



Speed Breeding: The Fast Track to Better Crop Varieties

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Abstract

Speed breeding is an advanced plant breeding strategy that accelerates generation turnover through precise manipulation of environmental parameters such as photoperiod, temperature, light intensity, carbon dioxide, and relative humidity under controlled conditions. This approach significantly shortens breeding cycles, enabling rapid development of stable and homozygous lines and enhancing genetic gain. Integration with conventional breeding, marker-assisted selection, and other molecular tools further improves selection efficiency and expedites variety development. Moreover, speed breeding facilitates rapid evaluation of breeding populations and supports the development of climate-resilient cultivars. However, high infrastructure costs and the need for standardized protocols limit its large-scale adoption.

Keywords

Speed breeding, rapid generation turnover, controlled environment and crop improvement

Speed Breeding for Rapid Advancement

Speed breeding is an advanced plant breeding approach that accelerates generation turnover by

precisely manipulating environmental parameters such as photoperiod, temperature, relative humidity, and light intensity, thereby shortening the breeding cycle and enabling rapid genetic advancement of crop populations. The technique enables rapid generation advancement, facilitating the development of stable and homozygous genotypes and accelerating the release of improved crop varieties (Watson *et al.*, 2018). Conventional plant breeding is a time-consuming process in which crossing, selection, and generation advancement require approximately 5-10 years for line development. This is followed by 3-5 years of field testing and an additional 1-3 years for variety release before reaching farmers' fields. Overall, the development of a new variety through conventional breeding typically takes more than a decade. In contrast, speed breeding significantly reduces this timeline by accelerating generation turnover under controlled environmental conditions. Line development can be achieved within 1-2 years, followed by 3-5 years of field testing and 1-3 years for variety release. By shortening the generation advancement phase, speed breeding enables faster delivery of improved cultivars to farmers (Samantara *et al.*, 2022).

History of Speed Breeding

The concept of speed breeding originated during the 1990s when researchers from NASA, in collaboration with Utah State University, investigated rapid-cycling wheat production under controlled environment conditions for space-based agriculture. This work led to the development of the dwarf wheat variety ‘**USU-Apogee**’ and demonstrated the potential of manipulating environmental factors to accelerate plant life cycles. Subsequently, scientists from the University of Queensland, University of Sydney, and the John Innes Centre refined the approach and formally popularized the term “speed breeding.” Their work emphasized the use of extended photoperiods and controlled growth environments to achieve rapid generation turnover in major crops. Initially, speed breeding protocols were optimized for long-day crops. Later, advancements in light-emitting diode (LED) technology enabled the development of protocols for short-day crops such as *Glycine max* and *Oryza sativa*. By adjusting photoperiods and modifying light spectra, researchers demonstrated accelerated growth and the possibility of achieving up to five generations per year.

Further progress was achieved by scientists at the International Rice Research Institute, who developed a robust speed breeding protocol specifically for rice, enabling approximately four to five generations annually. These advancements collectively established speed breeding as a powerful tool for accelerating crop improvement and enhancing genetic gain in modern plant breeding programs.

Controlled Environmental Parameters for Speed Breeding

Photoperiod - Photoperiod manipulation is central to speed breeding, as extended light duration accelerates vegetative growth and reduces time to flowering. Adjustment of day length enables rapid generation turnover and synchronization of developmental stages in different crops.

Light Intensity- Light intensity directly influences photosynthetic efficiency and biomass accumulation. Optimal illumination enhances plant growth and promotes early flowering, which is essential for achieving multiple generations per year.

Light Source - Effective speed breeding requires light within the photosynthetically active radiation range (400–700 nm). Light-emitting diodes (LEDs) are commonly preferred due to their energy efficiency, low heat emission, and adjustable spectral composition.

Light Quality - Light quality regulates key physiological processes including germination, stomatal movement, chloroplast activity, and photoperiodic flowering. Blue, red, and far-red wavelengths play important roles in controlling plant morphology and development.

Temperature - Stable temperature conditions are required for rapid growth, with an optimal range generally maintained between 22°C and 30°C. Proper temperature regulation prevents stress and supports accelerated development.

Carbon Dioxide - Carbon dioxide concentration affects photosynthesis and plant productivity. Reduced CO₂ limits growth, whereas elevated levels enhance carbon assimilation and promote transition to reproductive stages.

Humidity - Relative humidity influences transpiration and physiological balance.

Maintaining humidity around 60–70% supports optimal growth and minimizes stress under controlled speed breeding conditions.

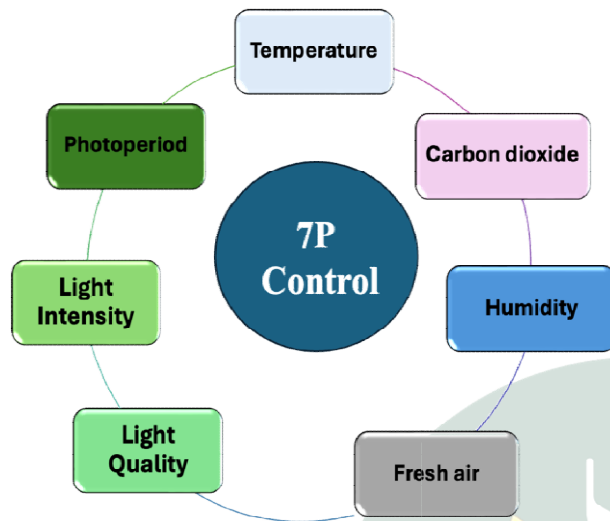


Figure 1. Key environmental parameters controlling speed breeding

Opportunities and Challenges

Opportunities

- Enhances the efficiency of conventional breeding by accelerating generation turnover
- Facilitates rapid advancement of transgenic lines and functional genomics studies
- Improves selection efficiency when integrated with genomic selection approaches
- Enables faster fixation of desirable alleles when combined with genome editing technologies

Challenges

- Controlled environments may increase the risk of pest and disease outbreaks

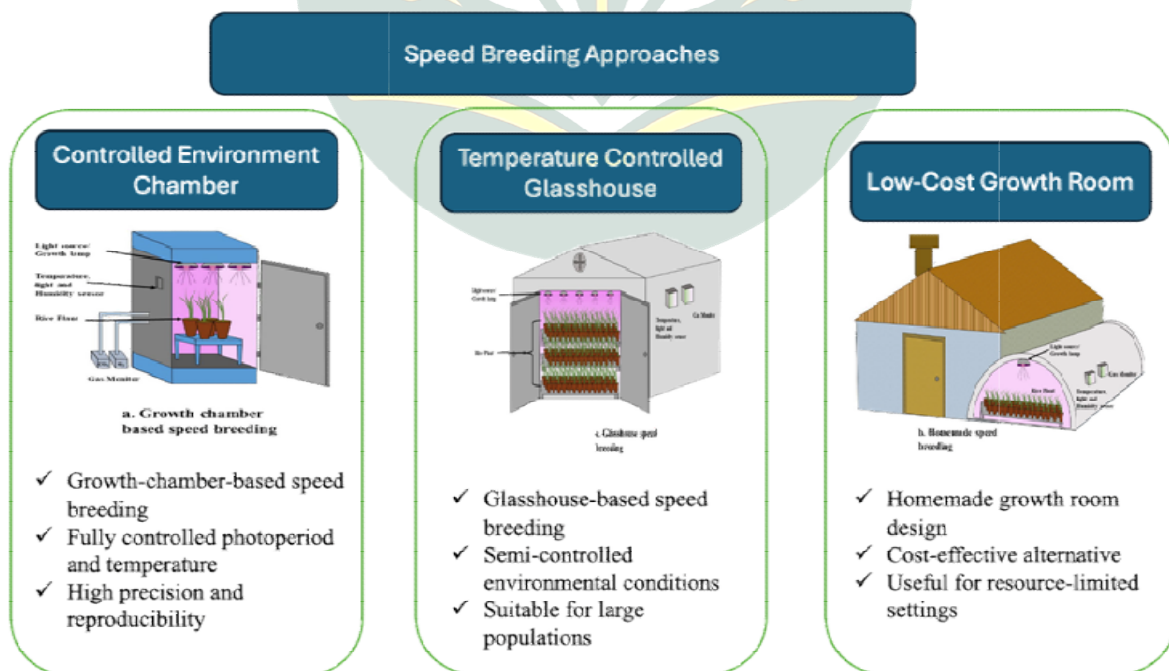


Figure 2: Different approaches used in speed breeding, including controlled environment chambers, temperature-controlled glasshouses, and low-cost growth room systems (Sharma *et al.*, 2023).

- High initial investment and operational costs for specialized infrastructure
- Requirement for sustained long-term funding to maintain facilities
- Limited availability of trained plant breeders and technical personnel

Conclusion

Speed breeding is an advanced breeding approach that accelerates the development of improved crop varieties by reducing generation time and enabling rapid genetic gain. This technique facilitates the efficient selection of elite genotypes and can be effectively integrated with conventional breeding, marker-assisted selection, and other innovative technologies to enhance breeding outcomes. Speed breeding also contributes to meeting future food demands by enabling the development of climate-resilient crop varieties within shorter timeframes, while requiring relatively smaller space due to controlled environment cultivation. However, standardized protocols for diverse field crops are still needed for wider application. Despite its

considerable potential, the adoption of speed breeding in resource-limited regions remains challenging because of infrastructure requirements and operational costs.

References

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