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Speed Breeding: A Powerful Innovative Tool in Agriculture

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Abstract

Speed breeding technology is a new innovation inspired by NASA's experiments to grow wheat in space, which involved using continuous light on wheat and triggered early plant reproduction and can enormously diminish the length of the breeding cycles of many crops. This innovation which have been developed by Australian scientists to accelerate the genetic gain and they confirmed that it is a powerful tool to accelerate crop research and breeding. It can boost the production of wheat crop by up to three times and enables six generations of the crop to be produced each year by using controlled temperature and extended photoperiod, thus accelerating development of inbred lines. They used supplemental lighting in a glasshouse environment that allowed rapid generation cycling through single seed descent and potential for adaptation to larger-scale crop improvement programs. There has been a lot of interest globally in this technique as it is one of many examples of the impact of space age research on the lives of the people on Earth. The adaptation of space farming and space age plant breeding technologies will be the inspiration for many other new innovations in agriculture and it will light the way for future crops in the forthcoming years here on planet Earth.

Keywords: *Speed breeding; Wheat; Innovative Agriculture Techniques; Plant sciences*

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The interest for higher yield is escalating because of a blasting human population, and the world needs to produce 60-80% more food by 2050 to sustain its nine billion people, however, yield development in numerous zones is stagnating due, to a limited extent, to an unpredictable climate change.

To give the fundamental yield progression, more efficient breeding schemes that increase the rate of genetic gain and create stable, drought tolerant, and disease tolerant cultivars are required. This could be accomplished through reconciliation of numerous, cutting-edge advances that encourage a speedier, more productive, breeding cycles.

NASA helped to challenge the breeding speed and efficiency of crops over a decade ago, where they began a series of studies into enhancing plant selection and growth conditions. Speed breeding technology is a new innovation inspired by NASA's experiments to grow wheat in space, which involved using continuous light on wheat and triggered early reproduction in the plants and can enormously

diminish the length of the breeding cycles of many crops. This innovation which have been developed by Australian scientists to accelerate the genetic gain in their plant breeding protocols and they confirmed that it is a powerful tool to accelerate crop research and breeding and can boost the production of wheat crop by up to three times. It also enables six generations of wheat to be produced each year by using controlled temperature and extended photoperiod, thus accelerating development of inbred lines.

According to the research team from the Alliance for Agriculture and Food Innovation (QAAFI), University of Queensland (UQ), Australia, that began speed breeding techniques more than 10 years ago, using speed breeding techniques in specially modified glasshouses grow six 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 – as opposed to two or three generations in a regular glasshouse, or a single generation in the field.

Owing to a collaboration between Australian scientists at the University of Sydney and the University of Queensland (UQ) and UK scientists from the John Innes Centre, the science of speed breeding has just leaped forward in both conception and reality. This cooperation is crowned by publishing a paper, which outlines all the protocols involved in establishing speed breeding systems and adaptation of regular glasshouse facilities. Their paper has been published in Nature Plants. [1].

They used supplemental lighting in a glasshouse environment that allowed rapid generation cycling through single seed descent and potential for adaptation to larger-scale crop improvement programs. They also outlined cost-saving through Light-emitting diode (LED) supplemental lighting. Their experiments showed that the quality and yield of the plants grown under controlled climate and extended daylight conditions was as good, or sometimes better, than those grown in regular glasshouses.

The authors demonstrated that speed breeding in fully-enclosed controlled-environment growth chambers can accelerate plant development for research purposes, including phenotyping of adult plant traits, mutant studies, and transformation. They predict great potential for integrating speed breeding with other modern crop breeding technologies, including high-throughput genotyping, genome editing, and genomic selection, accelerating the rate of crop improvement.

The low-cost management system has been refined over the past 8 years at UQ, utilizing controlled temperature regimes and 24-hour light to accelerate plant growth and development. The Australian scientists exploits this technology to facilitate crossing and development of improved F4-derived lines within just 12 months. They are using High-Throughput Phenotyping (HTP) methods as a key factor in improving the rate of genetic gain as it allows efficient assessment of proxy traits over large populations. This kind of efficiency is needed to fully take advantage of the shorter breeding cycles provided by speed breeding.

Amy Watson, a co-first author of the paper published in the journal Nature Plants, conducted some of the key experiments that documented the rapid plant growth and flexibility of the system for multiple crop species. Phenotypic screens for some target traits have been also adapted for use in the speed breeding system (e.g. grain dormancy, rust resistance, root traits), which enables selection in segregating populations during development of inbred lines. Traits that can be measured under speed breeding conditions involves: Awn suppressor genes, Green Revolution dwarfing genes, Fusarium headblight resistance, Glaucousness, Rust resistance, and Tan spot resistance.

Speed breeding is one of the many examples of the impact of space research innovations which has been applied at the International Space Station (ISS) on the lives of the people on Earth. With its 20-year anniversary in 2018 and continued operations until at least 2020, and likely beyond, there are many more benefits to look forward to from ISS research. The ISS serve as a stepping stone to future exploration and the adaptation of space farming and space age plant breeding technologies will be the inspiration for many other new innovations in agriculture.

Due to all these advances that can revolutionize plant breeding programs, there has been a lot of interest globally in this technique, and according to Lee Hickey, Senior Research Fellow at University of Queensland (UQ) in Australia, the speed breeding technique has largely been used for research purposes but is now being adopted by industry and they have started a partnership with Dow AgroSciences where they used the technique to develop the new 'DS Faraday' wheat variety, which is a high protein, milling wheat with tolerance to pre-harvest sprouting, due for release to industry this year. By using this speed breeding technology, they finally had a breakthrough in grain dormancy, and they solved a major problem facing wheat industry where breeders in Australia have been trying to solve for 40 years by introducing genes for grain dormancy so it can better handle wet weather at harvest time.

In summary, Cross-breeding for traits usually takes 4-6 generations to obtain a line that is stable enough for use. Any reduction in expended time and developing fast growing cultivars could benefit genome editing and selection breeding for other traits and would be a huge advantage to agricultural research all over the world. Speed breeding has largely been used for research purposes and is now being implemented by industry. State-of-the-art innovations in agriculture will light the way for the accelerating selection and establishment of future crops in the upcoming years here on planet Earth and will create a novel revolution in agriculture.

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