Fast-Tracking Agricultural Innovation with Speed Breeding

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Introduction

The story of speed breeding began with the inspiration drawn from NASA's controlled-environment agriculture experiments aimed at growing crops in space. This concept was later adapted to terrestrial agriculture, where researchers sought ways to accelerate crop improvement. The breakthrough came from the work of Dr. Lee Hickey and his team at the University of Queensland, who developed a method using extended photoperiods—up to 22 hours of light per day—under LED lights in controlled environments. This approach drastically reduced the life cycle of crops like wheat and barley, cutting generation times from six months to just six weeks. Initially designed for small grains, the technique quickly expanded to other crops like rice, chickpea, and lentils. By integrating modern breeding tools such as genomic selection and marker-assisted selection, speed breeding became a game-changer for developing climate-resilient, high-yielding crop varieties. Today, it plays a vital role in addressing global food security challenges, allowing researchers to fast-track the development of crops that can withstand the pressures of a rapidly changing environment.

Speed breeding: a rapid generation advancement method

Speed breeding is an advanced agricultural technique that accelerates the growth and reproduction of plants by optimizing environmental conditions, such as extended photoperiods (up to 22 hours of light per day), temperature control, and precise nutrient management. This approach enables plants to complete their life cycle—germination, flowering, and seed production—in a much shorter time compared to traditional growing methods. Speed breeding employs tailored protocols that leverage ideal light intensity, quality, photoperiod, and temperature conditions to expedite flowering in crop species. Additionally, it incorporates the practice of harvesting seeds at immature stages to further reduce generation times. For various plant species, specific methodologies are designed to trigger flowering in response to environmental signals.

Speed Breeding Protocols and Facilities

Since the emergence of speed breeding, protocols have evolved to suit different species. Watson et al. (2018) employed sophisticated growth chambers that utilized extended light exposure (22 hours), controlled temperatures (22°C daytime, 17°C nighttime), and high humidity (over 70%) to speed up flowering. They used LEDs and far-red lamps to simulate natural light cycles and suggested high-pressure sodium lamps in glasshouses for simpler setups.

Cost-Effective Solutions

ICRISAT researchers proposed low-cost greenhouses with natural light and evaporative cooling for pigeon pea. Watson et al. 2018 also recommended inexpensive, insulated rooms equipped with LED light boxes and domestic air conditioners, with a set photoperiod that increases from 12 to 18 hours.

Alternative Approaches for Orphan Crops

Chiurugwi et al. (2019) introduced low budget "speed breeding capsules" made from waste containers, offering temperature, light, and irrigation control. Additionally, regional speed breeding centres could serve as hubs for training and advancing orphan crop breeding.

Optimizing Speed Breeding for Long-Day and Short-Day Crops

Long-Day Crops

Long-day crops, including wheat, barley, chickpea, mustard, and pea, require 14–16 hours of light to flower. By extending the photoperiod beyond the critical threshold (such as 22 hours), the conversion of phytochrome (Pfr) to its inactive form (Pr) is prevented, promoting early flowering. This method has been successfully used in spring wheat, winter wheat, durum wheat, barley, chickpea, pea, and canola, allowing up to six generations per year. By optimizing light conditions, the generation time for these crops can be greatly reduced.

Short-Day Crops

Short-day crops, such as maize, rice, pigeon pea, soybean, and groundnut, need shorter photoperiods (8–10 hours) for flowering. These crops are sensitive to phytochrome accumulation and require a specific duration of darkness to convert Pfr to Pr. Extended light periods do not induce early flowering in short-day crops. However, selecting photoperiod-insensitive or phytochrome-deficient varieties and using far-red light can advance flowering in certain crops like soybean and groundnut.

Strengths of speed breeding

Faster Generation Advancement: Enables more breeding cycles per year, accelerating the development of new crop varieties.

Enhanced Phenotyping: Supports adult plant phenotyping for traits like disease resistance, pre-harvest sprouting, height, and root angle.

Accelerated Gene Discovery: Combines high-throughput phenotyping with speed breeding to speed up gene discovery and introgression into elite cultivars.

Synchronous Flowering: Facilitates flowering at different stages by shifting plants between long-day and short-day conditions.

Crop Domestication: Accelerates re-domestication and the development of synthetic polyploids to increase genetic diversity.

Reduced Breeding Time: When integrated with mutation breeding (SpeedMUT) or genome editing (Express Edit), the breeding process is shortened from 8–10 years to 5–6 years.

Accelerating DUS testing: Speed-DUS testing accelerates DUS evaluations, reducing labor and time, improving the efficiency of varietal registration without violating standards.

Limitations of speed breeding

Limited Crop Applicability: Not all crops, especially short-day crops, are suitable for speed breeding protocols.

High Infrastructure Costs: Speed breeding units and advanced systems are expensive and not accessible to all breeders.

Incomplete DUS Trait Evaluation: Some DUS traits cannot be fully evaluated in speed breeding conditions.

Genetic Bottlenecks: Rapid generation advancement may reduce genetic diversity and increase the risk of inbreeding.

Resource Limitations: Lack of proper facilities in some regions limits the widespread adoption of speed breeding.

References

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