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Speed Breeding in Pearl Millet. Fast Tracking Climate Resilient

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Pearl millet (*Pennisetum glaucum*), commonly known as bajra in South Asia, stands as one of the most climate-resilient cereal crops cultivated across the arid and semi-arid regions of Africa and Asia. It serves as a staple food for over 90 million people, providing essential nutrition in regions where other cereals struggle to thrive. Despite its inherent drought tolerance and nutritional value, pearl millet faces significant challenges from climate change, evolving pests and diseases, and the persistent issue of micronutrient deficiencies among consuming populations.

Traditional breeding methodologies for pearl millet typically require 7-10 years to develop, test, and release a new variety—a timeline that is increasingly incompatible with the rapid pace of climatic changes and growing food demands. This extended duration primarily stems from the crop's dependency on seasonal cycles, allowing only one, or at most two, generations per year under conventional field conditions. Such slow progress impedes the timely development of varieties with enhanced traits such as higher iron content, improved drought resilience, or resistance to emerging pathogens.

Enter speed breeding—an innovative agricultural technology that revolutionizes this timeline. By creating controlled environment conditions that optimize plant growth and development, speed breeding can compress generation cycles, enabling researchers to achieve 4-6 generations of pearl millet per year. This groundbreaking approach, originally pioneered for temperate cereals like wheat and barley, is now being successfully adapted for tropical nutri-cereals, offering a transformative tool for pearl millet improvement (Watson *et al*., 2018).

2. How Speed Breeding Works

Speed breeding manipulates three environmental factors:

2.1 Photoperiod Management: Extended light exposure (20-22 hours) using LED systems with red-blue spectra accelerates flowering. Pearl millet, a short-day plant, is tricked into rapid development.

2.2 Temperature Optimization: Maintaining 28-32°C during light periods and 22-25°C during dark periods ensures continuous growth without thermal stress.

2.3 Precision Cultivation: Hydroponic or soil-less systems with controlled humidity (60-70%) deliver optimal **nutrients, minimizing growth limitations.**

ICRISAT Protocol: Achieves seed-to-seed cycle in 65-70 days versus 100-120 days in field conditions (Govindaraj *et al*., 2020).

3. Applications in Pearl Millet

3**.1 Rapid Biofortification:** Speed breeding accelerates development of nutritionally enhanced varieties. Example: 'Dhanshakti' variety with 71 mg/kg iron (50% increase over conventional types) reached farmers in half the usual time.

3.2 Climate Resilience Breeding: Enables faster integration of:

- Heat tolerance (pollen viability >42°C)
- Drought adaptation (improved root architecture)
- Disease resistance (downy mildew, blast)

3.3 Hybrid Development: Reduces inbreeding time for parental lines from 6-7 years to 2-3 years, shortening hybrid development to 3-4 years versus traditional 8-10 years.

4. Integrated Approach

Speed breeding combines with:

4.1 Genomic Selection (GS): DNA marker analysis allows early selection of superior genotypes, even at seedling stage. Combined with speed breeding, this creates "breeding in a year" pipelines.

4.2 Gene Editing: CRISPR-Cas9 introduces precise genetic modifications. Speed breeding then rapidly multiplies edited lines for testing.

4.3 High-Throughput Phenotyping: Automated imaging systems monitor plant growth and stress responses, enabling data-driven selection each generation.

This convergence accelerates genetic gain 3-4 times compared to conventional methods (Varshney *et al*., 2021).

5. Challenges

- High infrastructure costs for controlled environments
- Technical skill requirements in physiology and genomics
- Genetic diversity risks if rapid cycling isn't monitored
- Farmer accessibility of improved seeds

6. Case Study: ICRISAT's Success

ICRISAT's speed breeding program developed high-yielding, drought-tolerant pearl millet lines showing 15-20% yield increases in testing. Their facility cycles 6 generations annually, compressing decade-long projects to 2-3 years (Ghosh *et al*., 2022).

7. Future Prospects

- AI-driven environments that adapt conditions in real-time
- Portable breeding units for decentralized research
- Participatory speed breeding involving farmer feedback
- Integration with seed systems for faster farmer access

8. Conclusion

Speed breeding transforms pearl millet improvement, making it responsive to climate and nutritional needs. By compressing breeding cycles, it offers a sustainable path to food security for vulnerable regions dependent on this climate-smart crop.

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