

Growing Tomorrow's Crops Today: The Magic of Speed Breeding

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ABSTRACT

The global population is projected to approach 10 billion within the next three decades, placing unprecedented pressure on agricultural systems to deliver higher yields under increasingly unstable climatic conditions. While conventional plant breeding has produced high-yielding and nutritious crop varieties, the process remains slow, often requiring more than a decade due to long crop cycles, seasonal constraints, and extensive field evaluation. Speed breeding has emerged as a transformative strategy to overcome these bottlenecks by manipulating environmental factors such as light intensity, photoperiod, and temperature to accelerate flowering and seed development. This approach enables up to 3–9 generations per year, compared to just 1–2 under traditional breeding. Built upon advances in controlled-environment agriculture and LED lighting technology, speed breeding enhances photosynthetic efficiency and rapid generation turnover. When integrated with modern tools such as single-seed descent, doubled haploidy, marker-assisted selection, and high-throughput phenotyping, speed breeding significantly shortens breeding timelines and improves selection efficiency. As climate change intensifies and food demand rises, speed breeding offers a powerful pathway to deliver improved crop varieties faster than ever before.

INTRODUCTION

The world is racing toward a population of ten billion, yet the crops that sustain humanity are struggling to keep pace. Climate change has reshaped agriculture into an arena of uncertainty—heat waves scorch crops, erratic rainfall disrupts planting calendars, and pests and diseases evolve faster than before. Farmers are now expected to produce more food on shrinking land resources and under increasingly unpredictable environmental conditions.

Traditionally, developing a new crop variety is a slow and labor-intensive process. Plant breeders typically require 8–12 years, and sometimes longer, to move from an initial cross to a farmer-ready variety. While this timeline once seemed reasonable, it now feels painfully inadequate. Climate change does not wait for breeding cycles to finish, and advancing only one generation per year is no longer sufficient to address urgent food security challenges.

This growing mismatch between agricultural demand and breeding speed has paved the way for innovative solutions, among which **speed breeding** stands out as a game-changer.

Speed breeding is a technique designed to accelerate plant growth and reproductive development by extending photoperiods and precisely controlling environmental factors such as temperature, light quality, soil medium, and plant spacing under controlled conditions. By creating “ideal” growth environments, plants flower earlier and complete their life cycles much faster than under natural field conditions.

Under speed breeding systems, crops that normally take four to six months per generation can complete a generation in just two to three months, allowing multiple

generations to be grown each year (Hickey *et al.*, 2019).

The Evolution of Speed Breeding

The concept of accelerating plant growth is not new. Its roots stretch back more than 150 years to early experiments on artificial lighting and plant development. A breakthrough occurred in the 1980s when NASA, in collaboration with Utah State University, developed rapid-cycling wheat lines for space missions. This effort resulted in the dwarf wheat variety ‘**USU-Apogee**’, capable of completing its life cycle in record time (Bugbee & Salisbury, 1988).

Inspired by these advances, researchers at the University of Queensland formally coined the term “**speed breeding**” in the early 2000s. Their work demonstrated that optimizing light intensity, photoperiod, and temperature could dramatically reduce generation time in crops such as wheat and barley (Watson *et al.*, 2018).

Unlike doubled-haploid technology, speed breeding is versatile across many genotypes, does not require specialized laboratories, and supports high-density planting at relatively low cost. A landmark success was the release of the spring wheat variety ‘**DS Faraday**’ in Australia in 2017, developed using speed breeding and noted for improved protein content and resistance to pre-harvest sprouting.

Speed Breeding vs. Traditional Breeding

| Feature | Conventional Breeding | Speed Breeding |
|-----------------------|-----------------------|-------------------|
| Time per generation | 4–6 months or more | 2–3 months |
| Generations per year | 1–2 | Up to 6 (or more) |
| Environmental control | Seasonal, field-based | Fully controlled |

| Feature | Conventional Breeding | Speed Breeding |
|-----------------------------|-----------------------|-------------------|
| Variety development time | 10–15 years | 5–7 years or less |
| Response to climate threats | Slow | Rapid |

By compressing breeding cycles, speed breeding allows breeders to respond swiftly to emerging stresses such as heat, drought, and new disease outbreaks.

Applications of Speed Breeding in Major Crops

Speed breeding has been successfully adapted across a wide range of crops, each with tailored protocols:

- **Wheat and Barley:** Accelerated rust and crown-rot resistance breeding using extended photoperiods and single-seed descent (Watson *et al.*, 2018).
- **Canola:** Faster improvement for reduced pod shattering through artificial light extension.
- **Chickpea and Lentil:** Rapid generation advancement and early flowering induction to shorten breeding cycles (Samineni *et al.*, 2020).
- **Soybean:** Overcoming short-day constraints using LED-based photoperiod manipulation.
- **Pigeonpea and Peanut:** Moderate generation acceleration using extended light regimes integrated with SSD systems.

These successes highlight the adaptability of speed breeding across cereals, pulses, and oilseed crops.

Challenges and Future Prospects

Despite its promise, speed breeding is not without challenges. Major constraints include:

- Limited availability of trained personnel
- High initial costs of controlled-environment infrastructure
- Inadequate electricity and water supply in some regions
- The need for crop- and genotype-specific protocol optimization

Growth chambers and climate-controlled facilities can be expensive, but innovative low-cost alternatives—such as LED-lit greenhouses and solar-powered containers—are making speed breeding increasingly accessible, especially in developing countries (Chiurugwi *et al.*, 2019).

Continued investment in infrastructure, capacity building, and protocol standardization will be essential to scale up this technology globally.

CONCLUSION

Speed breeding holds immense potential to revolutionize crop improvement by drastically reducing generation time and accelerating the development of climate-resilient, high-yielding varieties. When integrated with modern genomic tools such as marker-assisted selection, genomic selection, CRISPR-based gene editing, and high-throughput phenotyping, speed breeding enables faster and more precise selection for complex traits.

Emerging technologies—including artificial intelligence, machine learning, and drone-based imaging—are expected to further enhance breeding efficiency. By enabling rapid introgression of stress-tolerance traits, speed breeding supports timely adaptation to climate change and rising global food demands.

With continued research, training, and infrastructure development, speed breeding is poised to become a cornerstone of next-

generation plant breeding programs worldwide.

SUMMARY

Speed breeding is redefining how fast we can improve crops. By altering the light, temperature, and growth conditions, it enables breeders can grow several generations in a year, dramatically shortening breeding timelines. As climate challenges intensify and food demand rises, speed breeding offers a practical, scalable, and powerful solution to ensure food security for future generations.

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