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SPEED BREEDING: A FASHIONABLE BREEDING APPROACH

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The global population is said to reach 9 billion by 2050 and will strain the resources. Rapid climate change and the emergence of new pests and diseases threaten agricultural production. Thus, producing a higher amount of quality food for the ever-increasing population is a major concern today. Moreover, the amount of genetic gain has to be raised further than the levels presently achieved by the conventional breeding programs Lin *et al.,* (2016). New and innovative methods are the prime requirement now. Speed breeding is such a tool or technique for rapid generation advance that significantly reduces the harvest time of crops in order to speed up agricultural research and increase the production of food to meet the demand of the growing population Sankar *et al.*, (2020).

Speed breeding was first initiated by NASA targeting to raise wheat in space using extended photoperiods or constant light and precise temperature in order to overdrive photosynthesis and hasten plant growth (https://www.thehindubusinessline.com). Dr Lee Hickey and his co-workers were the first to adopt NASA'S Plan for the production of wheat and peanut at the University of Queensland, John Innes Centre and the University of Sydney in Australia.

The experiments done on wheat revealed that the yield and the quality of plants grown under controlled climate with extended daylight were the same as those of crops grown in regular glasshouse conditions Shivakumar *et al.*, (2018). Traits that we can measure using speed breeding are: Green Revolution dwarfing genes, Awn suppressor genes, Fusarium head blight resistance, Rust resistance, Glaucousness, and Tan spot resistanceTarek*et al.*, (2018).

Methods of Speed Breeding (Watson *et al.*, 2018)

1. Speed Breeding I – controlled environment chamber conditions (John Innes Centre, UK)

- Photoperiod : 22Hrs (light)/ 2Hrs Dark
- Temperature: 22°C (photoperiod)/ 17°C (Dark)
- Humidity: 70%
- Light: white LED, far-red LED & Ceramic metal hydrargyrum quartz iodide lamp
- Light Intensity: 360–380 μmol m^{-2} s^{-1} (highest value after ramping) at bench height and 490 – 500 μmol m^{-2} s^{-1} (highest value after ramping) at adult plant height (with reference to wheat, *T. aestivum* cv. Paragon)

2. Speed Breeding II – glasshouse conditions (Hickey Lab, Univ. of Queensland, Australia)

- A temperature-controlled glasshouse fitted with high pressure sodium vapour lamp
- Photoperiod: 22Hrs (light)/ 2Hrs Dark
- Temperature: 22°C (photoperiod)/ 17°C (Dark)
- Humidity: 70%
- Light Intensity: 440-650(Adult Plant height) μ mol m^{-2} s^{-1} (approximately 45cm above bench height).

3. Speed Breeding III- low-cost homemade growth room design (Hickey Lab, of Queensland, Australia)

- Photoperiod: 12Hrs-12Hrs (Light-Dark) for four weeks then increased to 18Hrs-6Hrs
- Temperature: 21°C (photoperiod)/ 18°C (Dark)
- Light: 7 -8 LED light boxes (Grow Candy)
- Intensity:210–260 (bench height) & 340–590 (Adult Plant height) μ mol m^{-2} s^{-1}

Advantage of Speed Breeding

1. Multiple generations in one year
2. Fast way to obtain fixed homozygous lines through Single Seed Descent method
3. Phenotypic selection in early segregating generations
4. Rapid introgression genes into elite lines using Marker Assisted Selection
5. Allows study of plant-pathogen interaction, flowering time etc.
6. Multi- environmental trail across years

Volume 3 – Issue 3
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www.agriallis.com

7. Integrated with genomics selection, genome editing etc.
8. High – throughput phenotypic screens for multiple traits
9. Exploit gene bank accessions and mutant collection for rapid gene discovery

Limitation of Speed Breeding

1. Extended photoperiods may cause injury in some crops
2. Unlikely to be successful in short-day crops
3. Disease outbreak using controlled environmental conditions
4. Plant losses in Single Seed Descent during greenhouse condition
5. Increased monetary costs
6. Incorporation of relatively simple inherited traits

Achievements

By speed breeding program, growing up to six generations per year is possible in wheat, barley, chickpea and up to four generations of canola Acquaah*et al.,* (2012). Speed breeding is also applied in pea, peanuts, grass pea, amaranth, quinoa, *Brachypodium, Medicago* and many more crops. The technique is responsible for the development of 'DS Faraday' wheat variety, which is a high protein, milling wheat with tolerance to pre-harvest sproutingTarek *et al.,* (2018).

'Scarlett' is the most extensively cultivated cultivar of barley in Argentina, which is susceptible to many diseases. By taking four lines with a modified backcrossing method, resistant lines were developed within two years Hickey *et al.,* (2017). Moreover, drought tolerance trait in barley can also be achieved by speed breeding Ghosh *et al.,* (2018).

'YNU31-2-4', a Salt tolerant rice variety, was developed with the help of speed breeding. The gene was inserted by SNP marker, and the breeding cycle accelerated by speed breeding (14h light/10h dark- germination to 30 days of germination, ten h light/14h dark-reproductive phase). The tillers were removed, and the embryo rescue technique was used to save time before seed maturity. Thus, enabling the researchers to get 4 to 5 generations of rice per year Rana *et al*., (2019).

Speed breeding surpasses "shuttle breeding" and produces three times a greater number of generations. With shuttle breeding, only two generations per year can be achieved, while with speed breeding, up to 6 generations can be obtained Ortiz *et al*., (2007).

Volume 3 – Issue 3
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www.agriallis.com

Conclusion

The breeding program should be at par with changing climate, and breeding for resilient climate crops is the immediate challenge that can be accomplished through the new ideas of speed breeding. Speed breeding can be considered an effective tool to achieve the 2050 genetic gain targets for the four Fs (Food, Feed, Fibre and Fuel). Speed breeding combined with new technologies like marker-assisted selection, genomic selection, CRISPR gene editing etc., can be used to get the end result much faster. In-country like ours, where resources are very limited, speed breeding can be one of the most viable options to shortening the breeding cycle and accelerating the research program.

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Volume 3 – Issue 3
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