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Speed Breeding in Agriculture

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Rapid climate change scenario and continuously burgeoning human population have increased global food demand by increasing food consumption to production ratio. Conventional breeding techniques are time consuming and are therefore unable to meet global food requirements. In this context, speed breeding has the potential to accelerate the rate of plant improvement as it mainly relies on early seed harvest, photoperiod, and temperature alterations in the controlled environment. Speed breeding techniques truncate plant lifecycle by promoting floral initiation, seed development and improve genetic gain per plant. Though speed breeding is extensively used in crop improvement programmes, certain limitations prevent its widespread application which is further improved by combining with other techniques. The efficiency of the speed breeding can be improved by combining with modern breeding techniques like gene editing, maker-assisted techniques, CRISPR/Cas9, single seed decent techniques, etc. which increase the genetic benefit of the plant and enable improved crop production under changing climate and ever-increasing human population.

Introduction

Radical changes in climate causes rising temperature, salinity and more frequent droughts and floods: consequently, farmers are facing huge yield losses. Burgeoning population on the other hand, increased food consumption to production ratio thereby increasing food security. To satisfy the increasing demand for food, annual yield enhancement of the crops must be doubled. Therefore, development of superior plant varieties with higher genetic potential and cutting-edge multidisciplinary research and implication of off-the-shell technology at the farm level is the need of the hour. Conventional breeding techniques involve lengthy breeding cycle (usually 5-10 years) from line development to its release as a plant variety, therefore, are inadequate for increasing plant genetic potential to develop new plant varieties and is therefore, unable to meet the requirements of the rapidly growing population. Thus, breeding techniques can be improved by improving genetic gain per unit time *i.e.*, by triggering the breeding cycle time. Speed breeding serve as a potential tool used to expedite breeding outcomes and accelerate the breeding outcomes. Speed breeding techniques involve growing of plants under controlled environmental conditions with manipulation of photoperiod hours, day/night temperature to accelerate embryo development and to promote early flowering and seed maturity and hence truncate plant lifecycle (Cazzola *et al.*, 2020).

The concept of speed breeding came into existence in 1980 when some researchers from NASA collaborated with Utah State University and worked on the growth of the plant under artificial constant light in space stations and developed dwarf wheat line "USU-Apogee" (Bugbee *et al.*, 1997). Inspired by their work, Queensland University, Australia coined the term Speed Breeding in 2003. The approach was initially described for wheat and peanut only but in recent time, speed breeding can also be implemented in barley, pea, chickpea, and canola.

The development of novel plant varieties cannot be accomplished by plant breeding using conventional methods. Different molecular techniques have been employed to identify the best hybrid lines in plant breeding to get around this challenge. The artificial selection and breeding of an attribute by the plant breeder is necessary to improve the plant phenotype for a certain desirable trait. Therefore, breeders favour using crops with shorter reproductive cycles because they enable the production of multiple generations in a single year and increase the production of the desired phenotypes through artificial selection compared to crops that only reproduce annually or perennial plants that only reproduce infrequently. Many researchers have focused on manipulating growth environment of the plant such as day/night temperature, photoperiod, and light intensity etc. Core manipulations during speed breeding that hastens embryo development include:

- **By altering photoperiod regime:** The duration of daily plant exposure to light and dark regimes which promote growth, development and specially flowering phase in the plant is referred to as photoperiod and directly affect the growth of the plant by influencing gaseous exchange parameters such as net photosynthetic rate, assimilation rate, stomatal conductance of leaves and most importantly trigger the floral initiation and maturity of the plant. Different crops have different requirement for the light to dark hours. Artificial long or short days can be created by manipulating natural photoperiods with the help of LED (Light Emitting Diodes) lights or artificial light emitting sources that emit photosynthetically active radiations (PAR) within the range of 400-700 nm (Ghosh *et al.*, 2018).

Adjusting the photoperiod is financially viable option while employing low energy LEDs which can be charged by solar panels in nations with erratic electricity supplies and a practical and ecological solution.

- **By manipulating temperature and humidity regimes:** An optimal temperature regime (maximum and minimum temperature) should be applied depending upon the environment and crop type. While a higher temperature kept during photoperiod hours, a lower temperature during the dark period might help the plant to cope in the stressful environment.

In speed breeding systems, temperature management mechanisms should be carefully considered to affect the rate of plant development. The temperature is generally kept at 18^0C during the night and 21^0C during the day and depending upon the type of crop plant under cultivation. By raising the temperature, several generations can be produced in a plant breeding programme in a noticeably short period of time and generally late spring temperatures is maintained. Similarly, for best plant growth and faster breeding, a humidity range of 60-70% is advised. A lower humidity level is favored for the crops that are mainly adapted to drier areas (Ghosh *et al.*, 2018).

- **Altering CO_2 levels:** For some plants, higher levels of CO_2 may accelerate plant development and the shift from vegetative to reproductive stages. However, the response of altered CO_2 level show high genotypic variation for e.g., days to flowering in soy, rice, and cowpea were shortened by 2, 7, and 12 days, respectively by increasing CO_2 levels of 400/700, 350/700, and 350/650/100 ppm. Modification of CO_2 levels during speed breeding require right equipment such as regulators, growth chambers, and CO_2 chambers, as well as operational expenditures. Additionally, when handling and utilizing CO_2 cylinders and valves, it is important to follow safety and health regulations.

In addition to these, different hormones (Indole-3-acetic acid, zeatin, and 6-benzylaminopurine) and plant nutrition have also been utilized to hasten growth, promoting flower and seed set and in vitro germination of immature seeds in speed breeding (Wanga *et al.*, 2021).

✓ Combining modern plant breeding techniques with speed breeding

As the traditional method of plant breeding has already demonstrated its ability to produce excellent high yielding varieties, one of the factors preventing further advancement in the crop quality is the genetic quality of crops, which is degrading because of continued selection and extensive domestication. Speed breeding and genomic selection is employed to increase the genetic benefit. Researchers have offered proof that genomic selection and speed breeding can increase the genetic value in different crops such as genetic gain in spring wheat is improved by combining genomic selection techniques with speed breeding. So, to satisfy the demand of plant-based product and increasing food demands different techniques to enhance cycle turnover that truncate plant life cycle are (Samantara *et al.*, 2022):

1) Accelerated Single Seed Decent (aSSD) - involves development of homozygous progeny
2) Rapid Generation Cycling (RGC) - involve increased breeding cycles per year by exploiting DNA marker technology
3) Fast Generation Cycling (FGC) – enhance cycle turnover per year with the help of stressed conditions which shortens the life cycle of plant and by invitro embryo culture technology
4) Rapid Generation Turnover (RGT) – increase in generation per year with the help of photoperiod alterations and harvesting of immature seeds
5) Plant domestication – this process involves early hybridization followed by selective breeding techniques

Challenges and limitations to speed breeding

Speed breeding is a useful strategy for accelerating traditional breeding programmes and development of high yielding and tolerant varieties. However, the technology needs knowledge, efficient plant phenomics facilities, complementary infrastructure, and adequate funding and ongoing research development. The availability of appropriate facilities, people trained in the protocol, adoption of the significant modification to breeding programme design and management, and the requirement for long term finance are the most prevalent obstacles to the use of speed breeding.

Secondly, species may display genotypic variations in response to extreme growth conditions once speed breeding is established. Limited speed production is frequently a result of intense growing circumstances, which can affect later field assessments. Importantly, to maximize speed, plants are cultivated beyond the limit of their physiological capacity. As a result, quick cycle turnover conditions frequently compromise a plant's ability to defend itself and, without careful management, can result in catastrophic losses of precious breeding stock. The management of pest and diseases under such harsh environment and the requirement of the tracking individual when generating mapping populations for gene-discovery purposes are additional significant obstacles when growing plants in speed breeding environment.

Conclusion

In agricultural sector, conventional breeding techniques such as cross breeding, mutation breeding, etc. are somewhat laborious and time consuming and are unable to meet global food demand. Speed breeding can be used to increase crop productivity by altering the length, intensity, and temperature of the controlled environment, producing disease resistant varieties, and reducing salt sensitivity in some specific crops. Furthermore, combining modern breeding techniques like plant tissue culture techniques, plant domestication, marker assisted techniques, CRISPR/Cas9 techniques provide new ways for genetic diversity and boost genetic gain. Thus, the speed breeding protocols can be gradually enhanced and integrated with contemporary breeding methods to achieve their promise for the identification and transfer of genes essential for crop resilience and adaptation. Hence, speed breeding can be helpful in meeting food and fodder demands of the continuously growing human and livestock population and will beat hunger and malnutrition.

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