

SPEED BREEDING: ONE OF THE RAPID GENERATION ADVANCEMENT APPROACH

Abstract

Speed breeding is a cutting-edge breeding method with the potential to revolutionize the agricultural industry. Speed breeding significantly reduces the time it takes for crops to mature, enabling the production of several generations each year. This is accomplished by adjusting environmental conditions like temperature, light quality, and photoperiod duration. Researchers and breeders can create new crop varieties with desired features more quickly thanks to this faster breeding procedure. Compared to conventional breeding techniques, speed breeding has a number of benefits. It makes it simpler to generate improved cultivars with higher yield, disease resistance, and other desirable qualities since it enables the swift evaluation and selection of plant attributes. Speed breeding speeds up the breeding process, allowing scientists to adapt to shifting environmental factors and developing agricultural problems more quickly. While speed breeding offers tremendous potential, there are also limitations and challenges associated with its implementation. Factors such as plant species, specific traits, and optimal growth conditions need to be carefully considered. This system involves manipulation of growing conditions by different way, here there three methods were described. As the population of world going increase day by day so to overcome the risk of global security and to cope with such future problems the such rapid crop improvement approach need to implement. Speed breeding approach was old but its implications in the field of breeding not applied in that much extent. However, ongoing advancements in technology and further research will likely overcome these challenges, making speed breeding an increasingly valuable tool for crop improvement in the future.

Keywords : Conventional, Photoperiod, Quick, Speed breeding, Temperature.

Introduction

In the next three decades, it is projected that the global human population will increase by 25%, reaching a total of 10 billion individuals. While traditional breeding methods have successfully generated nourishing crops with high yields that can be mechanically harvested to address the food requirements of the expanding population, the current rate of yield improvement for major crops like wheat, rice, and maize is inadequate to meet future demands. There is mounting pressure on breeders and plant scientists to enhance

existing crops and create new varieties that are not only higher yielding and more nutritious, but also resistant to pests, diseases, and adaptable to changing climates. The rapid changes in climate and the emergence of novel pests and diseases pose significant threats to agricultural production. Consequently, the urgent concern today is to produce a greater quantity of high-quality food to satisfy the ever-growing population. Additionally, there is a need to surpass the current levels of genetic progress achieved through conventional breeding programs, necessitating the adoption of new and innovative approaches. One such tool or technique is speed breeding, which expedites crop research and boosts food production by significantly reducing the time it takes for crops to mature and be harvested. The rapid generation advancement principle in crop breeding plays key role in future. As there is more hunger day by day as increasing population so it's a proposed agenda to breed the crop more yielding with short time. Hence the goal of this particular article to introduced one of the rapid advancement method to interested viz.Speed breeding.

Speed Breeding (SB)

‘Speed breeding’ is breeding which greatly shortens generation time of crops by adjusting the photoperiod length and controlled temperature to accelerates breeding facilitating more number of generation per year of crops and research programmes.

This method was initially developed by NASA partnered with Utah State University to explore the possibility of growing rapid cycling wheat under constant light on space stations and they were successful in developing dwarf wheat line. After NASAs experiment the team at the John Innes Centre, University of Queensland and University of Sydeny started this method for wheat. Then the term “Speed Breeding (SB)” was given by University of Queensland. Speed breeding also the form of Rapid Generation Advancement (RGA).

The initial method was initially explained and executed on wheat and peanuts. This technique utilizes specific light quality, intensity, day length, and temperature control to expedite the process of photosynthesis and flowering. Additionally, it involves early seed harvesting to shorten the time required for each generation. By employing speed breeding, it is possible to achieve up to six generations of spring wheat, durum wheat, barley, chickpea, and pea, as well as four generations of canola instead of the typical 2-3 generations in a regular greenhouse setting. The use of supplementary lighting in a greenhouse environment enables rapid cycling of generations through a technique called single seed descent (SSD), which has the potential to be applied to larger-scale crop improvement programs. SSD is commonly used in breeding and research initiatives to aid in the development of homozygous lines after a crossbreeding with desired traits. One of the reasons for utilizing SSD is to address the increasing population growth each year and reduce seed losses.

Furthermore, the use of light-emitting diode (LED) supplemental lighting is highlighted as a cost-saving measure in this breeding process. The speed breeding experiments, referred to as I, II and III, utilized artificial light sources with enhanced photosynthetically active radiation (PAR) in the blue, red, and far-red regions of the spectrum. LED lights are now manufactured with programmable features that optimize PAR, allowing customization of wavelength and intensity to suit different growth stages and plant species. In the case of most crop plants, the breeding of new and improved cultivars usually requires several years, which is particularly time-consuming for field-grown crops that typically go through only 1-2 generations per year. However, speed breeding, which involves extended photoperiods to accelerate plant development and the harvest and germination of immature seeds, has the potential to reduce generation time. To investigate the effectiveness of speed breeding in accelerating SSD, where plants are typically grown at high density, it was

observed that plants grown at higher density had shorter generation times. This could be attributed to stress or plant competition resulting from the increased density, which is known to expedite flowering. It is unlikely that the direct application of speed breeding protocols to short-day species such as maize or rice would yield successful results, as there is likely room for optimization to achieve faster generation times in these particular species. The growing global population and the impact of a changing environment have raised significant concerns regarding food security. Traditional breeding methods may not be able to meet future food demands. Therefore, the development of speed breeding as a breeding method aims to address this challenge. Speed breeding has the potential to significantly enhance plant growth performance in both academic and commercial research sectors, spanning a wide range of species.

Methods of Speed Breeding

Speed Breeding I : Controlled-environment chamber speed breeding.

Speed Breeding II : Glass house speed breeding conditions.

Speed Breeding III : Homemade growth room design for low-cost speed breeding.

1) Speed Breeding I : Controlled-environment chamber speed breeding.

- ✓ In this the Conviron BDW chamber used.
- ✓ Photoperiod is of 22 hours with 22°C temperature and 2 hour dark periods with 17°C temperature helpful to improve plant health.
- ✓ Humidity in such system maintained as 70%.
- ✓ In this system/method temperature were set to ramp up and down for 1 hour 30 minutes to mimic natural dawn and dusk condition.
- ✓ The lighting was supplied by mixtures of white LED bars, far -red LED lamps and ceramic metal hydrargyrum quartz iodide lamps.
- ✓ Light Intensity: 360–380 $\mu\text{mol}/\text{m}^2/\text{s}$ at bench height and 490 – 500 $\mu\text{mol}/\text{m}^2/\text{s}$ at adult plant height.
- ✓ This system were used for crops like wheat, barley and *brachypodium*.

2) Speed Breeding II : Glass house speed breeding conditions.

- ✓ In this method temperature controlled glass house fitted with high pressure sodium vapor lamps were used.
- ✓ The temperature is maintained 17/22 °C with 12 hour turnover.
- ✓ The photoperiod is 22 hour light and 2 hour dark period (helpful to Improve plant health) without lamps at 17 °C.
- ✓ In this method there is no any light and temperature ramping up or down procedure.
- ✓ Light Intensity: 440-650(Adult Plant height) $\mu\text{mol}/\text{m}^2/\text{s}$ (approximately 45cm above bench height).
- ✓ This system were used for crops wheat, barley, chickpea, and canola.

3) Speed Breeding III :Homemade growth room design for low-cost speed breeding.

- ✓ In this system room of 3m×3m×3m with insulated sandwich panelling fitted
- ✓ with seven LB-8 LED light boxes.
- ✓ A 1.5horsepower inverter split system domestic air conditioner was set up as a
- ✓ low-cost alternative to the Conviron BDW chamber.
- ✓ Automatic watering was achieved with the Irrigation Controller.
- ✓ The humidity conditions were ambient.
- ✓ The lighting was set to run a 12-hour photoperiod (12hours of darkness) for 4weeks and then increased to an 18-hour photoperiod (6hours of darkness).
- ✓ The lights did not ramp up and down during the switch between light and dark periods in the 24-hour cycle.
- ✓ The air-conditioner was set to run at 18 °C in darkness and 21 °C when the LED lights were on, with fluctuation being no more than ± 1 °C.
- ✓ Intensity:210–260 (bench height) & 340–590 (Adult Plant height) $\mu\text{mol}/\text{m}^2/\text{s}$
- ✓ This system were used for the crops Wheat, barley, oat and triticale.

Source : Watson *et al.* 2018

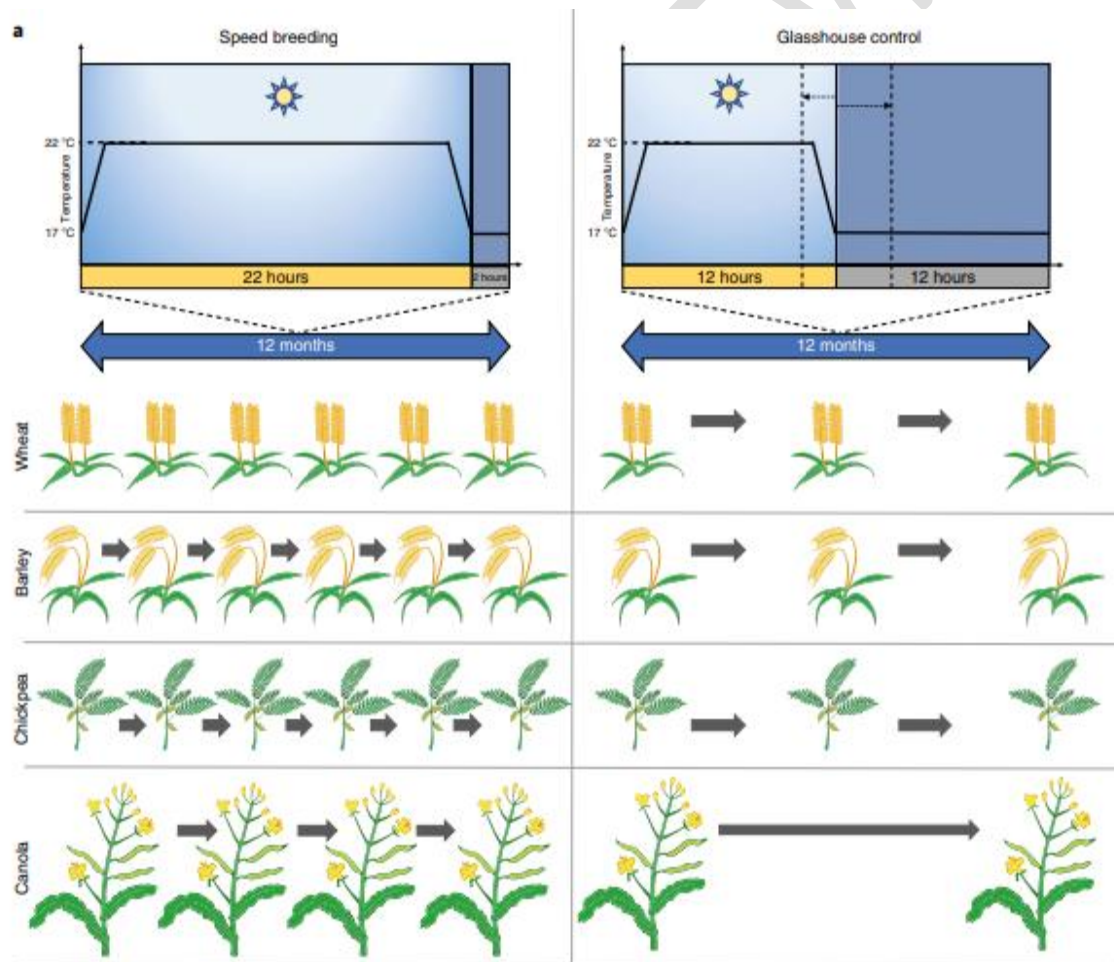


Fig.1. Speed breeding accelerating plant generation as compare to normal glasshouse condition.

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141 **Application of Speed Breeding**

142 1. The document also provides information on the cost-saving benefits of implementing light-emitting diode
143 (LED) supplemental lighting.

144 2. The results obtained from this method demonstrate the potential of applying speed breeding to various
145 significant crop species, such as wheat, barley, and chickpea, enabling the production of 4 to 6 generations
146 per year depending on the variety, without compromising subsequent generations' yield.

147 3. By combining speed breeding and SSD techniques, it is possible to expedite the generation of inbred lines
148 for research and plant breeding programs effectively.

149 4. Speed breeding offers the opportunity to accelerate the generation time and phenotype key adult plants,
150 such as wheat and barley.

151 5. Another valuable aspect of speed breeding is its usefulness in evaluating diseases by introducing resistant
152 and susceptible plants, like infecting wheat spikes with *Fusarium graminearum*, which causes fusarium head
153 blight (FHB).

154 6. Speed breeding proves useful in assessing the loss of function of a specific locus across different
155 generations, as demonstrated in the F6 recombinant inbred line of Paragon x W352 under speed breeding
156 conditions, focusing on the FLOWERING LOCUS T-B1.

157 7. The study also examines the pairing of polyploid wheat chromosomes at metaphase I during meiosis, both
158 with and without the PAIRING HOMOEOLGOUS 1 (Ph1) locus.

159 8. Adult plant phenotypes can be accurately recapitulated much faster compared to the corresponding
160 conditions in a greenhouse.

161 9. Other growth parameters, such as photoperiod, temperatures, plant density, and watering regime, can be
162 adjusted to accelerate the generation time.

163 10. Speed breeding allows for the rapid generation of fixed populations through SSD, which may be a cost-
164 effective alternative to generating double haploids, facilitating subsequent field evaluation and selection and
165 enhancing genetic gain and cultivar production.

166 11. In the case of genetically well-defined traits, speed breeding can be employed to swiftly introgress genes
167 or haplotypes into elite lines using marker-assisted selection.

168 12. In the context of breeding, the ability to rapidly advance generations to homozygosity after crossing
169 enhances genetic gain for essential traits.

170 13. Speed breeding enables breeding programs to produce improved cultivars more rapidly.

14. It is valuable for comparing the physiological, morphological, and yield parameters of crops.
15. Speed breeding requires less land, labor, and machinery compared to field breeding.
16. The speed breeding system is less vulnerable to adverse biotic and abiotic stresses, such as reduced rainfall, low diurnal temperatures, and foliar diseases. Moreover, it provides breeders with greater flexibility in generating new breeding materials.
17. Speed breeding can expedite the discovery and utilization of allelic diversity in landraces and wild relatives of crops. For instance, screening the Vavilov wheat collection for leaf rust resistance using speed breeding, combined with DNA markers linked to known genes, led to the identification of new sources of resistance.
18. It can be seamlessly integrated with genomic selection, genome editing, and other techniques.

Limitation of Speed Breeding

1. Plant species exhibit distinct responses when subjected to prolonged periods of light exposure.
2. Extended photoperiods often accelerate the time to flowering in long day plants by surpassing the critical day length. Day-neutral plants also exhibit this phenomenon, as they flower irrespective of the photoperiod.
3. Short-day (SD) plants require a photoperiod shorter than the critical day length for flowering, which may conflict with extended light conditions.
4. When the response to photoperiod is unclear or intricate, it becomes necessary to experiment with light and temperature variables to optimize a strategy for extended light conditions.
5. While this approach works well for certain activities like crossing, single seed descent (SSD), and screening for simple traits, other tasks such as selecting for adaptation to the target environment still need to be carried out in the field.
6. Expediting the generation time through early harvest of immature seeds can hinder the phenotyping of certain seed traits.
7. If suitable facilities are not already available, establishing a greenhouse or acquiring a growth chamber with appropriate supplementary lighting and temperature control capabilities entails a significant initial investment.
8. The cost-benefit analysis depends on the budget of the research or breeding program.
9. The outcomes are heavily reliant on the crop species and can vary significantly among different cultivars.
10. The quality of light, duration of the photoperiod, and temperature conditions also influence the extent to which the generation time is reduced.
11. It's important to note that the strength and duration of ambient sunlight vary with location and season, leading to variations in the rate of plant development.
12. Manipulating basic growth conditions like soil type can be employed to achieve optimal parameters for the specific crop of interest.

Achievements of Speed Breeding :

1. USU-Apogee - a dwarf wheat line – NASA and Utah State University.
2. DS Faraday – High protein and milling wheat variety.
3. YNU31-2-4 – Salt Tolerance rice variety.
4. By speed breeding program, growing up to six generation per year is possible in wheat, barley, chickpea and up to four generations of canola.

Other method to reduce generation time :

1. Use of embryo rescue
2. Growth regulator
3. Increasing physiological stress
4. Increasing CO₂ concentration.
5. Double haploid (DH) techniques,etc

Conclusion

The breeding program needs to align with the changing climate, and the immediate challenge is to breed resilient crops that can withstand these changes. This challenge can be addressed through innovative approaches like speed breeding. Speed breeding is an effective tool that can help achieve the genetic gain targets for food, feed, fiber, and fuel by 2050. By combining speed breeding with technologies such as marker-assisted selection, genomic selection, and CRISPR gene editing, the desired outcomes can be achieved much faster. In countries with limited resources like ours, speed breeding is a viable option to shorten the breeding cycle and accelerate the research program. The field of agricultural science has extensively explored various research avenues and has leveraged plant biology and ecology to enhance traits. Speed breeding involves developing crop-specific protocols by manipulating the photoperiod, optimizing controlled environmental conditions like temperature, humidity, and light, and implementing stage-specific assessments to achieve more than five generations per year without compromising yield. This approach not only emphasizes greenhouse control measures but also prioritizes the specific needs of the plants when establishing the protocols. The article primarily focuses on wheat crops and discusses key aspects and limitations of speed breeding, including the high initial cost and the variation in protocols depending on the crops involved.

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