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Speed Breeding For Next Generation Agriculture, Principles, Progress, and Future Prospects

*Vikas Yadav, Rahul Yadav, Mukesh Bhatheshwar, Rakesh Choudhary and Naveen Lamror
M.Sc. Scholar, CoA, Nagaur, AU, Jodhpur, Rajasthan, India
*Corresponding Author's email: yadavvikas7073@gmail.com

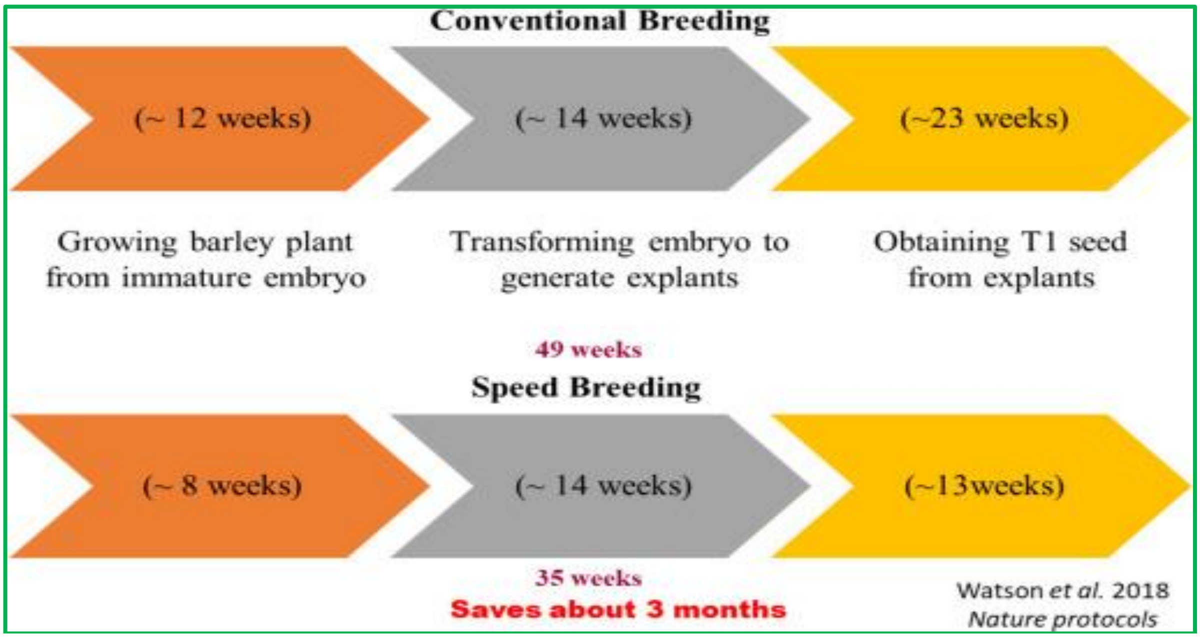
Plant breeding has had a significant impact on global food production since the early 1900s and has been essential to guaranteeing food security and safety . However, as a result of the overwhelming food requirements for the fast growing human population, issues with food quantity and quality have emerged globally in recent years. Additionally, drought and heat stress are being brought on by drastic weather fluctuations brought on by global climate change; as a result, farmers worldwide are experiencing large production losses. Millions of people died as a result of food shortages during global epidemics like the Southern corn leaf blight in the United States in the 1970s and the Irish potato blight in the 1840s.[1]

The slow pace of development of each generation during conventional breeding is due to the intrinsic character of crop cycles, and field selection procedures require an entire season. The normal crop cycle for common grain and legume crops is three to six months per crop, each generation, and per year. One breeding generation in other crops, such cassava, takes 15 to 18 months. There can only be one crop cycle per year in certain agro-ecologies due to unpredictable meteorological circumstances like severe temperatures, irregular and poor rainfall distribution, day duration, etc. It is possible to produce two generations annually under certain tropical agricultural growing circumstances.[2]

The goal of speed breeding (SB), a successful technique that has recently surfaced, is to reduce the breeding cycle (i.e., the interval between crossing and the selection of progeny to utilize as parents for the next cross) and speed up crop improvement by RGA, or rapid generation advancement. This is accomplished by establishing growing conditions in controlled settings that encourage quick plant development and accelerate flowering. SB has the potential to revolutionize plant breeding and increase crop yields because it allows researchers to quickly produce new crop cultivars to achieve rapid genetic gain.[3]

History and evolution of speed breeding

John W. Finley and Todd T. Herzog of the USDA's Agricultural Research Service in Mississippi initiated speed breeding in the 1980s. They increased the quantity of wheat crops annually by using artificial illumination. The USU-Apogee was the first dwarf wheat cultivar developed using the "speed breeding" method. NASA and Utah State University worked together on a research program in the 1980s to advance wheat generation on a space station, opening the door for opportunities of crop breeding in space to satisfy astronauts' dietary needs. The University of Wisconsin in the United States evaluated the effects of LED lights on plant growth and development in the 1990s.This discovery helped to accelerate research and application of speed breeding for crop improvement.[4]



Principles of speed breeding

Traditional breeding approaches for the development of new crop varieties are frequently time-consuming and may not adequately address the rapidly escalating demand for food production. However, researchers and breeders may now create new types more quickly because to recent discoveries and technological improvements. Speed breeding, a cutting-edge method in plant science that seeks to speed up the development of crop varieties by modifying growth conditions to shorten the time from seed to seed, is a crucial technique in this regard. It uses controlled environments to promote quick and accelerated transitions from the vegetative to the reproductive stage in high-density planting. Optimizing the environment in which plants grow is the fundamental idea of SB, which enables researchers and breeders to speed up the breeding cycle and occasionally produce multiple generations in a single year.[5]

Progress

List of speed breeding protocols across different crops, detailing their photoperiod response and the corresponding number of generations achieved per year under speed breeding conditions.[6]

crop	Speed breeding protocol	Speed breeding protocol	Generation Time/year
Rice	CO_2 (560–800 ppm) supplementation, 10 h light (far-red), 27/25 °C temperature	SD	4-5
Tomato	Agronomic treatments (cold priming, potassium supplementation) with embryo rescu	Day-neutral	3-4
Wheat	22-h light, 25/22°C temperature	LD	4
Soybean	Red–blue light coupled with photothermal conditions	SD	5
Cowpea	11-day-old pod seeds oven-dried at 39°C.	SD	5
Chickpea	22-h light, (25 ± 1) °C temperature and immature seed harvest.	LD	**7**
Oat and Triticale	20-h photoperiod, 25/22°C day/ night temperature, 65/85% day/night RH, In vitro culture of immature embryos.	LD	6-7

Limitations

Although SB is a potent technique for boosting the pace of genetic gain in various plant species, it has several limitations. One major obstacle is the lack of advanced controlled environment facilities, which can raise the cost of establishing controlled environment that is ideal for the target species' rapid cycling. In addition, maintaining a steady supply of electricity and maintaining a comfortable temperature can be difficult, especially in resource-poor nations with inadequate infrastructures and continual financial help from foreign organizations.Due to the rigorous growth circumstances, SB can lead to a low seed output and genotypic variations in plant species. These variations may affect the stability and uniformity of crops, raising concerns about the consistency of crop performance across different environments. Additionally, an excessive photoperiod can slow down plant growth and cause stress hormone levels to rise. Flowering in Amaranth, rice, and soybean treated with 10 hr. photoperiods using blue-enriched and far-red deprived light had no impact on soybean flowering but in some genotypes of amaranth and rice, flowering time was reduced by 20 and 10 days, respectively. However, some rice genotypes demonstrated flowering variations due to light intensity. [7]

Conclusions and prospects

One method that shows promise for improving crop breeding programs' efficacy and efficiency is speed breeding. By quickly screening for desirable features using controlled surroundings, ideal growing circumstances, and cutting-edge molecular tools, breeders can use speed breeding to shorten the generation time of rice plants. We have learned a great deal about the challenges of using speed breeding in rice by clarifying important elements including temperature, humidity, light, and genetic materials. Furthermore, in order to fully realize the potential of speed breeding in rice, our review emphasizes the need for a nuanced understanding and optimization of these factors. Additionally, using advanced breeding techniques and genomic approaches in conjunction with speed breeding techniques can improve rice crop yield and quality, increase resistance to pests and diseases,and improve toleranceto environmental stressors[8]

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