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Speed Breeding: A Best Method for Rapid Generation Advancement (RGA) in New Era

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Around 150 years ago, botanists first showed that plants can grow under artificial light using carbon arc lamps. Arthur and colleagues reported that flowering was faster under constant light for the majority of almost 100 plant species, including vegetables, grains, weed species, herbs and garden ornamentals. The concept of speed breeding was originally inspired by the US National Aeronautics and Space Administration (NASA) that promises to develop new crop varieties faster, offering hope for food security in the continent. It was started from University of Queensland, John Innes Centre and University of Sydney in Australia by Dr. Lee Hickey and co- workers in wheat and peanut.

What is Speed Breeding?

Speed Breeding is a technique which involves extending photoperiod and controlled growing conditions such as temperature, light, RH, soil media, spacing etc. in glasshouses, enabling rapid generation advancement by shortening the breeding cycles of crops plants.

Introduction

With an ever-increasing human population, predicted to be 10 billion people by 2050, studies estimate that we need to double the rate of genetic gain in our crop improvement programs globally to meet this demand, with the current improvement rate of several important crops it is inadequate to meet the future demand. This slow improvement rate is attributed partly to the long generation times of crop plants. Here a method called 'speed breeding', which greatly shortens generation time and accelerates breeding and research programs. Speed breeding can be used to achieve up to 6 generations per year for spring wheat (*Triticum aestivum*), durum wheat (*T. durum*), barley (*Hordeum vulgare*), chickpea (*Cicer arietinum*), and pea (*Pisum sativum*) and 4 generations for canola (*Brassica napus*), instead of 2-3 under normal glasshouse conditions. To improve the productivity and stability of crops, there is pressure to fast-track research andincrease the rate of variety development. The generation time of most plant species represents a bottleneck in applied research programs and breeding, creating the need for technologies that accelerate plant development and generation turnover. Speed breeding' (SB) shortens the breeding cycle and accelerates crop research through rapid generation advancement. SB can be carried out in numerous ways, one of which involves extending the duration of plants' daily exposure to light, combined with early seed harvest, to cycle quickly from seed to seed, thereby reducing the generation times for some long-day (LD) or day-neutral crops.

We need to develop more robust and productive crops faster than traditional approaches allow. The challenges we are facing call for an integration of technologies to enable us todevelop crops faster than ever before. Speed breeding is all about growing plants quickly, efficiently and as cheaply as possible.

Speed Breeding Setup

- **Light:** PAR region (400-700nm), ambient lighting with LED
- **Photoperiod:** 22 hours with 2 hours of darkness
- **Temperature:** 22˚ C/ 17 ˚C for 22 hours' light and 2 hours' dark
- **Humidity:** Ideally 60-70%

Methods

There are three methods

- Speed breeding I -Controlled environment chamber speed breeding.
- Speed breeding II -Glasshouse speed breeding conditions
- Speed breeding III -Homemade growth room design for low cost speed breeding

Why it is Needed?

- The growing human population and a changing environment have raised significant concern for global food security, with the current improvement rate of several important crops are inadequate to meet future demand. This slow improvement rate is attributed partly to the long generation times of crop plants.
- In a temperature controlled glasshouse fitted with high pressure sodium lamps to extend the photoperiod to a day length of 22 hours.
- Time to anthesis was significantly reduced for all crop species relative to the 12-hour day neutral photoperiod conditions, where the average reduction was, depending on genotype, 20 -24 days (wheat), 56-72 days (Barley), 63-82 days (Canola) and 31-35 days (chickpea).
- Wheat plants produced significantly more spikes than those in day neutral conditions and grain number was unaffected by the rapid development in both wheat and barley.

As we know there are many problems of conventional breeding *viz*.,

- Only one generation raised per year
- More time required to develop homozygous line
- It poses some environmental risks and low yield
- Management of input such as irrigation, fertilizer and pesticide difficult
- No control over environment

To overcome these problems speed breeding is a technique which involves extending photoperiod and controlled growing conditions such as temperature, light, RH, soil media, spacing etc. in glasshouses, enabling rapid generation advancement by shortening the breeding cycles of crops plants.

Advantages of Speed Breeding

- Recipe to meet the future demand and
- Solution to increase productivity
- Coupled with all breeding methods
- Used for research purpose
- Commercial scale utilization
- Optimum utilization of Input resource
- Control of Environmental effect

Implications in Crop Improvement

- Speed breeding is likely to reduce generation time for other crop species, such as sunflower (*Helianthus annuus*), pepper (*Capsicum annuum*), and radish (*Raphanus sativus*), which have been shown to respond well to extended photoperiod. Speed breeding methods have already been successfully applied to accelerate breeding objectives for amaranth (*Amaranthus* spp.) and peanut (*Arachis hypogaea*). For species that require short days to trigger the reproductive phase, such as rice (*Oryza sativa*) and maize (*Zea mays*), the speed breeding technique could be used to promote rapid vegetative growth prior to reducing the photoperiod.

- Six generations per year for spring wheat (*Triticum aestivum*), durum wheat (*T. durum*), barley (*Hordeum vulgare*), chickpea (*Cicer arietinum*) and pea (*Pisum sativum*).
- Commercial peanut breeding program.
- Multiple disease resistance in barley (*Hordeum vulgare*).
- Multiple quantitative traits in durum wheat (*T. durum*)
- Physiological traits *viz*. awn morphology, flowering time, plant height etc.
- Mutant transformation i.e. waxy less mutant in barley

Challenges & Limitations

- Different responses of different plant species when exposed to extended photoperiod
- Early harvest of immature seed interferes with phenotyping of some seed traits
- Initial investment is high
- No universal protocol due to diverse response of plant species to photoperiod

Integration with SSD

By integrating speed breeding and SSD techniques can effectively accelerate the generation of inbred lines for research and plant breeding programs. Single seed descent (SSD) is commonly used in breeding programs and research to facilitate development of homozygous lines following a cross. This process only requires one seed per plant to advance each generation. To investigate the ability of speed breeding to accelerate SSD, where plants are typically grown at high density, wheat and barley genotypes were grown in 100-cell trays under both speed breeding and 12-hour day-neutral photoperiod conditions in the glasshouse.

Conclusion

Speed breeding could be used to rapidly generate fixed populations through SSD, which in some species may be cheaper than generating double haploids, for subsequent field evaluation and selection, thus facilitating genetic gain and production of improved cultivars. Time to anthesis was more uniform within each species under speed breeding conditions and important feature, as synchronous flowering across genotypes is desirable for crossing. These results highlight the opportunity to apply speed breeding across several important crop species without jeopardizing the production of subsequent generations

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