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Speed Breeding: An Innovative Approach to Accelerate Crop Improvement

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Global food security has become a major source of concern due to the expanding human population and the changing environment. The current improvement rate of several important crops is inadequate to meet future demand, this is primarily due to the long generation times of crop plants. A method called 'speed breeding', greatly shortens generation time and accelerates the breeding programme of crop plant, and ultimately enhance genetic gain. During the early stages of breeding after the first cross with parental genotypes, a huge amount of time, space, and resources are used for selection and genetic advancement. In past eras breeding, new and high-performing cultivars with market-preferred traits can take more than ten years. Speed breeding recolonizes the normal breeding process and shortens the time to develop, market, and commercialize cultivars. Speed breeding is an innovative and revolutionary technology that seeks to shorten the crop breeding cycle and accelerate crop improvement and genetic gain through rapid generation advancement.

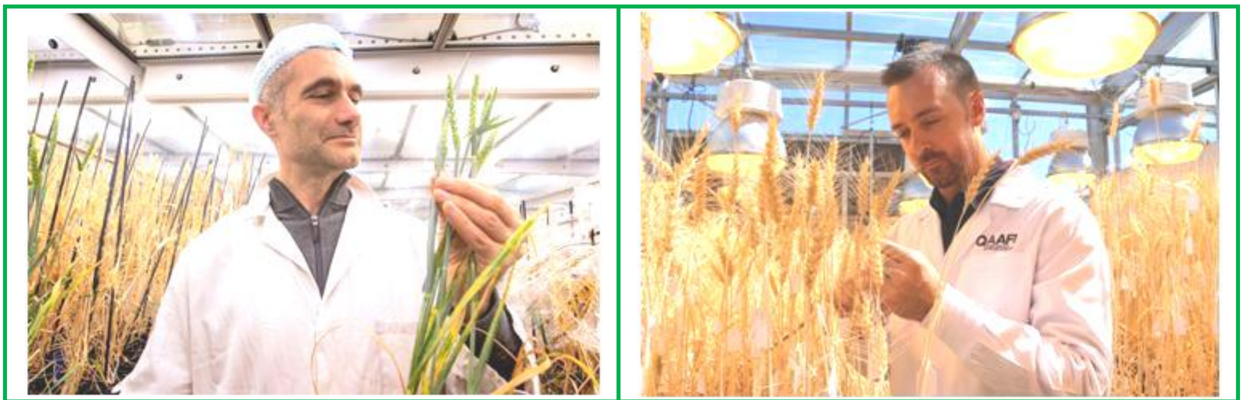
Speed breeding involves changing the environmental conditions under which crop genotypes are grown in an effort to hasten the blooming and seed development process and, ultimately, to reach the next breeding generation as quickly as is achievable. Shuttle breeding, single seed descent (SSD) and double haploid (DH) etc. are used previously by many plant breeders with the aim of rapid generation advancement. With all these technologies breeders are able to shorten the breeding cycle and speed up the breeding programme. However, the term 'speed breeding' was coined by researchers at the University of Queensland during a wheat breeding programme in the early 20th century. Compared to one to two generations per year with traditional selection procedures, speed breeding provides three to nine generations each year. As a result, it enables the rapid generational progression and production of homozygous and stable genotypes, leading to the creation and introduction of novel cultivars. Breeders are able to produce up to 6 generations of wheat, barley, and chickpea per year and 4 generations of canola per year by prolonging the photoperiod and increasing the light intensity throughout plant growth.

Methods of selection suitable for speed breeding

Single seed descent (SSD) and single pod descent (SPD) approaches are the most suitable selection strategies that are compatible with speed breeding. Single seed descent (SSD) is a rapid method to achieving homozygous populations through successive inbreeding of segregating populations (F_2 onwards commonly up to F_4 or F_5) by retaining one seed from each F_2 plant and advancing these individuals to the next generation. The need for a less growing area and labour for managing the early separation generation, and the possibility of adopting high-density planting in a greenhouse or chamber are the advantages of the SSD method. Single pod descent (SPD) method involves the selection of one pod per plant from each F_2 –F_4 plant instead of a single seed in pulses like soybean. Modern approaches like high-throughput genotyping, marker-assisted selection or pyramiding, genomic selection, genome editing, gene mapping, adult plant phenotyping, genetic engineering etc. can be successfully combined with speed breeding.

Called for manipulating the environment

Rapid generation advancement in speed breeding is entirely dependent on the alteration of environmental factors according to crop protocol. As we know, major environmental factors for plant growth and reproductive cycle are temperature, photoperiod, light intensity and quality, humidity, CO_2 concentration, and soil moisture content. Optimal minimum and maximum temperatures vary crop-wise. Most crops need temperatures between 12 to 30°C to germinate, although the ideal range for development, flowering, and seed set is often between 25 and 30°C. Many crops, including wheat, barley, chickpea, pea and canola successfully used light sources that emitted photosynthetic active radiation (PAR) within the range of 400–700 nm with an intensity of 360–650 μmol/m^2/s in order to facilitate rapid generation progression in speed breeding. Normally photoperiod of 22h with 2h darkness and a range of 60-70% humidity is maintained in a growth chamber. Crops that are adapted to drought conditions require lower humidity levels. Increased levels of CO2 results in reduced days to flowering in crop plants. Early flowering and maturation can be triggered by stress from drought or flooding, which can be employed in speed breeding. Different crop species and genotypes within species have variable environmental requirements for flower induction and seed set.



Dr. Brande Wulff (left) and Dr. Lee Hickey look at speed-bred wheat crops. Photo: Hickey Lab/University of Queensland

Accelerating genetic gain

The breeder's equation is used to predict the change in a trait with respect to genetic gain (ΔG). The equation can be written as $\Delta G = (\sigma_a)\ (i)\ (r)\ /\ L$), where, σ_a; represents the additive genetic variation within the population, *i*; means selection intensity, *r;* denotes selection accuracy, and *L;* is the length of the breeding cycle. Based on this equation, speed breeding protocols can hasten genetic gain by increasing the number of plant generations completed per year.

Speed breeding's obstacles

A useful strategy for accelerating traditional breeding programmes is the employment of speed breeding techniques. However, some hurdles are hindrances in the way of progress and these are listed below.

- Scarcity of knowledgeable plant breeders or speed breeding specialists.
- Lack of breeding protocol for all the major crops.
- Non-availability of advanced greenhouse facilities.

- Long-term funding is required.
- In many developing nations, institutional support for public plant breeding programmes is limited.
- The significant financial investment required to continue breeding and building infrastructure.
- Absence of policy and financial support from the government to start and maintain speed breeding in public plant breeding programmes.

Future Prospects

Population growth is likely to outpace grain yield and call for larger investments in crop breeding to keep pace with future demand. The job of feeding 9.7 billion people by 2050 is intimidating, but breeding has overcome similar obstacles in the past. One of the major constraints in crop breeding is the long growth and reproduction period and high weather dependence of crop plants. These problems are overcome by adopting speed breeding as a complementary approach to traditional and modern plant breeding techniques. In developing countries such as India, support from government policies is necessary so that public plant breeding systems can beat population growth.