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Speed Breeding in Vegetable Crops

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Speed breeding is a technique which involves extending photoperiod and controlled growing conditions such as temperature, soil media, spacing etc. in glasshouses, enabling rapid generation advancement by shortening the breeding cycle. It is a NASA-developed approach that significantly reduces generation time and accelerates global plant breeding and research programmes. It is a strategy that shortens the breeding cycle and accelerates crop research by rapidly advancing generations. Speed breeding can be performed in a variety of methods, including shortening generation time, boosting plant light exposure, combining early seed harvest, and cycling swiftly from seed to seed.

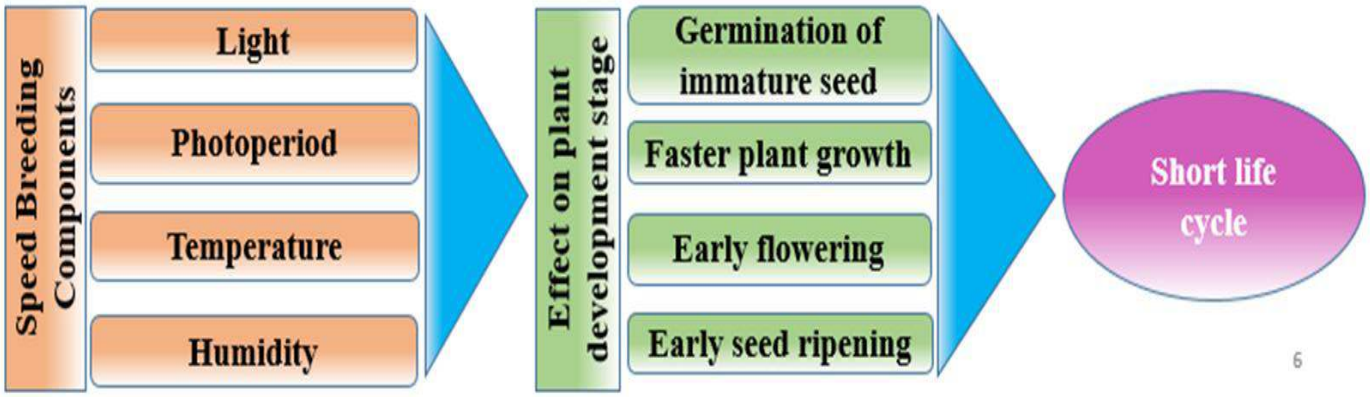

Figure 1: Speed Breeding Components and Their Effect During Plant Development

Need

- Traditional breeding procedures are successful but time-consuming, taking several years to generate desired crop kinds.
- Speed breeding is a transformative methodology that uses controlled conditions, genetic breakthroughs, and high-throughput phenotyping tools to speed up the breeding process.
- Researchers can speed up plant growth and development, resulting in more plant generations in less time.
- This strategy allows for speedier selection of desirable features and genetic improvement.
- Speed breeding has garnered widespread recognition as a potential crop enhancement approach.

Speed Breeding Setup

Light	PAR region (400-700nm)- focus on the blue, red and far-red ranges- LEDs or SVLs
Photoperiod	22h with 2h of darkness
Temperature	❖ High temperature during the photoperiod ❖ Low temperature during the dark period can aid in stress recovery
Humidity	60-70% is ideal.

Key Components of The Speed Breeding Process

Speed breeding includes optimising growth conditions in controlled circumstances to expedite plant development. The stages below highlight the major components of the speed breeding process:

1. Plant Material Selection: Select the plant species or crop that you want to develop through speed breeding.
2. Controlled Environment Setup: Set up a controlled environment, such a growth chamber or greenhouse, control lighting, temperature, humidity, and nutrition levels for maximum plant development.
3. Lighting Manipulation: Use artificial lighting to extend photoperiod and increase photosynthetic activity. eg: high-intensity light-emitting diodes (LEDs
4. Temperature and Humidity Control: Maintain ideal temperature and humidity levels to promote plant growth.
5. Seed Preparation and Sowing: Prepare the seeds for sowing, confirming their quality and viability. Sow the seeds in the proper growth medium or trays.
6.
7. Crop Management: Monitor and maintain a steady growing environment to promote plant growth and development.
8. Accelerated Growth Cycle: Reduce the duration of the vegetative and reproductive periods by adjusting illumination, temperature, and nutrition availability. This enables for numerous generations of plants in a single year.
9. High-Throughput Phenotyping: Use imaging technology, sensors, and data processing tools to measure and assess plant height, leaf area, blooming time, yield, disease resistance, and nutritional value.
10. Trait Selection and Breeding Strategies: Choose the best-performing plants from each generation to breed for desired qualities and transfer desirable features into new varieties with suitable breeding procedure.
11. Data Analysis and Genetic Tools: Assess genetic diversity and find markers associated with desirable qualities to enable more targeted and effective breeding.
12. Evaluation and Release of New Varieties: Evaluate selected plant lines or cultivars for performance, stability, and adaptation under field circumstances. Collaborate with farmers, researchers, and regulatory organisations to successfully introduce improved varieties into the agricultural sector.

Table 1: Speed breeding protocols optimized for shortening the breeding cycle of Vegetable crops

Crop	Type of plant	Growth parameters under RGA OR SB				Generation time (days)	
		Photoperiod	Temperature	Light and other parameters	Humidity (%)	Field conditions	Speed breeding
Pea	LD	22 h	22˚C/17˚C light/dark	360-500 µmol $m^{-2}s^{-1}$	70	84	51
	LD	16 h	In vivo 24 ˚C /20 ˚C In vitro 24 ˚C /22 ˚C	In vitro plus in vivo system and embryo axis explants	70	143	67
Tomato	DN	-	-	Introgressed a continuous light-tolerance gene CAB13, which increased productivity under continuous light	-	80	-
Potato	LD or DN	-	-	Speed breeding protocol is under development at James Hutton Institute	-	140	-
Amaranthus	Quantitative SD	LD- 16 h in initial stage SD- 8 H later stage	LD- 35 ˚C/30 ˚C day/night SD- 30 ˚C/25 ˚C day/night	LD-150 mmol SD- 150 mmol	-	180	-
Faba bean	DN or LD	18 h	22˚C/18˚C light/dark	178 µmol $m^{-2}s^{-1}$	-	365 field, 120 greenhouse	54

Note: SD- Short day plant LD- Long day plant DN- Day neutral plant

Advances in The Optimization of Conditions for Speed Breeding

Crop-specific protocols are designed and speed-breeding components optimised to reduce generation time. Three ways were used for fast breeding:

- controlled environment chambers
- greenhouse settings
- benchtop growth cabinets.
- Benchtop growth cabinet to undertake tests before scaling up to larger glasshouses.
- Currently, speed breeding is successful for long-day and day-neutral plants that do not require vernalization (Table 1).

Acceleration of Plant Growth

Speed breeding combines several of these strategies to avoid deficits and stress while providing an adequate

amount of water and nutrients throughout growth. eg: Using a 22-hour photoperiod and controlled temperature lowered production times for pea plants compared to those cultivated in a field or glasshouse without extra light (Table 1).

Induction of Early Flowering

During photoperiod, plants maintain a greater temperature, whereas during the dark period, a decrease in temperature might speed up blooming. eg: In amaranth (*Amaranthus spp*. L.), prolonged light was used before and after a shorter photoperiod to stimulate flowering and accelerate initial vegetative growth.

Induction of early seed ripening

Higher temperatures or water shortages can speed seed ripening, allowing for harvesting one week after the seed has set in the plant. Optimal values may vary according on species, cultivar, and planting conditions.

Abiotic Stresses: Where Speed Breeding Can Be Implemented

Drought

The speed-breeding platform aids in the identification of a representative drought stress state, resulting in a uniform screening environment. The evaluation of genotypes in controlled conditions results in the selection of potential individual plants.

Salinity

To develop salt-tolerant cultivars, effort is being made through approaches like convention breeding, transgenics, and marker-assisted breeding. But speed breeding can further hasten these

processes. Speed breeding offers scope to improve salinity tolerance and develop better cultivars in vegetables at a faster rate.

Temperature

Extreme temperatures (high and low) had a substantial detrimental impact on agricultural productivity worldwide. Crop improvement to three primary abiotic stresses (drought, salt, and temperature) can be accelerated by incorporating speed breeding techniques.

Conclusion

Overall, speed breeding is an innovative technology that has the potential to significantly accelerate crop development efforts. Accelerating the breeding process can lead to crop varieties with better agronomic features, higher production potential, resistance to pests and diseases, and adaptability to local climates. Speed breeding can significantly improve global food security and agricultural sustainability with continued developments and collaboration.

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