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Speed Breeding and Its Implication for Crop Improvement

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Speed breeding is a technique used in plant breeding to accelerate the development of new crop varieties. It involves manipulating the growth conditions of plants, typically by controlling factors like light, temperature, and carbon dioxide levels, to promote rapid growth and shortening the breeding cycle. This approach has significant implications for crop improvement, including:

(a) Faster Variety Development **(b)** Increased Genetic Diversity **(c)** Crop Adaptation to Climate Change **(d)** Enhanced Yield and Quality **(e)** Reduction in Resource Requirements **(f)** Rapid Response to Emerging Challenges **(g)** Improved Genetic Mapping and Understanding **(h)** Commercial Benefits

The speed breeding technology along with these artificial conditions reduces the crop generation time much less than normal glass house conditions the crop with these certain type of modifications can produces better results in that special glass house conditions. The crop matures within half time of crop grown in normal glass house conditions. Speed breeding was first initiated by US NASA targeting to raise wheat in space using extended photoperiods or constant light and precise temperature in order to overdrive photosynthesis and hasten plant growth. Dr Lee Hickey and his co-workers were the first to adopt NASA Plan for the production of wheat and peanut at the University of Queensland, John Innes Centre and the University of Sydney in Australia.

Methods of Speed Breeding

(1) Speed breeding I: Controlled environment chamber conditions : 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, In wheat the intensity is 360-380 µ mol m^{-2} s^{-1} during vegetative stages and 490-500 µ mol m^{-2} s^{-1}at adult stage.

(2) Speed breeding II: Glasshouse conditions: 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: Photoperiod: 12 hrs-12 hrs (Light-Dark) for four weeks then increased to 18 hrs- 6 hrs**, 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}.

Role of Speed Breeding In Enhancement of Crop Plants

(1) Integrated phenotyping with speed breeding as a tool for improving yield **(2)** Gene editing in combination with speed breeding for crop improvement **(3)** Speed breeding to accelerate domestication **(4)** Multiple disease resistance by speed breeding **(5)** Speed breeding with SNP

Marker-Assisted Selection reducing salt tolerance **(6)** Speed breeding as a tool in other breeding methods. Conventional breeding technology along with speed breeding technology helps to maintain good relationship with nature and improves the speed of current conventional breeding technology in general in traditional breeding method of plant breeding we can yield of 1 or 2 maximum but by using speed breeding technology we can boost up the pace of traditional breeding methods for to completing 6 generations of crop within year and jump in to next crop this advance tool rapidly drives and improves and save time by developing a variety with pace along with growing population around the globe it also helps to maintain the stability of crops and increase the productivity, food security rapidly.

Combining speed breeding technology with other state-art-technologies

(a) Integration with transgenic approach **(b)** Integration with double haploid programme **(c)** Integration with high density plant production systems **(d)** Speed breeding and marker assisted selection **(e)** Speed breeding and rapid development of RILs. **(f)** Speed breeding and Association mapping **(g)** Speed breeding and genomic selection **(h)** The speed breeding is ideally suited to a backcrossing breeding strategy.

Challenges of Speed Breeding

1. Access to suitable facilities **2.** Staff trained in the protocol **3.** Adopting major changes to breeding programme design and operations **4.** The need for long-term funding **5.** A lack of trained plant breeders and breeding technician**s 6.** Inadequate infrastructure **7.** Unreliable water and electricity supplies for sustainable operations.

Applications of Speed Breeding

1. Accelerating the crop improvement programmes by achieving upto 6 generations per year in photo insensitive crops and 2-3 generations in case of photo sensitive crops **2.** Speeding up the process of genomic selection **3.** An ideal method for generating large breeding populations. **4.** For boosting transgenic and CRISPR pipelines **5.** It can be extended to study physiological traits of importance in crop plant.

Achievements

(a) This technique is responsible for the development of "DS Faraday" wheat variety, which is a high protein, milling wheat with tolerance to pre-harvest sprouting**.**

(b) 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**.**

(c) YNU31-2-4 a Salt tolerant rice variety was developed with the help of speed breeding. 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**.**

Advantage of Speed Breeding

1. Multiple generations in one year **2.** Fast way to obtain fixed homozygous lines through Single Seed Descent method **3.** Phenotypic selection in early segregating generations 4. Rapid introgression genes into elite lines using Marker Assisted Selection **5.** Allows study of plant-pathogen interaction, flowering time etc. **6.** Multi- environmental trail across years **7.** Integrated with genomics selection, genome editing etc. **8.** High – throughput phenotypic screens for multiple traits **9.** Exploit gene bank accessions and mutant collection for rapid gene discovery

Limitation of Speed Breeding

1.Extended photoperiods may cause injury in some crops **2.** Unlikely to be successful in short-day crops **3.** Disease outbreak using controlled environmental conditions **4.** Plant losses in Single Seed Descent during greenhouse condition **5.** Increased monetary cost **6.**

Incorporation of relatively simple inherited traits **7.** The early harvest of immature seeds before completing normal ripening process interferes with the phenotyping of some seed traits. **8.** There is no universal protocol of speed breeding because of diverse response of plant species to photoperiodic conditions. **9.** Differential responses of various plant species when exposed to extended photoperiodic conditions. **10.** Initial investment of setup is high.

Future of Speed Breeding

Speed breeding likely to reduce generation time for other crop species, such as sunflower, pepper and radish which have been shown to respond well to extended photoperiod. The future of speed breeding holds promise and potential in several key areas: **(1)** Precision Breeding **(2)** High-Throughput Technologies **(3)** Data-Driven Approaches **(4)** Climate-Resilient Crops **(5)** Customized Crops **(6)** Biotechnology Integration **(7)** Expanded Crop Variety Availability **(8)** Resource Efficiency **(9)** Global Collaboration **(10)** Regulatory Considerations **(11)** Consumer Preferences **(12)** Crop Diversity Conservation. Overall, the future of speed breeding is closely tied to advancements in science and technology, and it will continue to be a key driver of innovation in agriculture. This method has the potential to address the evolving challenges facing the agricultural sector, from climate change and population growth to the need for sustainable, resource-efficient, and resilient crop production.

Conclusion

Speed breeding is a form of protocol that can be used to increase agricultural yield by altering the light duration, intensity and temperature-controlled zone, as well as the generation of disease-resistant varieties and lowering salt sensitivity in crops. The photosynthetic process is improved via speed breeding, resulting in faster crop development. In comparison to traditional breeding, this approach allows for the release of several generations of the same crop in a shorter amount of time. Speed breeding is a revolutionary technique for rapidly creating new long-day plant cultivars by lowering the generation time. To address food security challenges, more generation times each year are required. By lowering the amount of time, space, and resources invested in the selection and genetic progression of superior crop varieties, speed breeding can hasten the production of high-performing cultivars with market-preferred features.

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