

Speed Breeding for Crop Improvement

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Speed breeding is an emerging breeding strategy to develop new varieties in a shorter time and it involves optimizing growing conditions, such as light, temperature, and photoperiod, to accelerate plant growth and development. It is considered to be a promising solution to achieve more precise and expedited outcomes in crop enhancement thereby enhancing climate resilience, long-term yield and nutritional security (Imam et al.2024). This methodology is considered to be precise than the doubled haploid (DH) production and shuttle breeding and can be well combined with other breeding tools like marker assisted selection, high throughput genotyping, phenotyping, gene editing etc. (Shreya et al. 2022). The term 'Speed breeding' was coined in 2003 by group of researchers from University of Queensland inspired by NASA's technology of raising wheat variety 'USU-Apogee' in space station with constant light.

Need for speed breeding

The growing world population, escalated food demand, climate change vagaries and abating land area were the chief driving forces behind the breeding efforts in various crops all over the world. In spite of the significant yield increase achieved in many crops via several advanced breeding efforts, most crops suffered slow progress due to their long duration which in turn hindered the progress in enhancing traits such as yield, disease resistance, and climate resilience. In the context of growing food

security challenges and climate change impacts, there arose an urgent need to accelerate breeding programs and speed breeding was evolved to achieve faster variety development.

Techniques used in speed breeding

Speed breeding (SB) chiefly involves manipulation of temperature, light spectrum and intensity, photoperiod duration and humidity regime to reduce time to floral initiation, hasten embryo development and seed maturity (Pfeiffer et al. 1926, Radha et al. 2007, Shreya et al. 2022). Use of LED lights or other artificial illuminating sources to manipulate light, solar/battery- powered air-conditioning systems to manipulate temperatures, drought or flooding stress to manipulate soil moisture levels, CO₂ cylinders and regulators to manipulate CO₂ levels, high planting density to stimulate rapid generation advancement and use of plant growth regulators to accelerate germination were successfully employed to trigger flower initiation and reduce generation time in many crops such as wheat, barley and legumes (Potts et al. 2023).

Speed breeding technology utilizes full spectrum light and control growth chambers, making it superior and more advanced than glasshouses and field rapid generation advance (RGA) technology. The potential to further improve breeding efficiency by cutting down on breeding cycle time, facilitating early phenotypic assessment, optimising resource use, and raising selec-

tion accuracy and genetic gain annually is provided by combining SB with genomic techniques like genome editing, genomic selection, and marker-assisted selection (Ceran et al. 2024)

Advantages of speed breeding

Speed breeding is being used to accelerate the breeding process in crops, significantly reducing the time it takes to develop new varieties with desirable traits. This methodology helps breeders to evaluate more plants in a shorter time resulting in the development of varieties with higher yields, better pest resistance, and improved nutritional profiles in shorter timeframes with significant genetic gain.

Speed breeding will allow breeders to create superior genotypes that keep up with the ever-increasing human population and changing environment when paired with biotechnological technologies like plant tissue culture techniques and genomic selection. This technique has successfully shortened the breeding cycles of various crops, including wheat, barley, and chickpea. By creating ideal controlled environments, plants can be induced to flower earlier and complete their life cycle faster.

Limitations of speed breeding

Although SB can be used as a potential technique to accelerate crop improvement and achieve significant genetic gain in many crops, it requires advanced controlled environment facilities, expertise, appropriate infrastructure and several other technological breakthroughs to achieve significant gains.

Moreover, striking the right balance between accelerating growth and avoiding stress-induced responses, avoiding phenotyping bias in controlled conditions, lack of technical expertise and huge costs involved in creating controlled facilities for SB are some of the challenges posed to implement SB in developing countries.

Potential of speed breeding for cassava improvement

Cassava is vegetatively propagated via stem cuttings. This characteristic is advantageous for breeders because it permits to quickly get enough clonal materials to perform large scale crossings between selected parental lines. Breeders use crossing and seed propagation but getting desired crosses (traits) is not easy because of poor flowering, non-synchronization of flowering time and low pollen viability.

Moreover, the cassava life cycle is very long and there is often a strong GXE component to flowering. Methods that stimulate early flowering with an increased number of viable flowers could be instrumental to shorten the long cassava breeding cycle. One of the most important factors to consider for speed breeding in cassava is flower induction and boosting flower initiation in genotypes that are poorly flowering. Cassava flowering is associated with branching ability and growth type. However, erect growing genotypes are usually preferred over branching genotypes which further limit the potential to efficiently cross the parental material. Different approaches such as grafting, plant hormones, photoperiod extension and genetic engineering such as introgression of flower-inducing genes in cassava have been reported to induce cassava flowering, but not all of them are practically efficient.

Given the long cassava breeding cycle, the so-called speed

breeding techniques hold a great potential to revolutionize cassava breeding.

Speed breeding facilities available in India

A first-of-its-kind facility in the country, a speed breeding crop facility named the National Speed Breeding Crop Facility, was established at Mohali's National Agri Food Biotechnology Institute (NABI). This technological leap will aid in developing new varieties of wheat, pea, tomato, rice, etc.

The facility boasts the capability to develop up to four generations of a crop per year with the use of precisely controlling aspects of the environment such as temperature, light, and humidity. The focus behind starting such a ground-breaking facility in the country is to not only improve the farmer's produce in terms of quality but to also guarantee a quantitative boost. Other facilities available in India are SpeedBreed facility at the IRRI South Asia Regional Centre (ISARC) in Varanasi and speed breeding facility, Navsari Agricultural University.

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