Speed Breeding in Vegetable Crops

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In conventional plant breeding, the parents that will make the best offspring are crossed. Following that, parents are chosen and screened for the desired attributes. This process takes a lot of time. The selected materials for generation advancement are responsible for the long time. Therefore, the development of a new variety takes 8–10 years. Every plant in this place has undergone this gradual process of improvement. Accelerating research and speeding up cultivar development are both necessary to maximize the stability and production of crops to cope with changing climatic circumstances. Every crop requires some time to modify its breeding and generational plans, thus it is necessary to develop and make use of technology that can speed up the growth of plants. Speed breeding can be used to solve this fundamental issue.

Speed breeding, a cutting-edge technology created by Lee Hickey and colleagues to overcome all these disadvantages, shortens the breeding cycle and speeds up crop improvement through frequent generation cycling. Speed breeding was used to create the first spring wheat variety, "DS Faraday," which was introduced in 2017 in Australia. It is a method of plant breeding intended to hasten the creation of new crop types. It entails modifying the growing environment of plants to encourage quick development and shorten the time needed to finish a reproductive cycle. Speed breeding's main objective is to create several generations of plants in a year, which enables the creation of new crop types and the quicker selection of desired features. The first crops were agronomical ones in which speed breeding is applied. However, it is now also feasible for horticulture crops. Vegetable crops are just one of the many crop plants that can benefit from speed breeding. This method has been used to generate 6 generations and 4 generations annually. *Pisum sativum* (pea), *Hordeum vulgare* (barley), *Triticum aestivum* (spring bread wheat), *Triticum durum* (durum wheat), *Cicer arietinum* (chickpea), and *Brassica napus* (canola) were the first plants to adopt this technique. Research is being done on carrot, tomato, and cauliflower. Crops produced using a speed breeding technology go through a typical developing phase. It has a high seed germination rate and is easily or quickly crossed.

Speed breeding setup

The following are the primary environmental factors for setting up fast breeding technique:

1. Temperature
2. Light
3. Photoperiodic regime
4. Humidity

Comparison among different approaches

- **Exerting physiological stress** – It entails limiting plant growth, limiting nutrients or water, and thinning the plant canopy, which will cause early flowering and seed germination. Example: Pea instance demonstrated.
- **Embryo rescue** – It involves inducing embryos to germinate on culture media in vitro, either with or without the use of PGRs. Example: Ochatt *et al.* (2002) and Mobini and Warkentin (2016) reported that without PGR it required 6.9 and 5.3 generation each year, respectively, however Mobini *et al.* (2015) sprayed PGR to stimulate early flowering and embryo rescue in faba bean and obtained up to 6.5 generation per year. Furthermore, fast breeding without embryo rescue can provide 6 generations of pea every year.
- **Carbon concentration (%)** – Increasing the CO_2 content can also encourage plant growth.
- **Double haploids –** Extensively and frequently used in the breeding of numerous crop species, requiring only two generations instead of six or more to produce homozygous lines. However, it has some drawbacks, including expensive techniques, a need

for specialized knowledge, and a variable success rate that might be genotype-specific. Notably, by accelerating the procedures of crossing, plant regeneration, and seed multiplication, speed breeding has the potential to expedite the development of DH lines even more.

Speed breeding in vegetable crops

Extending the photoperiod has shortened generation intervals in vegetables, such as pepper, tomato, and amaranth, which respond effectively to increased daylight. In tomato, germination of immature seeds from different maturity levels provided new possibilities to achieve five generations instead of the conventionally grown three (Bhattaraj *et al.*, 2009). Similarly, in pepper and tomato, in vitro germination of immature embryos enabled authors to obtain one more generation compared to conventional breeding practice (Manzur *et al.*, 2014). In grain amaranth, photoperiod manipulation was reported to be helpful in flowering synchronization in different germplasm lines, which, in combination with DNA marker technology, led to the development and identification of true hybrids, thus, accelerating the breeding program (Shetter *et al.*, 2016). Other methodologies that can improve generation turnover in vegetables by promoting early flowering involve higher expression of flowering genes such as the CaFT-LIKE gene in pepper (Borovsky *et al.*, 2020). Similarly, in tomato, introgression of the gene CAB-13 can impart tolerance to continuous light, thus, adapting plants to extended photoperiods (Velez-Ramirez *et al.*, 2014).

Applications

1. Rapid generation of Breeding population.
2. Development of mapping populations. Example – RILs have been developed in case of pea.
3. Mutation studies
4. Gene introgression using MAS
5. Accelerating the rate of crop improvement.
6. High throughput genotyping
7. Speeding up the conventional approaches.

Limitations of Speed Breeding

- Under prolonged photoperiods, the time to flowering is frequently accelerated in long day plants. Conversely, short day plants need photoperiods that are below the minimum necessary for flowering, which may not be compatible with rapid breeding circumstances.
- Limited phenotyping of some seed properties is the outcome of the further reduction in generation time. Phenotyping grain dormancy is an example.
- Plant injuries may be troubleshooting like chlorosis.
- Initial set-up cost is very high.
- Requires skilled person.

Conclusion

Researchers studying plants can now move their attention from model plants to crop plants thanks to recent improvements in genomic techniques and resources and the falling cost of sequencing. Despite these developments, a significant entry barrier still exists due to the lengthy production times of many crop species. Since speed breeding is a very versatile method, it uses prolonged photoperiods to hasten plant growth and the germination of immature seed, shortening the generation period. It is clear that speed breeding in conjunction with these techniques and resources will enable more plant scientists to conduct research on crop plants directly, further expediting crop improvement research. Additionally, a rapid generation advance may aid in the development of homozygosity after crossing, which will ease genetic gain for important traits and enable breeding operations to produce superior cultivars more quickly.

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