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What is Speed Breeding? Speed Breeding Methods, Advantages, Limitations, and Achievements of Speed Breeding

Ajeet Kumar Gupta[1*], Abhinav Yadav[1], Syed Kulsoom Fatima Jafri[1], Piyusha Singh[2]

What is Speed Breeding?

Speed breeding is a suite of techniques that involves the manipulation of environmental conditions under which crop genotypes are grown, aiming to accelerate flowering and seed set, to advance to the next breeding generation as quickly as possible. The method saves breeding time and resources through rapid generation advancement. Various selection methods can be integrated into speed breeding, such as single seed descent (SSD), single pod descent (SPD), single plant selection (SPS), clonal selection, and marker-assisted selection (MAS) to shorten the breeding cycle. Speed breeding results in ~3 to 9 generations per year compared to 1 to 2 generations per year achieved with conventional selection approaches. As a result, speed breeding offers opportunities to rapidly develop homozygous and stable genotypes, and to facilitate rapid generation advancement, resulting in the accelerated development and release of new cultivars. Also, speed breeding technology fits well with MAS and high-throughput phenotyping methodologies for multiple trait selection.

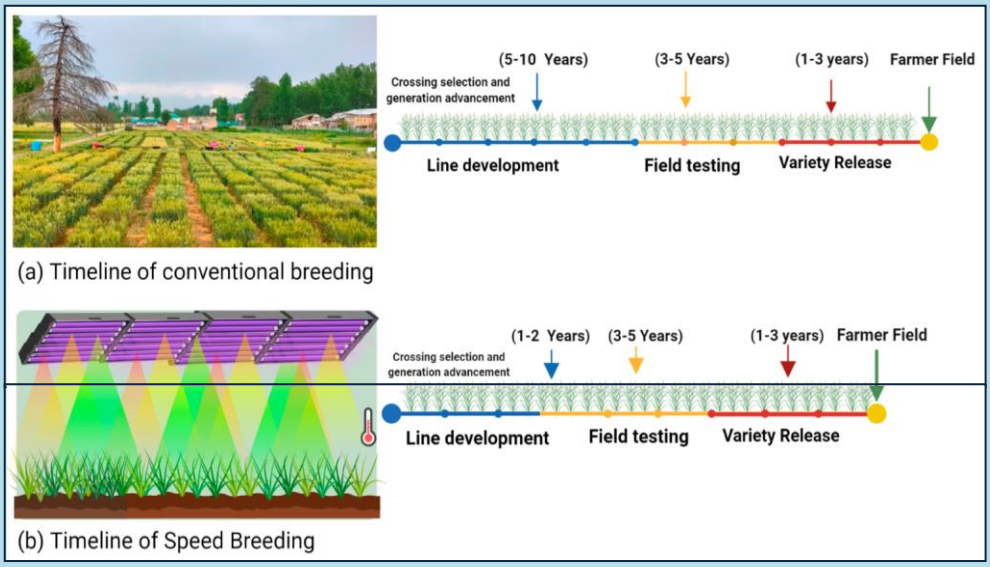

Fig. 1: Timelines of varietal development with (a) conventional breeding and (b) speed breeding.

Ajeet Kumar Gupta[1*], Abhinav Yadav[1], Syed Kulsoom Fatima Jafri[1], Piyusha Singh[2]

[1*]Ph.D. Scholar, Dept. of Genetics and Plant Breeding, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh (224229), India.

[2]Assistant Professor, Dept. of Genetics and Plant Breeding, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh (224229), India.

Introduction

The global population is said to reach 9 billion by 2050 which will strain resources. Rapid climate change and the emergence of new pests and diseases threaten agricultural production. Thus, producing a higher amount of quality food for the ever-increasing population is a major concern today. Moreover, the amount of genetic gain must be raised further than the levels presently achieved by conventional breeding programs. New and innovative methods are the prime requirement now. Speed breeding is a tool or technique for rapid generation advance that significantly reduces the harvest time of crops to speed up agricultural research and increase the production of food to meet the demand of the growing population.

Speed breeding was first initiated by NASA targeting to raise wheat in space using extended photoperiods or constant light and precise temperature to overdrive photosynthesis and hasten plant growth. Dr. Lee Hickey and his co-workers were the first to adopt NASA'S Plan to produce wheat and peanut at the University of Queensland, John Innes Centre, and the University of Sydney in Australia.

The experiments done on wheat revealed that the yield and the quality of plants grown under a controlled climate with extended daylight were the same as those of crops grown in regular glasshouse conditions. Traits that we can measure using speed breeding are: Green Revolution dwarfing genes, Awn suppressor genes, Fusarium head blight resistance, Rust resistance, Glaucousness, and Tan spot resistance.

Methods of Speed Breeding (Watson *et al.*, 2018)

1. **Speed Breeding I** – controlled environment chamber conditions (John Innes Centre, UK)
   - ❖ Photoperiod: 22Hrs (light)/ 2Hrs Dark
   - ❖ Temperature: 22°C (photoperiod)/ 17°C (Dark)
   - ❖ Humidity: 70%
   - ❖ Light: white LED, far-red LED & Ceramic metal hydrargyrum quartz iodide lamp
   - ❖ Light Intensity: 360–380 µmol m−2 s−1 (highest value after ramping) at bench height and 490 – 500 µmol m−2 s−1 (highest value after ramping) at adult plant height (concerning wheat, *T. aestivum* cv. Paragon)
2. **Speed Breeding II** – glasshouse conditions (Hickey Lab, Univ. of Queensland, Australia)
   - ❖ A temperature-controlled glasshouse fitted with high-pressure sodium vapour lamp
   - ❖ Photoperiod: 22Hrs (light)/ 2Hrs Dark

- ❖ Temperature: 22°C (photoperiod)/ 17°C (Dark)
- ❖ Humidity: 70%
- ❖ Light Intensity: 440-650(Adult Plant height) µ mol m−2 s−1 (approximately 45cm above bench height).

3. **Speed Breeding III**- low-cost homemade growth room design (Hickey Lab, of Queensland, Australia)
   - ❖ Photoperiod: 12Hrs-12Hrs (Light-Dark) for four weeks then increased to 18Hrs-6Hrs
   - ❖ Temperature: 21°C (photoperiod)/ 18°C (Dark) Light: 7 -8 LED light boxes (Grow Candy)
   - ❖ Intensity:210–260 (bench height) & 340–590 (Adult Plant height) µ mol m−2 s−1

Advantages of Speed Breeding

- Multiple generations in one year
- Fast way to obtain fixed homozygous lines through the Single Seed Descent method
- Phenotypic selection in early segregating generations
- Rapid introgression genes into elite lines using Marker Assisted Selection
- Allows study of plant-pathogen interaction, flowering time, etc.
- Multi-environmental trial across years
- Integrated with genomics selection, genome editing, etc.
- High–throughput phenotypic screens for multiple traits
- Exploit gene bank accessions and mutant collection for rapid gene discovery

Limitation of Speed Breeding

- Extended photoperiods may cause injury in some crops
- Unlikely to be successful in short-day crops
- Disease outbreak using controlled environmental conditions
- Plant losses in Single Seed Descent during greenhouse condition
- Increased monetary costs
- Incorporation of relatively simple inherited traits

Achievements

By speed breeding program, growing up to six generations per year is possible in wheat, barley, and chickpea up to four generations of canola. Speed breeding is also applied in peas, peanuts, grass peas, amaranth, quinoa, *Brachypodium*, *Medicago*, and many more crops. The technique is responsible for the development of the 'DS Faraday' wheat variety, which is a high protein, milling wheat with tolerance to pre-harvest sprouting.

'Scarlett' is the most extensively cultivated cultivar of barley in Argentina, which is susceptible to many diseases. By taking four lines with a modified backcrossing method, resistant lines were developed within two years. Moreover, drought tolerance trait in barley can also be achieved by speed breeding. 'YNU31-2-4' a Salt tolerant rice variety, was developed with the help of speed breeding. The gene was inserted by SNP marker, and the breeding cycle accelerated by speed breeding (14h light/10h dark- germination to 30 days of germination, ten h light/14h dark reproductive phase). The tillers were removed, and the embryo rescue technique was used to save time before seed maturity. Thus, enabling the researchers to get 4 to 5 generations of rice per year.

Speed breeding surpasses "shuttle breeding" and produces three times a greater number of generations. With shuttle breeding, only two generations per year can be achieved, while with speed breeding, up to 6 generations can be obtained.

Conclusion

The breeding programme should adapt to the changing climate, and the current problem of breeding for resilient climatic crops can be solved by using new ideas of speed breeding. Speed breeding can be considered an effective tool to achieve the 2050 genetic gain targets for the four Fs (Food, Feed, Fibre, and Fuel). Speed breeding combined with new technologies like marker-assisted selection, genomic selection, CRISPR gene editing, etc., can be used to get the result much faster. In-country like ours, where resources are very limited, speed breeding can be one of the most viable options for shortening the breeding cycle and accelerating the research program.