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SPEED BREEDING: A BOON FOR THE CROP IMPROVEMENT

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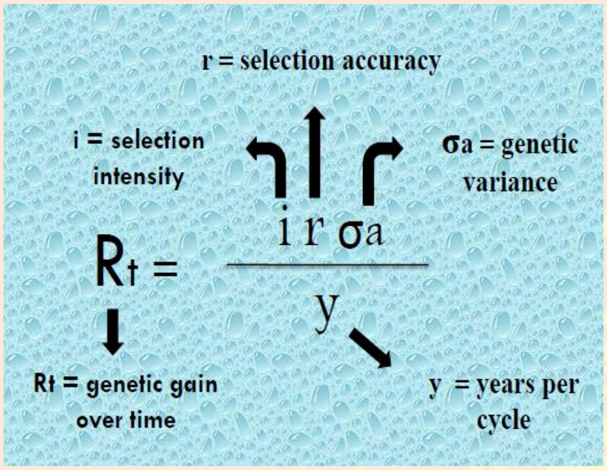
Introduction:

Speed breeding is a modern technique of generation advancement of crops in order to shorten the life cycle duration. In speed breeding fast growth and development of plants is achieved by growing them in controlled environmental condition and manipulating their photoperiod, temperature requirement, light duration and intensity and humidity. By the use of speed breeding more than six generations of photo-insensitive crops and two to three generations of all other crops can be grown. This technique is used to develop new varieties of crops in a very short period of time than conventional breeding methods taking at least 8 - 10 years, because of accelerated generation advancement process. Speed breeding is also used to accelerate breeding process, selection at genomic level, development of transgenics, CRISPR pipelines and in study of important physiological traits of crop plants in order to bred new cultivars for enhanced quality of produce and yield to meet global food security challenges (**4**). Fast tracking research and increased rate of cultivar development both are necessary for boosting up the agricultural productivity as well as stability in response to changing climatic conditions. Plants complete their long mating cycle in a very short period by manipulating environmental conditions such as lowering flowering time and seed setting under controlled temperature and photoperiod that results gain of increased number of generations per year (**9** and **7**).

Innovation of Speed Breeding Concept:

The modern era is following the mantra of “More work in least time” that results the increased efficiency of work. Thus, plant breeders tried to apply the same with the crop plants through accelerating their production cycle. In this way the concept of speed breeding or accelerated breeding came in to existence. In the 1980s NASA scientists laid down the foundation of this concept for growing crops in less time with faster growth rate in space. NASA scientist’s grown wheat plant in small chambers by providing them continuous light that results their quick growth and development. Further this concept of speed breeding was elaborated by Dr. Lee Hickey, Dr. Brande Wulff, Dr. Allan Rattey and Shreya Ghosh at John Innes Centre, University of Queensland and University of Sydney.

Breeders Equation: Efficiency of any breeding procedure for its application in any crop is measured on the basis of breeders most popular equation i.e., breeder's equation,



where efficiency is measured on the terms of increased genetic gain over time, increased selection intensity, selection accuracy, genetic variance and with decreased year per cycle.

Speed Breeding Set-Up: To start an effective speed breeding system certain factors need more attention such as light, photoperiod, temperature and humidity for accelerating the breeding procedure.

Ingredients for Speed Breeding: all the ingredients in adequate amount as required in photosynthesis are required for speeding up the growth and development of plants in controlled environmental condition. Among them the critical ones are described below:

Light: In photosynthesis chloroplast in the plants absorbs the light energy of certain wavelengths.

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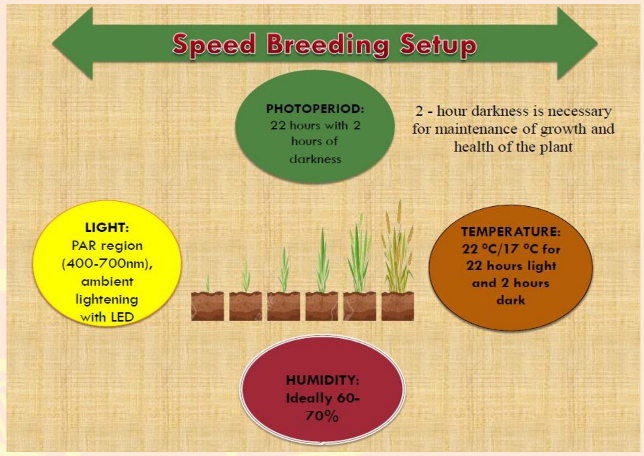

Fig. 1: Speed Breeding Setup, diagrammatic representation

The most suitable photosynthetically active radiation wavelength of visible light fall in blue range (425-450nm) and red range (600-700). Thus, the best light source used in photosynthesis is red, far-red and blue. In controlled conditions of speed breeding, Light Emitting Diodes (LEDs) or LEDs and halogen lamps are used to achieve this spectrum of light.

Photoperiod: For speed breeding 22 hours of light followed by 2 hours of darkness is required in 24 hours cycle. Two hours of darkness is required for maintenance of growth and plant health.

Temperature: Temperature requirement of plants differ from species to species. Each species require a specific minimum and maximum temperature range for its growth, besides that different growth stages of plant viz., vegetative and reproductive requires separate range of temperature. So growth stage and crop wise temperature is adjusted in speed breeding setup. Extremely low or high temperature causes stress and damage to the plants.

Humidity: Humidity is another important factor for plant growth and development. Moderately 60-70% relative humidity is beneficial for plant growth. In speed breeding under controlled environment humidity adjustment is modified according to the requirement of crop growth stage and type.

Speed breeding versus glasshouse condition: Speed breeding is practiced in cereals, pulses and oilseed crops and significantly hastens the generation advancement. In cereals such as Barley (Hordeum vulgare), Bread wheat (*Triticum aestivum*), Duram wheat (*Triticum duram*); in pulses chickpea (*Cicer arietinum*) and pea (Pisum sativum) up to six generations per year and in oilseed crop Canola (*Brassica napus*) up to 4 generations per year achieved through speed breeding approach. Whereas, under standard glasshouse condition only two to three generations of these crops obtained. In Arabidopsis thaliana up to nine generations can be achieved through speed breeding by reducing flowering time 20-26 days, manipulating plant hormone ratio and photoperiod along with the germination of immature seeds.

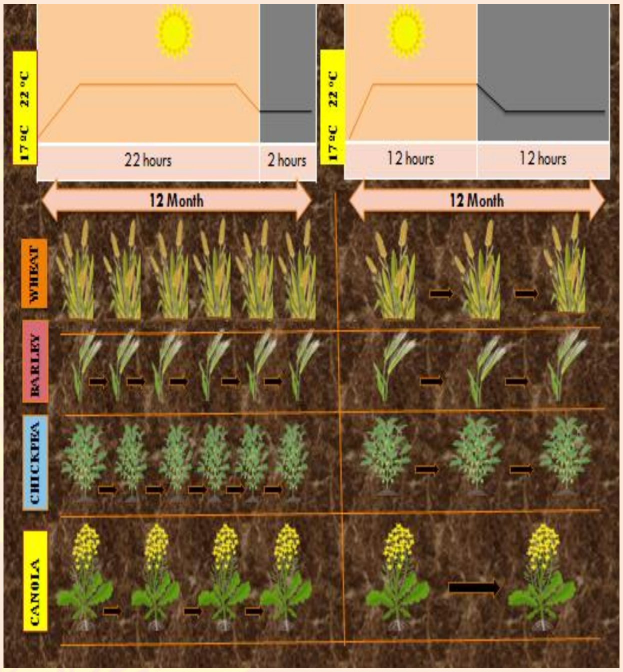

Fig. 2: Comparison of number of generations of crops obtained per year through speed breeding (4-6 generations per year) versus glasshouse conditions (2-3 generations per year).

Speeding up the breeding pipeline: Conventional breeding methods take 5 to 7 years for crossing, selection and generation advancement and 3 to 5 years in field testing in multiplications yield trials, after that varietal release takes from 1 to 3 years. Whereas, in speed breeding the line development process takes up to 1 to 2 years, 3 to 5 years for field testing and 1 to 3 years for variety release.

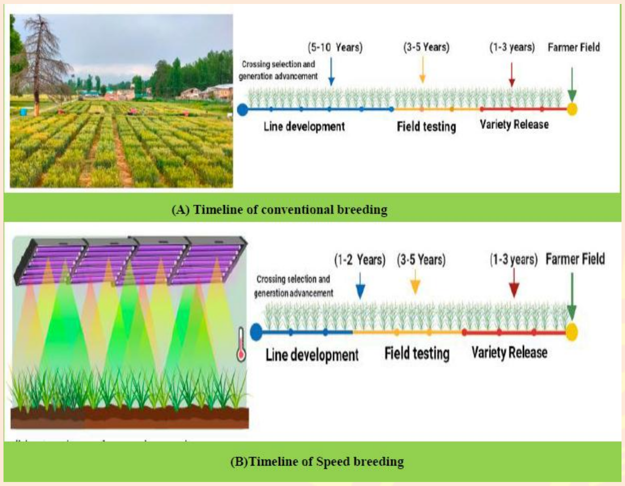

Fig. 3: Timeline of variety development through (A) conventional and (B) speed breeding

Single seed descent technique is great for achieving speed breeding, especially for cereals. We can achieve quick cycling of multiple lines with healthy plants and viable seed by increasing the sowing density in speed breeding. Plant grown under controlled conditions in speed breeding attains anthesis in about half the time taken in glasshouse condition. Wheat, barley, oat and triticale have been bred using this method.

Immature spike harvesting:

Generally, crop is harvested at maturity and laid down in the field to reduce moisture for threshing, after that the seeds are dried and stored at sufficient moisture at 10 to 12 percent. Storage moisture of seed varies from crop to crop. Whereas, in speed breeding crop is harvested when spike/pods are still green and placed in a dehydrator at 35 0C for three days for speeding up the maturity. So speed breeding reduce process of ripening and drying up to 15 days than naturally harvested and threshed seeds (**19**).

Speed Breeding Applications:

- ✓ Speeding up the crop improvement programmes as more than six generations can be achieved per year
- ✓ Speed up the genomic selection process
- ✓ Helps in fast screening of crop plants for biotic as well as abiotic stress resistance
- ✓ Fast germplasm screening
- ✓ Reduce varietal developmental time
- ✓ Accelerate transgenic and CRISPR pipeline
- ✓ Developing multiple disease resistance crops

Achievements:

- ➢ First wheat variety developed by Lee Hickey through speed breeding i.e., DS Faraday with high protein content, milling quality and tolerant to pre-harvest sprouting

(Source: www.seednet.com.au)

Figure1: **I[st] wheat variety 'DS Faraday' developed through Speed Breeding**

- SB technique has been used for fast screening to biotic stresses (diseases) and abiotic stresses in cereals. Examples are leaf rust in wheat with reduced flowering time (**3** and **1**),
- Development of resistance line of barley against rust and spot blotch (6) and reduced breeding cycle, time to anthesis and increased number of generations per year in sorghum (15) and oat (18).

Table-1: Crops in which speed breeding increased generation turnover

Crop group	Crop	Generations /year	Reference
Cereals	Wheat (Triticum aestivum L.)	4-6, generations	Mukade et al., (11)
	Barley (Hordeum vulgare)	6, generations	Hickey et al., (6)
	Oat (Avena sativa)	7, generations	Liu et al., (8)
	Rice (Oryza sativa)	4-5, generations	Rana et al., (14)
	Sorghum (Sorghum bicolor)	4, generations	Forster et al., (2)
Pulses	Lentil (Lens culinaris)	8, generations	Mobini et al., (10)
	Pea (Pisum sativum)	6.8, generations	Ochatte et al., (12)
	Chickpea (Cicer arietinum)	6, generations	Watson et al., (19)
	Faba bean (Vicia faba)	7, generations	Mobini et al., (10)
	Pigeonpea (Cajanus cajan)	4, generations	Saxena et al., (16)
Oilseed	Rapeseed (Brassica napus)	5, generations	Watson et al., (19)
	Flax (Linum usitatissimum)	3, generations	Sysoeva et al., (17)
	Soybean (Glycine max)	5, generations	Jahne et al., (7)
	Groundnut (Arachis hypogaea)	4, generations	O'Connor et al., (13)

Conclusion:

As the world population increasing day by day and climatic conditions are going to be adverse for crop production, this will present an alarming situation of food security in upcoming years. Thus researchers must have to set a goal to boost up the crop production by employing recent technologies to feed the burgeoning population effectively. In recent years speed breeding has emerged as an advance technology of crop improvement having sufficient potential to boost up the crop production by increased generation turnover of crops. Speed breeding in combination with recent breeding strategies, genome editing, genomic selection and genotyping can improve the existing varieties as well as will emerge new cultivar having high yield potential with low input demand. Speed breeding helps in screening the tolerant cultivars against various abiotic as well as biotic stresses, thus evolves resistance cultivars for various stresses that reduces the risk of crop damage. This technique also speed up the breeding programmes as it increases the number of generations per year, thus reduces the time taken in variety development. Speed breeding needs more attention of researchers. In India, this technique is employed in a very few crops such as wheat, which can be extended to other crops.

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