JUST AGRICULTURE
multidisciplinary e-Newsletter

ARTICLE ID: 09

Accelerated crop improvement through speed breeding.

Anju Pathania[1] and Lakhmir Singh[2*]

[1]Faculty of Agricultural Sciences, DAV University, Jalandhar

[2]Department of Biotechnology, DAV University, Jalandhar

* Corresponding author, Email - Lsingh05@gmail.com

Introduction

Speed breeding techniques utilize manipulations in temperature, light intensity, and duration under controlled conditions to enhance the growth of crops that are photo- and thermo-sensitive. This technology was initially developed to reduce the time span of long-day crops by artificially providing the light of the required intensity, spectrum, and duration to speed up crop growth and development, which later extended to day-neutral and short-day crop plants. The idea of stimulating crop growth by using an artificial environment was first apprehended by a team of botanists more than a decade ago, and in the mid-1980s, NASA, in collaboration with Utah State University, conducted an experiment on wheat on the space station in the presence of continuous light to reduce the life cycle of wheat. Inspired by the research conducted by NASA, scientists at Queensland University, Australia, coined the term 'speeding breeding' in 2003 for a set of breeding methods to accelerate wheat breeding. Conventional breeding methods take longer for varietal development due to long crop cycles and specific climatic requirements such as temperature and photoperiod. To accelerate the variety and line development processes, conventional breeding methods can be integrated with modern breeding techniques and a controlled environment to reduce breeding cycles. With the use of this technique, approximately six generations per year have been obtained in crops like wheat, barley, oats, chickpeas, faba beans, and lentils, and four generations in rice. Accelerated genetic improvement can be achieved by

i) accelerated crop growth and

ii) crop improvement augmented with modern breeding approaches.

JUST AGRICULTURE
multidisciplinary e-Newsletter

i. Accelerated crop growth under controlled environment

The speed breeding technique intentionally employs manipulations in environmental conditions for rapid completion of one crop cycle so that we can raise multiple generations in one year to reduce the time required for generation advancement. Different crop growth chambers are equipped with provisions for adjusting light intensity, photoperiod, temperature, soil moisture, carbon dioxide, and nutrition, which affect plant photosynthesis and other physiological processes.

- By modifying the exposure of light, scientists were able to induce early flowering in the IR64 variety of rice and
- By enhancing the light exposure to 22 hours, we reduced the flowering duration in wheat.
- The photosynthetic active radiation also plays an important role in photosynthesis, gas exchange, transpiration, stomatal conductance, and other mechanisms related to physiological processes in plants, and early flowering was observed in legumes with the use of the blue and far red light spectrums.
- Temperature is another parameter that is crucial for the transition of plants from the vegetative phase to the reproductive phase. Variation in temperature influences seed germination, plant growth, flowering time, seed setting, and maturity.
- The transition of plants from vegetative to flowering stages is also observed at elevated levels of CO2, and optimal concentrations are required to be standardized for different crops, although plant responses to CO_2 levels are genotype-specific. In soybean, crop cycle was enhanced up to 5 generations in a year by changing carbon dioxide supply (>400 ppm) along with 14 hours of light exposure in a growth chamber.
- Soil moisture content is another factor that results in early flowering in many crop species, and manipulation of moisture regimes in speed breeding may result in rapid generation advancement. Grain filling and maturity were enhanced in wheat, barley, and chickpea upon reducing moisture levels towards the end of flowering.
- Besides these factors, high-density planting, the use of plant growth regulators like auxins, cytokinins, etc., and nutrients also regulate flowering and seed development in

different crops. In lentils, 7-8 generations were reported in one year after the application of growth hormones coupled with an early seed harvest.

ii. **Crop improvement augmented with modern breeding approaches**

Speed breeding is a technique that allows the integration of modern breeding techniques with rapid generation advancement under controlled conditions. Since conventional breeding techniques take longer to develop new improved lines and varieties, the integration of modern approaches, including high-throughput phenotyping and genotyping protocols, can reduce the breeding cycle in the development of improved lines and varieties (fig. 1).

- Selection methods based on single plant selections (segregating generations) when followed with artificial selection for specific traits during early generations can reduce the population size, and more than one generation can be harvested within a year by growing experimental plants in a glass house, through shuttle breeding, or in a controlled growth chamber.
- The single seed descent method can be used for rapid generation advancement by raising segregating generations in a controlled growth chamber due to the small population size. Generally, 2-3 generations are harvested under glass house conditions or in shuttle breeding using modern breeding techniques, which can be increased up to 4-6 generations per year in a controlled growth chamber.
- Similarly, backcross generations can also be advanced under glass house conditions due to the small population size needed to get 2-3 generations, but integration with modern breeding techniques like MAS/MAB, GS, and speed breeding protocols can accelerate the generation advancement.
- Also, the development of mapping populations through conventional methods takes longer, which can be reduced through the inclusion of speed breeding. The integration of different strategies rapidly reduced the time taken for varietal development.
- Marker-assisted selection for QTL further paved the way for precise selection of genotypes with specific traits. The inclusion of speed breeding systems further facilitate the rapid improvement of complex traits related to yield and pest resistance.

- Next-generation sequencing techniques reduce the time and cost involved in genomic selection. In genomic selection, the estimated breeding values can be accurately predicted on the basis of genotypic and phenotypic data recorded in the training population, resulting in a more reliable estimation of the genetic potential of a genotype.
- Double haploid breeding is another technique that can be integrated with a speed breeding system to further reduce the breeding cycle and facilitate the rapid development of improved varieties.
- Genome editing can be done directly in the speed breeding system using the edit express approach to avoid the regeneration of plants in the laboratory. The Cas9 gene and sgRNA can be directly applied to the plants.

Challenges in the speed breeding system

Speed breeding protocols resulted in accelerated crop growth along with accelerated crop improvement for developing varieties in a super-reduced time span. This process requires proper planning and execution of different activities to achieve desirable results. Despite the fact that scientists have made great efforts to standardize various protocols for various crops in order to reap the greatest benefits of speed breeding, there are still numerous difficulties in using this strategy.

- This technique requires specific lab infrastructure, equipment with a controlled environment, and highly skilled technical staff. The developing countries cannot afford such facilities to carry out research on a large scale.
- The lack of funding and support policies further hampers the adoption of this technique.
- A limited number of crosses and populations can be maintained in small, controlled growth chambers.
- New breeding techniques are not frequently used in the research laboratories due to poor financial, technical, and infrastructural facilities.
- Sensitivity to environmental conditions is crop- and genotype-specific. Therefore, standardization of environmental conditions is required for each and every genotype to be improved.

JUST AGRICULTURE
multidisciplinary e-Newsletter

Conclusion

Speed breeding is a process in which different combinations of various conventional and modern breeding techniques are employed in a controlled environment for the rapid development of improved varieties. Since the population of the world is increasing at an alarming rate, meeting increasing human demands requires new and innovative techniques to ensure food security. The development of crop varieties with improved agronomic traits, enhanced yield, resistance to pests and diseases, and resilience to unfavorable climatic conditions can be expedited by speed breeding. Ongoing advancements and collaboration among various research organizations in different parts of the world can avoid duplication of work and have the potential for efficient utilization of the limited resources available on this planet for the sustainable growth and development. Being a transformative technique, speed breeding holds great promise for sustainable agricultural and global food security

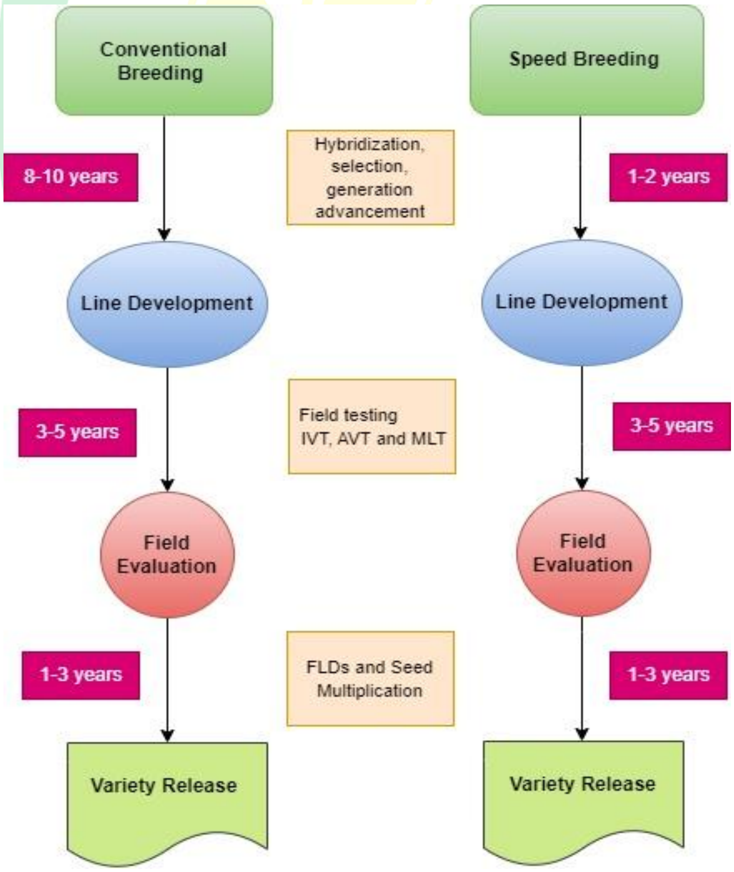

Figure 1: Timeline of conventional breeding and speed breeding