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Speed Breeding: A Powerful Tool to Accelerate Crop Research

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Abstract

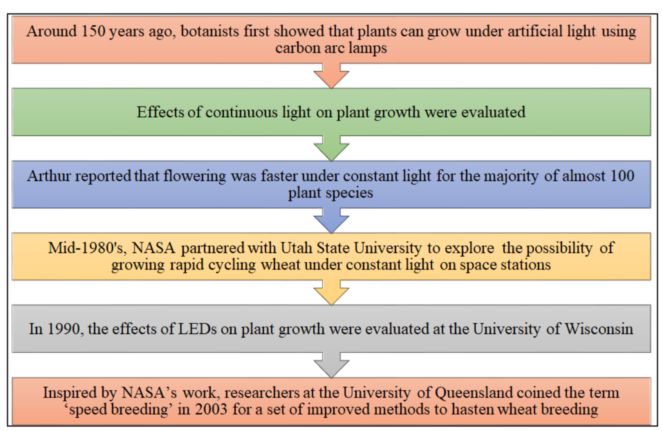
Speed Breeding is a novel and exciting way to breeding that was inspired by the US National Aeronautics and Space Administration (NASA) that promises to develop new crop types faster, giving hope to the continent's food security. The method entails growing plants in continuous light for 20-22 hours. Plants can photosynthesize over extended periods of time, resulting in faster growth. Under normal growth conditions, two generations of wheat plants can be developed per year, but with this approach, four to six generations can be grown per year. As a result, researchers are increasingly employing this technique in plant phenotyping and the pyramiding of several traits for the production of novel crop varieties. However, significant problems and constraints prevent its widespread implementation across a wide range of crops.

Introduction

Speed breeding is the technology which shortens the breeding cycle and accelerates crop research through rapid generation advancement. Speed breeding 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, thereby reducing the generation time.

This effort started back in the 1980's, NASA with Utah State University to explore the possibility of growing wheat under constant light on space stations. This joint effort resulted in the development of 'USU-Apogee', a dwarf wheat line bred for rapid cycling. It was a full dwarf variety and was selected to grow fast under a continuous 24-hour light. In long-day plants such as wheat, the extra light triggers the reproductive stage and so plants flower earlier and produce grain faster (Watson *et al.*, 2018). So far speed breeding has been reported inBread wheat, Durum wheat, Barley, Chickpea, Oat, Canola, Pea, Quinoa, Grass pea, Peanuts, Lentils and Potatoes.

Evolution of Speed Breeding



Advanced Plant Habitat (APH) is a fully automated plant growth facility that is used to conduct plant bioscience research on the International Space Station. The APH was installed at the international space station (ISS) in 2017, and the growth of dwarf wheat and Arabidopsis was marked its first harvest.

Figure 1: Advanced Plant Habitat

These NASA's experiments to grow wheat in space were the inspiration for University of Queensland scientists to develop the world's first 'speed breeding' procedures here on planet Earth. Scientists at the John Innes Centre, UK and the University of Queensland, Australia have improved this technique, adapting it to work in vast glasshouses and in the growth chambers. Dr. Lee Hicky, Brande Wuff, Amy Watson, and Sreya Ghosh were key scientists involved in the development of the speed breeding protocol.

Figure 2: Key scientists of speed breeding protocol development

Major 'Components' for Setting up Speed Breeding Conditions

Lights

Any light that produces a spectrum that reasonably covers the PAR region (400-700 nm), with particular focus on the blue, red and far-red ranges, is suitable to use for SB. This can be achieved through LEDs and other lighting sources (*e.g.*, halogen lamps), sodium vapor lamps. Photosynthetic photon flux density (PPFD) of ~ 450-500 µmol $m^{-2}s^{-1}$ at plant canopy height is recommended (Watson *et al.*, 2018).

Photoperiod

A photoperiod of 22 h with 2 h of darkness in a 24-h diurnal cycle is recommended.

Temperature

A higher temperature during the photoperiod, whereas a fall in temperature during the dark period. A temperature cycling regime of 22 °C/ 17 °C for 22 h of light and 2 h of dark, respectively.

Humidity

A reasonable range of 60-70%. For crops that are more adapted to drier conditions, a lower humidity level may be advisable.

Comparison between Glasshouse and Speed Breeding Condition

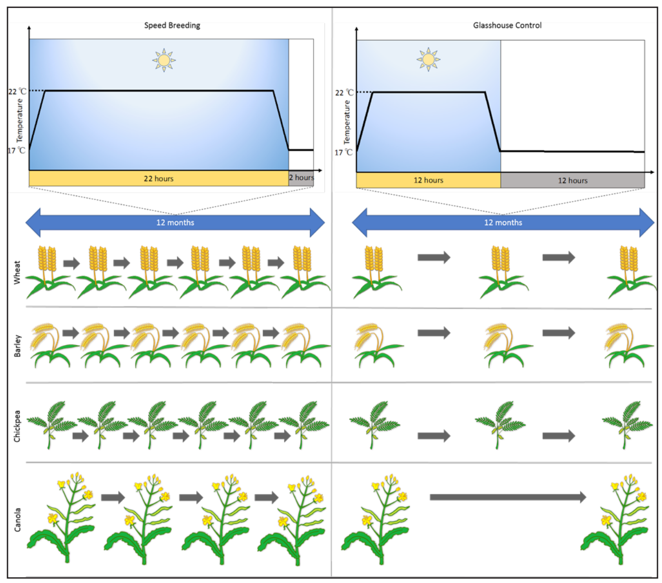


Figure 3: Compared to a glasshouse with a natural variable photoperiod (10-16 hours), where only 2-3 generations of wheat, barley, chickpea and canola can be achieved per year (right), speed breeding enables 4-6 generations of these crops to be grown in a year (left) (Ghosh *et al.*, 2018)

Role of Light on Plants

The light plays very pivotal role in the plants by effecting their photosynthetic process, flowering time and there is particular process in plants with respective to growth and developments of plants is called Photo-morphogenesis. The response of plants to light is mediated by different photoreceptors, which are comprised of a protein covalently bonded to a light absorbing pigment called a chromophore. Together, the two are called a chromoprotein. The particular spectrum of visible light called red/far-red and violet-blue regions trigger structural development in plants. Sensory photoreceptors absorb light in these particular regions of the visible light spectrum and light absorption by chlorophylls peaks in the blue and red regions of the spectrum. As light filters through the canopy and the blue and red wavelengths are absorbed, the spectrum shifts to the far-red end, shifting the plant community to those plants better adapted to respond to far-red light.

Advantages of Speed Breeding

• Under speed breeding crop cycle is reduced to half for example it can achieve 6 generations per year for wheat, barley, chickpea, pea and 4 generations for canola instead of 2-3 under normal glasshouse conditions (Ghosh *et al*., 2018).

• Unlike doubled haploid technology speed breeding is suitable for diverse germplasm and does not require specialized labs for in vitro culturing.

• Accelerate progress in plant research activities such as crossing, development of mapping populations and adult plant phenotyping for particular traits can be performed in the speed breeding system.

• Speed breeding as a platform can be combined with several other technological such as MAS, genomic selection, CRISPR gene editing *etc*. to get to the end result faster.

• Speed breeding can accelerate backcrossing and pyramiding of traits.

Limitations of Speed Breeding

• Short day plants require the photoperiod less than the critical day length to flower, so speed breeding is an odd one in case of short day plants.

• The SB procedures take place in an enclosed, artificial environment, which differs significantly from the field where eventual crop production may occur.

• The initial investment to build a glasshouse or purchase a growth chamber with appropriate supplementary lighting and temperature control capabilities is high.

• Ability to shorten generation time further through early harvest of immature seed can interfere with the phenotyping of some seed traits.

Future Prospects

To respond faster to the changing climate, evolving pathogens a breakthrough technology in genetics and plant breeding programme should be needed and speed breeding will definitely full fill that in future. Breeding programmes should be at par with the changing climate and breeding for climate-resilient crops is the immediate challenge which can be accomplished through new ideas like speed breeding. As it increases the breeding generation per year, more number of research will be carried out and documented in future.

Conclusion

Speed breeding is a very powerful tool to accelerate the crop research and breeding programmes. The study has clearly shown that generation time can be reduced substantially within a speed breeding/SSD system, and hence new varieties could be developed up to two years quicker compared to using conventional field based pedigree breeding strategies. The study has demonstrated that speed breeding technologies previously developed for wheat and barley can be successfully transferred to the cultivated peanut and other crops, offers breeders a new tool to develop improved cultivars more quickly. To meet the ongoing demand in food production and to feed a global population of 9-10 billion by 2050, speed breeding is considered as the most innovative way of approach, followed by shuttle breeding.

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