India is the largest producer, consumer, and importer of pulses globally, yet the productivity of pulse crops remains disappointingly low. While cereals like rice and wheat have witnessed dramatic yield gains during the Green Revolution, pulses have lagged (Varshney *et al.*, 2013). This stagnation has raised an important question for researchers and policymakers on ways to improve the yields.

THE IMPORTANCE OF PULSES IN INDIAN AGRICULTURE

Pulses play a critical role in ensuring nutritional security, especially for vegetarian populations. They supply nearly one-third of daily protein intake for millions of Indians. Pulses are also low in fat, rich in complex carbohydrates and help prevent lifestyle diseases such as diabetes and heart ailments. From an agronomic perspective, pulses are nature’s gift to farmers. Their ability to fix atmospheric nitrogen through symbiosis with rhizobium bacteria reduces dependency on chemical fertilizers. When included in crop rotations, pulses improve soil structure, enhance microbial activity and increase the productivity of subsequent crops (Massawe *et al.*, 2016). In rainfed and marginal environments, pulse crops often serve as a lifeline for small and marginal farmers.

WHY ARE PULSE YIELDS STAGNANT?

Despite their importance, pulse crops face a unique combination of challenges that limit their yield potential.

1. Dependence on Rainfed Agriculture

Most pulse crops in India are grown under rainfed conditions, often on marginal lands with poor soil fertility. Irregular rainfall, prolonged dry spells, and terminal drought frequently coincide with critical growth stages such as flowering and pod filling, leading to severe yield losses. Climate change has further aggravated the problem. Rising temperatures, unpredictable rainfall and increased frequency of extreme weather events have made pulse cultivation increasingly risky.

2. Abiotic Stresses: Silent Yield Killers

Abiotic stresses account for a major share of yield losses in pulses:

- Drought reduces photosynthesis, disrupts metabolism, and leads to flower and pod drop.
- Heat stress, particularly during flowering, severely affects pollen viability and seed set.
- Waterlogging, especially in pigeonpea and mungbean, creates oxygen deficiency in the root zone and damages plant tissues.
- Soil salinity and metal toxicity reduce nutrient uptake and delay flowering, resulting in poor pod formation.

Unlike cereals, pulse crops are inherently sensitive to environmental stresses, making yield stability a major concern (Choudhary *et al.*, 2011).

3. Biotic Stresses: Pests and Diseases

Pulse crops are highly vulnerable to insect pests and diseases:

- Chickpea is severely affected by pod borer (*Helicoverpa armigera*), Fusarium wilt and Botrytis grey mould.
- Pigeonpea suffers from sterility mosaic disease, Fusarium wilt and pod fly, often resulting in catastrophic crop failures.
- Mungbean and black gram are plagued by mungbean yellow mosaic virus (MYMV), whiteflies and bruchids.

Yield losses due to pests alone can range from 30 to 80 per cent, discouraging farmers from investing in pulse cultivation.

4. Narrow Genetic Base

One of the most fundamental limitations in pulse improvement is the lack of genetic diversity. Many pulse crops are highly self-pollinated and have undergone repeated selection for similar traits, leading to a narrow genetic base. This restricts the availability of novel genes for yield improvement, stress tolerance and resistance to pests and diseases. Wild relatives possess valuable traits such as stress tolerance and disease resistance, but their use is limited due to linkage drag, poor agronomic performance and long breeding cycles (Massawe *et al.*, 2016).

CROP-SPECIFIC YIELD CONSTRAINTS

Chickpea: Chickpea is a cool-season crop but is increasingly exposed to heat stress during reproductive stages due to shifts in sowing time and climate change. Diseases like Botrytis grey mould and Fusarium wilt further constrain productivity. Breeding priorities include heat tolerance, disease resistance, and plant types suitable for mechanical harvesting.

Pigeonpea: Pigeonpea is a hardy crop with deep roots, yet its productivity is limited by long duration, photo-sensitivity, and severe pest pressure. Hybrid pigeonpea, developed using male-sterility systems, has shown significant yield advantages and represents a breakthrough (Bohra *et al.*, 2012).

Mungbean and Black Gram: These short-duration crops are ideal for crop intensification but are highly sensitive to viral diseases and abiotic stresses. Breeding efforts focus on disease resistance, early maturity, and stress tolerance without sacrificing yield.

MODERN BREEDING APPROACHES TO BREAK YIELD BARRIERS

To overcome these complex challenges, pulse breeding has entered a new era, combining classical breeding with modern genomic tools (Bevan *et al.*, 2017; Varshney *et al.*, 2013).

- **Pre-breeding and Wild Germplasm Utilization:** Pre-breeding aims to transfer useful genes from wild relatives into cultivated backgrounds. Though time-consuming, it is essential for widening the genetic base of pulse crops.
- **Genomics-Assisted Breeding:** Advances in genomics have revolutionized pulse improvement. Molecular markers allow precise selection of desirable traits, reducing breeding time and increasing efficiency. Marker-assisted selection has been successfully used to improve disease resistance and seed traits.
- **Mutation and Transgenic Approaches:** Mutation breeding has generated novel variability for traits such as disease resistance and stress tolerance. Transgenic approaches have also demonstrated success, particularly for developing pod borer-resistant chickpea.

- **Genomic Selection:** Genomic selection uses genome-wide markers to predict breeding values, enabling faster improvement of complex traits like yield and stress tolerance.
- **Speed Breeding and Rapid Generation Advancement:** Speed breeding techniques allow multiple generations per year, dramatically reducing the time required to release new varieties. When combined with genomic tools, speed breeding can significantly accelerate genetic gains.

FUTURE PROSPECTS AND POLICY SUPPORT

Breaking the yield barriers in pulses will require a multi-pronged strategy, including, conservation and systematic use of wild germplasm, development of climate-resilient varieties, strengthening seed production and distribution systems, promoting pulse-based cropping systems and enhancing farmer awareness and adoption of improved technologies. With sustained research investment and policy support, pulses can emerge as a cornerstone of nutritional security, sustainable agriculture and climate resilience.

CONCLUSION

Pulses are far more than supplementary crops in Indian agriculture; they are pillars of nutritional security, ecological sustainability, and livelihood support for millions of smallholder farmers. The persistent stagnation in pulse yields is the result of multiple interacting constraints, including harsh production environments, high vulnerability to stresses, and limited genetic diversity. However, the convergence of modern genomics, innovative breeding strategies, and accelerated generation technologies offers unprecedented opportunities to overcome these limitations. Future progress will depend on

effectively harnessing wild germplasm, developing climate-resilient and pest-resistant varieties, strengthening seed systems, and promoting pulse-based cropping systems at scale. Equally important is strong policy backing and sustained investment in pulse research and development. With coordinated efforts across research, extension, and policy domains, pulses can transition from low-input, low-output crops to high-impact contributors to India's food and nutrition system, helping build a healthier, more resilient, and sustainable agricultural future.

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