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Speed Breeding: Dramatically Cuts the Timeline for New Crop Varieties

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Traditional crop improvement starts with choosing two complementary parent lines that carry desirable traits. These breeding pairs are crossed, and the resulting progeny undergo several rounds of selection and advancement to identify superior lines that can be developed into candidate cultivars meeting market needs that is time taking process (Shimelis & Laing, 2012). While speed breeding is an innovative strategy in crop improvement that aims to quicken the development of superior wheat varieties. By shortening the generation interval and enabling rapid successive generations, this approach responds to the increasing demand for climate-resilient crops and enhanced food security. The technique achieves faster plant growth and reproduction by adjusting growth conditions such as temperature, light quality and duration, and photoperiod. When compared with traditional field-based breeding, speed breeding significantly reduces cycle times, enabling many wheat generations to be evaluated within a shorter overall timeframe (Watson *et al.*, 2018). Speed breeding comprises a set of methods that adjust the growing environment for different crop genotypes with the goal of speeding up flowering and seed production, thereby moving quickly to the next generation in the breeding process. By accelerating generation turnover, this approach saves time and resources in plant improvement. A range of selection strategies can be incorporated into speed breeding, including single seed descent (SSD), single pod descent (SPD), single plant selection (SPS), clonal selection, and marker-assisted selection (MAS). These techniques help shorten the breeding cycle and optimize resource use (Hickey *et al.*, 2017; Samineni *et al.*, 2019; Watson *et al.*, 2018).

Why Speed Breeding Matters Today

- **Accelerated crop improvement to meet growing food demand**

With a rising global population and changing dietary patterns, there is need to develop higher-yielding, more resilient varieties faster. Speed breeding cuts generation times, enabling quicker introgression of desirable traits and faster release of improved cultivars.

- **Climate change adaptation**

Crops face more frequent and extreme stresses (heat, drought, salinity, and new pests/diseases). Speed breeding, especially when paired with precise phenotyping and genomic tools, speeds the identification and deployment of stress-tolerant alleles and resilient phenotypes.

- **Rapid response to emerging threats**

Outbreaks of new diseases or pests require swift breeding responses. Shorter breeding cycles allow faster development of resistant lines and, if needed, rapid deployment of emergency cultivars.

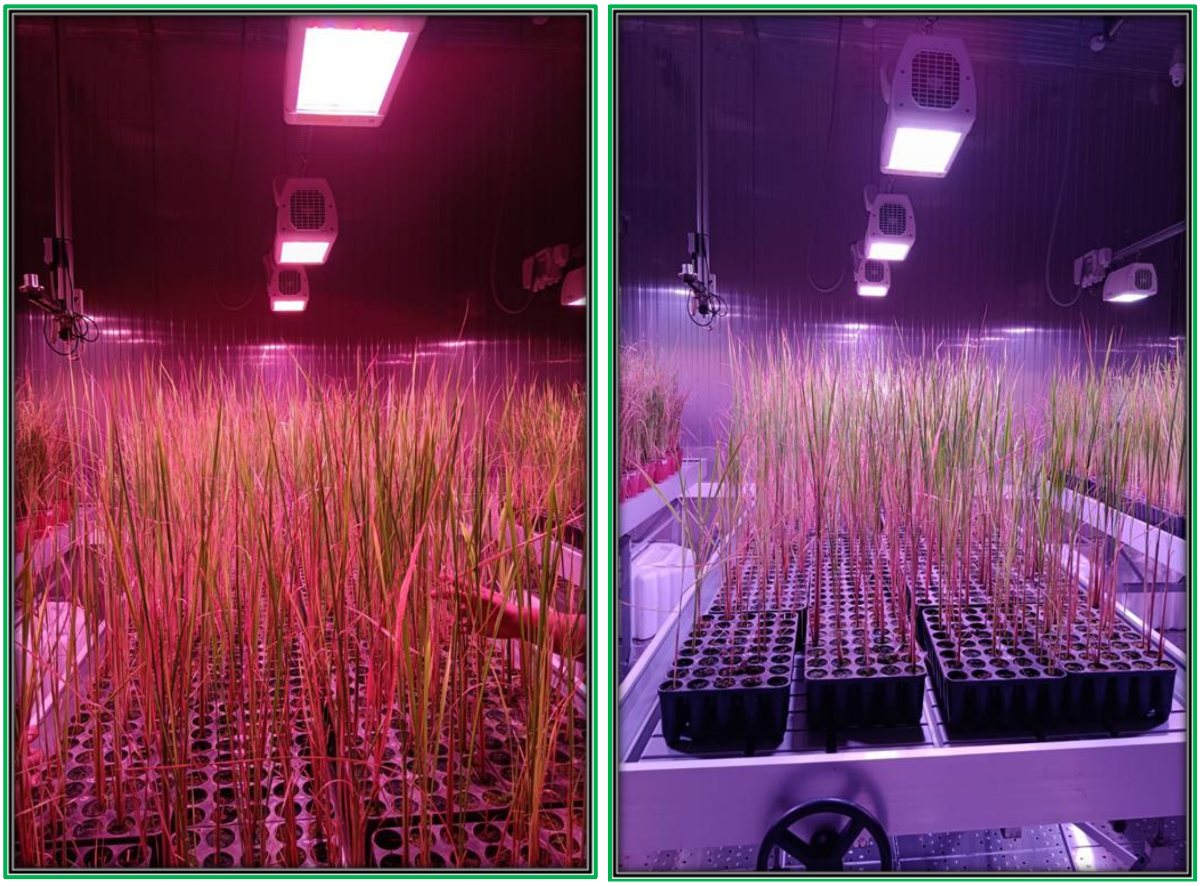

Figure 1. : Speed breed optimization and multiplication chamber for rice at Navsari Agricultural University Navsari, Gujarat.

- **Integration with modern genomics and biotechnology**

Speed breeding synergizes with genome editing, marker-assisted selection, genomic selection, doubled haploids, embryology, and high-throughput phenotyping This integrated approach enhances precision, reduces time to market, and improves resource use efficiency.

- **Resource optimization and sustainability**

Shorter cycles can reduce water, fertilizer, and land use per generation when managed effectively. Early screening of many lines in controlled environments also lowers field trial costs and risk.

- **Support for breeding programs in developing regions**

In regions with shorter growing seasons or limited breeding capacity, speed breeding can boost local variety development, enabling quicker adaptation to local conditions and diets.

- **Economic and food-security impact**

More rapid development of disease-resistant, high-yielding, and climate-tolerant varieties can stabilize yields, reduce losses, and contribute to price stability and farmer livelihoods.

Unlocking the Benefits of Speed Breeding Methods

Fast creation of stable, homozygous lines to speed up breeding progress

Altering the photoperiod to influence plant development: Photoperiod is the amount of time each day that a plant experiences light and darkness within a 24-hour cycle. This light–dark schedule influences key processes such as vegetative growth, the transition to flowering, and seed production, with effects that vary by species and cultivar (Vince-Prue, 1994).

Controlling ambient temperature to steer growth: Adjustments in soil and air temperatures influence germination and growth, promoting faster development, earlier flowering, seed production, and progression to maturity. Both low and high temperature extremes trigger diverse responses that alter the rate of plant development, including a shift from vegetative growth to the reproductive phase (Hatfield & Prueger, 2015; McClung *et al.*, 2016).

Managing soil moisture to affect plant performance: Soil moisture stress can markedly alter how plants grow and develop, impacting metrics such as overall height, the time to flowering, and the formation of seeds reaching maturity (Anjum *et al.*, 2017; Hussain *et al.*, 2018).

Adjusting plant density to optimize growth conditions: High-density planting involves cultivating crops at densities exceeding those needed for maximum yield. When plants are crowded, competition for light often causes them to grow taller, and this crowding accelerates the shift from vegetative growth to reproduction (Warnasooriya & Brutnell, 2014).

Modulating atmospheric CO2 concentrations for growth effects: Elevated atmospheric CO2 concentrations can promote faster vegetative growth and accelerate the shift from vegetative to reproductive development in certain plant species (Jagadish *et al.*, 2016).

Utilizing plant nutrients, growth regulators, and techniques from tissue culture: Nutritional inputs and plant hormones have been employed to speed up growth, trigger flowering and seed production, and stimulate germination of immature seeds in vitro (Bermejo *et al.*, 2016).

Compatibility with various selection strategies and methods

Single seed descent method: Single seed descent (SSD) aims to produce genetically uniform, homozygous lines by repeatedly selfing or inbreeding a segregating population and keeping one seed from each F2 plant to advance to the next generation. Each resulting inbred line can be traced back to its originating F2 plant (Fehr, 1991).

Single pod descent method: Because most legume crops produce multiple seeds per pod, single seed descent (SSD) is less efficient at preserving each F2 plant through successive generations than single plant selection, whereas selecting multiple seeds per pod (SPD) increases the likelihood that every F2 plant remains represented in later generations.

Single plant selection method: In the single plant selection (SPS) approach, every F2 plant is advanced by collecting and planting all seeds produced by that plant, effectively moving the next generation from plant to row. This SPS strategy has been applied in a modified backcross framework to create introgression lines (ILs) in barley, achieving the development within about two years (Hickey *et al.*, 2017).

Integrated approach: Speed breeding combined with genomic technologies accelerates plant improvement

Speed breeding speeds up plant-breeding research by shortening generation times, enabling quicker development of new varieties, trait analysis, and the creation of mapping populations. It supports rapid crossing, backcrossing, and stacking multiple traits into a single line, aided by genotyping for disease resistance and the exploration of targeted phenotyping and transgenic pipelines. When combined with modern tools such as SSD, doubled haploids, embryo rescue, high-throughput genotyping and phenotyping, genome editing, genomic selection, and DNA markers, speed breeding accelerates crop improvement, improves cross-pollination testing, ensures cultivar purity, and speeds gene introgression into recurrent parents (Watson *et al.* 2018).

What traits are targeted

The integration with genome editing and mutagenesis can boost crop biofortification (e.g., increasing vitamin B9 in rice) and trait removals (e.g., anti-nutritional compounds in quinoa and Brassica spp., and toxins in Lathyrus sativus). In addition, speed breeding paired with biotechnological methods has supported disease-resistance work (such as wheat leaf rust scoring) and demonstrated cytological stability of certain wheat-rye hybrids under speed-breeding conditions. Finally, coupling speed breeding with genetic transformation has been shown to shorten seed production timelines (e.g., viable barley seeds in about 6 weeks) compared with conventional conditions. Abiotic stress tolerance (Improved screening speed for traits like drought, heat, and salinity tolerance due to shortened generation turnover and repeatable environmental conditions). Phenology and development timing (Accelerated flowering, earlier maturity, and shortened generation cycles due to controlled photoperiod, temperature, and light quality). Plant architecture and vigour (selection for desirable traits such as compact stature, leaf area, and plant vigour, assessed across multiple speed cycles).

Challenges of Adopting Speed Breeding

- ✓ Need for Specialized Expertise
- ✓ Inadequate Educational Frameworks
- ✓ Lack of Suitable Infrastructure
- ✓ Financial and Institutional Constraints
- ✓ Unreliable Utility Supplies
- ✓ Operational and Policy Hurdles
- ✓ Over-reliance on External Donors
- ✓ Talent Retention Issues
- ✓ Unreliable water and electricity supplies for sustainable operations

Conclusion

Speed Breeding is a cutting-edge crop improvement technique that drastically reduces the time required to develop new varieties by shortening the generation interval. It achieves this by precisely adjusting growth conditions, including photoperiod, temperature, and light quality. This innovation is essential for addressing global challenges: accelerating crop improvement to feed a rising population, adapting plants to climate change, and rapidly responding to new threats. By integrating with modern tools like genomic selection and marker-assisted selection (MAS), Speed Breeding fast-tracks the development of climate-resilient, high-yielding cultivars, securing future food stability.

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