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on

Speed Breeding: A Ray of Hope for Food Security

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Speed Breeding: A Ray of Hope for Food Security[1]

by

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ABSTRACT

Global population growth and climate change continue to put pressure on the world's food supply; innovative solutions are needed to ensure food security. One potential approach is speed breeding, a technology that accelerates the breeding cycle of crops to increase yields and improve crop resilience. This review paper aims to provide a comprehensive overview of speed breeding, its applications in agriculture, and its potential as a tool to address food security issues worldwide. Different suggested methods of speed breeding, like speed breeding I, II, and III, have been proven successful for different crops. It has been tested on various cereal, legume, oilseed, fruit trees, and vegetable crops, and the results indicate that it can typically produce 2–8 generations per year. Cereal crops like oats, barley, wheat, rice, and sorghum have shown significant rapid generation advancement. Among them, wheat showed the highest number of eight generations per year. Different legumes, oilseed crops, fruit trees and vegetables have shorter crop durations thanks to the speed breeding technique. It also encourages vigorous vegetative growth in fruit trees and vegetable crops so that flowering happens much sooner than usual, which ultimately helps in plant breeding programs. This makes it superior to traditional breeding methods. Using it with other modern technology makes the breeding program faster. But as a new technology, it has some drawbacks, like an initial cost, inadequate infrastructure, and the requirement of skilled personnel. However, if it is used effectively, agricultural research and production will accelerate and help to ensure food security.

Keywords: Photoperiod, light, environment, breeding cycle, generation advancement

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CHAPTER I

INTRODUCTION

The world's population is expected to increase by nearly 2 billion people in the next 30 years, from the current 8 billion to 10 billion in 2050 (United Nations, 2022). Globalization replaces agricultural land areas, which is causing climate change along with varied abiotic and biotic stresses (Tiwari, 2021). Rapid climate change and the emergence of new pests and diseases threaten agricultural production. Thus, the exponential rise in human population and the intensifying effects of climate change provide a huge barrier to sustainable food production to feed the increasing population. Plant breeding plays a significant role in resolving agricultural problems and enhancing both production and productivity, which are needed to feed the growing population.

The conventional approach to breeding requires the selection of complementary parental genotypes with desired traits, followed by crosses and a series of selections and advancements of superior progenies to release cultivars that meet market demands (Shimelis & Laing, 2012). Breeding goals in any crop cultivar development program include higher yield, better nutritional quality, and higher tolerance to biotic and abiotic stresses (Tester & Langridge, 2010). However, this procedure can take a decade to develop and release an improved variety (Ahmar *et al*., 2020). The modern world has stepped up its game, with more work being done in the shortest amount of time, from quick communications to quick answers; everything is speeding up. This depicts that in the future, progress is another name for modernization and advances. In an era where everything reaches the next generation by increasing its rate, why not plants? The question that arose here led to the discovery of the preeminent method of breeding, which is speed breeding.

Speed breeding is a group of methods that involve changing the environmental conditions in which crop genotypes are grown to accelerate flowering and seed set to move as quickly as possible to the following breeding generation (Wanga *et al*., 2021). This technique involves exposing plants to extended periods of light to stimulate growth and controlled environments to optimize their growing conditions. Thus, it can produce several generations of crops in a single year, reducing the time it takes to develop new varieties and improving the chances of developing crops that are resistant to pests and diseases, have improved yields, and are better adapted to changing climatic conditions.

Speed breeding protocols were earlier proposed by Watson *et al*. (2018). After that, many researchers tried this to improve crop varieties. Many protocols are available for different varieties of plant crops, such as cereal crops like wheat, oats, and barley; legumes and oilseed crops like soybean, lentil, and pea; and different fruit trees and vegetable crops are provided with optimal light quality, light intensity, and proper temperature, which enhance the process of photosynthesis and increase growth and breeding. Speed breeding, besides enhancing growth, also has several advantages over other technologies and can work better when integrated with other modern plant breeding technologies (Haroon *et al*., 2020). Speed breeding is a new protocol, but there are still many challenges and limitations. But it significantly reduces the crop duration, which can speed up agricultural research, increase the production of food to meet the demand of the growing population, and have a significant impact on ensuring food security.

Considering the facts present study was undertaken with the following objectives:

1. To provide an overview of the concept of speed breeding
2. To find out the key crops that can benefit from speed breeding techniques
3. To explore the potentiality of speed breeding in food security, its opportunities, and challenges

CHAPTER II

MATERIALS AND METHODS

This seminar paper is exclusively a review paper. It is primarily based on secondary sources. Therefore, all the information was collected from secondary sources with a view to preparing this paper. Information is gathered from related e-books, different journal articles, statistical yearbooks, and websites that are accessible online. Constructive feedback from my major professor and course instructors helped me improve this paper. After gathering all relevant information, it was compiled and logically presented in its current form.

CHAPTER III

REVIEW OF FINDINGS

3.1 History and evolution of speed breeding

Crop productivity has decreased significantly as a result of changing climatic circumstances, putting pressure on researchers to utilize appropriate crop improvement techniques. The process of creating new varieties using traditional techniques often takes 10 to 15 years from the first crossing to the variety's release. Botanists demonstrated that plants can grow under artificial light about 150 years ago, giving rise to the concept of speed breeding (Sharma *et al*., 2018). Eventually, the influence of light on several plant species was investigated. For the majority of nearly 100 plant species, flowering was faster under steady light (Meena *et al*., 2022). NASA established a joint research program with Utah State University in the 1980s for the rapid generation advancement of wheat on the space station, bringing about a new era of crop breeding and exploring the possibility of growing food in space to meet the needs of astronauts on the space-station (Bugbee & Koerner, 1997). "USU-Apogee" was the first dwarf wheat variety developed through speed breeding (Bugbee & Koerner, 1997).

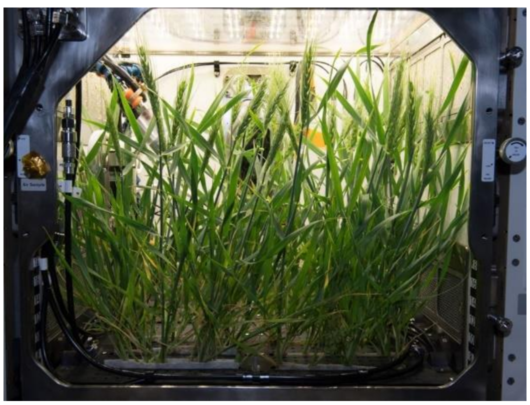

Figure 1. USU-Apogee in advanced plant habitat

(Source: Baldwin, 2017)

The discovery of light-emitting iodide (LEDs) in the 1990s, and their effect on plant growth and development, at the University of Wisconsin in the United States, has accelerated more advanced research and the application of speed breeding for crop improvement (Hickey *et al*., 2019). In 2003, the University of Queensland proposed the term "Speed breeding" to accelerate the rapid generation advancement of wheat breeding, inspired by NASA's work (Watson *et al*., 2018).

3.2 Major components of speed breeding

Speed breeding typically involves growing crops in controlled environments that optimize growth conditions and accelerate the breeding process. Here are some key elements of a speed breeding setup:

3.2.1 Controlled environment growth chambers

Speed breeding requires growing crops in controlled environments that mimic ideal growing conditions, such as temperature, humidity, and lighting. Growth chambers with adjustable light and temperature settings can be used to create these conditions and speed up the growth of plants (Watson *et al*., 2018).

3.2.2 Light

Speed breeding frequently involves utilizing artificial lighting, such as LEDs, to give crops consistent light in order to hasten plant growth. Speed breeding can be done with any light that generates a spectrum that reasonably spans the PAR (Photosynthetically Active Radiation) region (400–700 nm), with an emphasis on the blue, red, and far-red ranges (Tiwari, 2021).

3.2.3 Photoperiod

Photoperiodism is the response to changes in day length that enables plants to adapt to seasonal changes in their environment (Thomas, 2017). Photoperiod is a crucial factor in speed breeding, as it helps to control the flowering time of plants and accelerate the breeding process. A photoperiod of 22 hours with 2 hours of darkness in a 24-hour diurnal cycle is recommended (Meena *et al*., 2022). However, the specific photoperiod used for speed breeding can vary depending on the crop species and the goals of the breeding program.

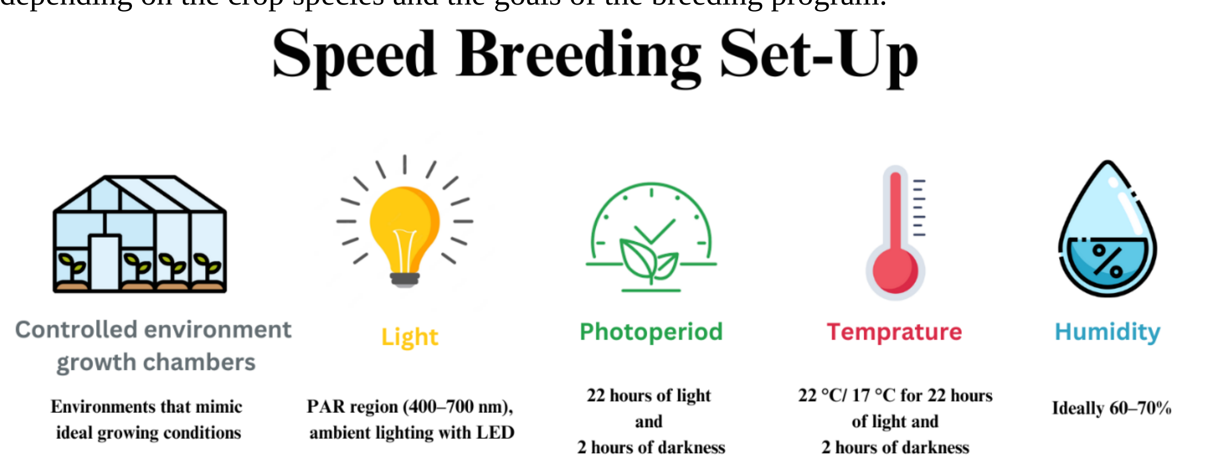

Figure 2. A Set-Up for Speed Breeding

Source: Tiwari (2021), Meena *et al*. (2022)

3.2.4 Temperature

A higher temperature during the photoperiod, whereas a fall in temperature during the dark period. A temperature cycling regime of 22 °C and 17 °C for 22 hours of light and 2 hours of darkness, respectively (Meena *et al*., 2022).

3.2.5 Humidity:

A reasonable range is 60–70% (Tiwari, 2021). For crops that are more adapted to drier conditions, a lower humidity level may be advisable.

3.3 Methods of speed breeding

The basic principle behind speed breeding is to accelerate the rate of photosynthesis. So, temperature, photoperiod, light intensity, soil nutrition, soil moisture, CO_2 levels, and plant density are all cardinal to the photosynthetic efficiency of the plant. Detailed regulation of these factors is paramount to achieving optimal results in speed breeding protocols (Wanga *et al*., 2021). According to Watson *et al*. (2018); there are mainly three speed breeding methods mainly depending on their infrastructure and conditions - Speed Breeding I, Speed Breeding II, and Speed Breeding III.

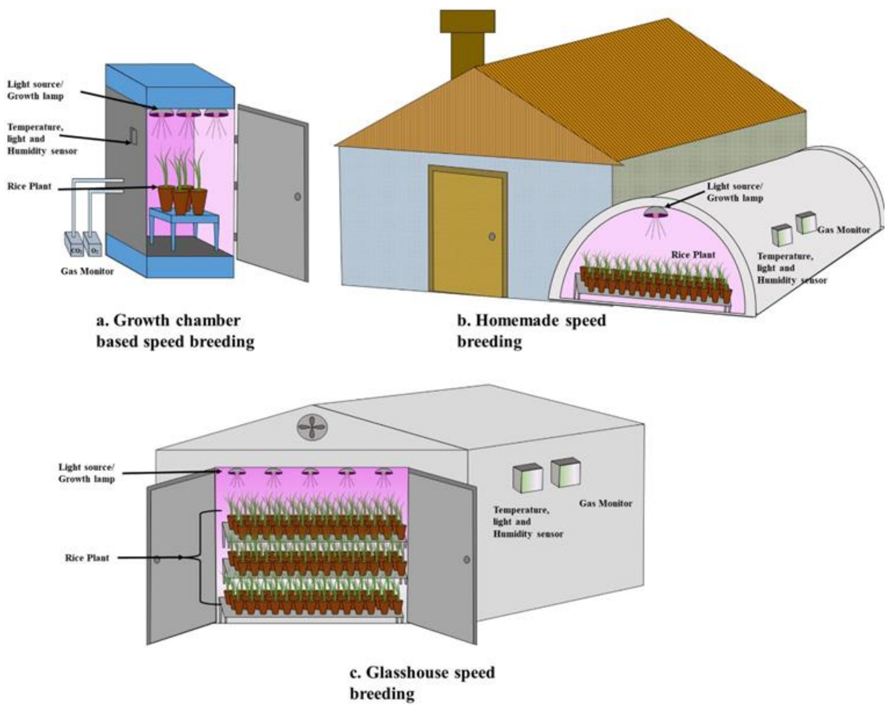

Figure 3. Different Methods of Speed Breeding

3a. Speed Breeding I; 3b. S Speed Breeding III and 3c. Speed Breeding III

Source: (Sharma *et al*., 2022)

3.3.1 Speed Breeding I – Controlled environment chamber conditions

Photoperiod: 22 hours (light)/ 2 hours 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 (bench height) & 490–500 (Adult Plant height) µmol m^{-2} s^{-1}

An experiment was conducted at the John Innes Centre, UK, to track growth in speed breeding condition I and a controlled condition. For the control condition, researchers used a glasshouse with no supplementary light. A minimum temperature of 12 °C was used. Pots were moved around every 2–3 days in a rotating fashion to ensure uniformity of growth conditions.

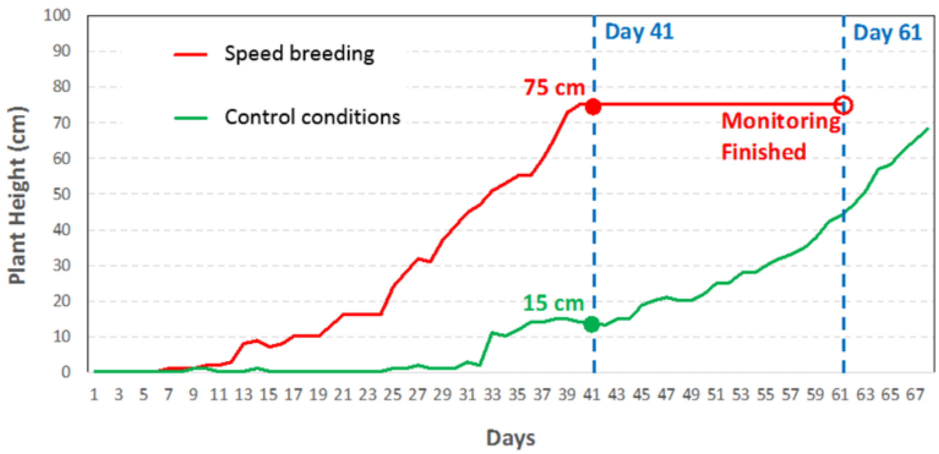

Figure 4. Growth curves tracking the development of *Triticum aestivum* cv. Paragon under speed breeding condition I ("Speed breeding") and control glasshouse conditions ("Control conditions")

Figure 4 showed that in speed breeding condition that the vegetative growth achieved 20 days earlier than the greenhouse condition.

3.3.2 Speed Breeding II – Glasshouse conditions

A temperature-controlled glasshouse fitted with a high-pressure sodium vapor lamp

Photoperiod: 22 hours (light)/ 2 hours Dark

Temperature: 22°C (photoperiod)/ 17°C (Dark)

Humidity: 70%

Light Intensity: 440-650 (Adult Plant height) µmol m^{-2} s^{-1}

Another experiment was conducted under speed breeding condition II and glasshouse conditions with no supplementary light at Hickey Lab, University of Queensland, Australia. Days to anthesis, total generation time, mean yield per plant (g/plant), and generation achieved per year were measured for wheat, barley, canola, and chickpea.

Table 1. Summary of generation time and yield measurements of wheat, barley, canola and chickpea under speed breeding condition II (SB) and glasshouse (GH) conditions

Crops		**Days to Anthesis**	**Total generation time**[1]	**Mean yield per plant (g/plant)**	**Generation achieved /year**
Wheat	SB	41.4 ± 1.7	65.4	3.5 ± 1.2	5.6
	GH	63.1 ± 2.8	87.1	2.5 ± 1.0	4.2
Barley	SB	30.4 ± 1.4	68.4	5.9 ± 1.4	5.3
	GH	94.0 ± 14.4	132.0	9.4 ± 4.8	2.8
Canola	SB	46.2 ± 2.2	98.2	8.3 ± 2.2	3.7
	GH	119.1 ± 15.3	171.1	9.2 ± 2.4	2.1
Chickpea	SB	30.1 ± 0.7	82.1	1.9 ± 1.3	4.5
	GH	62.6 ± 3.7	114.6	2.4 ± 1.7	3.2

Values indicated are expressed as mean ± Standard deviation.

[1] Total generation time calculated according to: mean days to anthesis of all cultivars + mean days to sample seed + 5 days drying at 35 °C + 1 day imbibing seed at room temperature + 4 days chilling at 4 °C.

(Source: Watson *et al.*, 2018)

From the Table 1. it is stated that the anthesis in approximately half the time than those in green house. So, more generations achieved than control condition. Wheat plants produced significantly more yield than in control condition, where other crops yield was reduced than greenhouse condition.

3.3.3 Speed Breeding III – Low-cost homemade growth room design

Photoperiod: 12 hours-12 hours (Light-Dark) for four weeks then increased to 18 hours-6 hours

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) µmol m^{-2} s^{-1}

These methods can be highly fixable according to crop type and breeding objectives.

3.4 Crops benefitted from speed breeding

One important application of speed breeding techniques is in the acceleration of crop breeding programs. This method allows for the rapid generation of plant material, which can shorten the time to develop new varieties of crops. Here are some key crops that can benefit from speed breeding techniques:

3.4.1 Cereal crops

Cereals are plants in the Poaceae family that are grown mainly for their starchy fruits, including wheat, rice, corn, rye, oats, barley, sorghum, and millets. Speed breeding has been used to develop new varieties with desirable traits such as disease resistance, drought tolerance, and higher yields. A salt-tolerant rice variety, "YNU31-2-4," was developed with the help of speed breeding. An SNP (single nucleotide polymorphism) marker was used to insert the gene (Rana *et al*., 2019). The breeding cycle was accelerated by speed breeding using a 14-hour light/10-hour dark period from germination to 30 days of germination and 10 hours light/14 hours dark in the reproductive phase (Rana *et al*., 2019).

Table 2. List of cereal crops where speed breeding has increased generation turnover

Crops	**Type of photo-period**	**Techniques**	**Days to flowering**	**Generations achieved/year**	**Trait enhanced**	**Refere nce**
Oat	Long day	Photoperiod (LED light), temperature and micro-nutrients	21	3	Shortening of the generation time and early panicle harvest	Liu *et al*. (2016)
Barley	Long day	Photoperiod (sodium vapour lamps) and temperature	24–36	6	rapidly transfer multiple disease resistance	Hickey *et al*. (2017)
Wheat	Long day	Photoperiod (incandescent lights) and temperature, embryo culture	24-36	8	Rapid production of segregating populations and pure lines	Zheng *et al*. (2013)

Crops	Type of photo-period	Techniques	Days to flowering	Generations achieved/year	Trait enhanced	Reference
Rice	Short day	Photoperiod (LED light), temperature	75-85	4	Rapid development of high yielding variety	Collard *et al*. (2017)
Sorghum	Short day	Photoperiod (LED light), temperature and immature seed germination	40-50	6	Rapid development of high yielding variety	Forster (2014)

(Source: modified from Wanga *et al*., 2021 and Samantara *et al*., 2022)

Table 2 shows that photoperiod extension has been widely used to manipulate the time to flowering, and hence the generation times achieved in these cereal crops are in the range of 3 to 8. Temperature manipulation, embryo rescue, and immature seed germination were also used to improve the process.

3.4.2 Legumes and oilseeds

Many protocols have been developed to reduce generation times in oilseeds and legumes like soybeans, lentils, chickpeas, canola, and sunflower. According to Croser *et al*. (2016), speed breeding was used to produce multiple generations of maize in a year, allowing them to perform genomic selection for various traits such as grain yield, grain moisture, and plant height. They showed that speed breeding can quicken the breeding process and increase the precision of genomic selection. Nagatoshi and Fujita (2019) created a standardized rapid generation advancement protocol for the Japanese soybean cultivar Enrej that cut the crop's duration from 102-132 days to just 70 days. The availability of such methods enables five generations per year instead of one to two generations in a year.

Table 3. List of crops legumes and oilseed crops where speed breeding has increased generation turnover

Crops	Type of Photo-period	Techniques	Days to Flowering	Generations achieved/ year	Trait enhanced	Reference
Lentil	Long day	Plant hormones, photoperiod, light intensity & immature seed	31–33	8	Early flowering and seed development	Mobini *et al*. (2015)
Chickpea	Long day	Photoperiod and immature seed germination	33	7	Biotic stress tolerance and development of pure lines	Samineni *et al*. (2020)
Pea	Long day	Plant hormones, photoperiod and immature seed Germination	33	5	Production of recombinant inbred lines	Mobini and Warkentin (2016)
Groundnut	Long day	Photoperiod and temperature	25–27	4	Advancement of early generation breeding material	O'Connor *et al*. (2013)
Faba bean	Long day	Photoperiod (LED light) and temperature, growth regulator	29-32	7	Early flowering and seed development	Mobini *et al*. (2015)
Canola	Long day	Photoperiod, light intensity, temperature, immature Seed germination and soil moisture	73	4	Pod shattering resistance	Watson *et al*. (2018)
Soybean	Short day	Photoperiod incandescent lights) and temperature	21	5	Production of recombinant inbred lines	Jähne *et al*. (2020)
Pigeon pea	Short day	Photoperiod, temperature, immature seed Germination	50–56	4	Development of photoperiod insensitive lines	Saxena *et al*. (2017)

Crops	Type of Photo-period	Techniques	Days to Flowering	Generations achieved/ year	Trait enhanced	Reference
Clover	Short day	Photoperiod incandescent lights) and temperature, growth regulators	32–35	6	Rapid development of bi-parental and multi-parental populations	Pazos-Navarro *et al*. (2017)

(Source: modified from Wanga *et al*., 2021 and Samantara *et al*., 2022)

Table 3 shows that Legume and oilseed crops also showed success under speed breeding conditions. The highest eight generations per year are achieved in lentils. Also, biotic stress tolerance in chickpeas and pod-shattering resistance in canola have been developed along with rapid generation advancement.

3.4.3 Fruit trees

According to Van Nocker and Gardiner (2014) flowering occurs after a juvenile phase, which can range from a few years to more than twenty years for most fruit trees. Therefore, efforts to speed up fruit tree breeding have primarily focused on shortening the juvenile period. There have been some reports of protocols that encourage such vigorous vegetative growth that flowering happens much sooner than usual, such as in two years rather than seven for chestnuts (*Castanea sativa*) (Baier *et al*., 2012) and in ten months rather than five years for apples (*Malus domestica*) (Van Nocker & Gardiner, 2014). The primary issue with speed breeding tree crops is the requirement for additional resources or procedure changes to keep the plants from growing too tall and becoming difficult to regulate inside controlled environment facilities.

3.4.4 Vegetable crops

Vegetables that respond well to longer daylight hours, like pepper, tomato, and amaranth, have shortened generation intervals as a response to the photoperiod being extended. Velez-Ramirez *et al*. (2014) discovered that introducing the CAB-13 gene into tomatoes can improve the plant's tolerance to continuous light, allowing it to adapt to extended periods of photoperiod. Almost all root and tuber crops are vegetatively propagated, with flowering occurring in rare circumstances or after several years, and because of this, they lack diversity (Chiurugwi *et al*., 2019). Thus, speed breeding can make it possible to facilitate the breeding program of many vegetable crops.

Table 4. List of vegetable crops where speed breeding was implemented in crop improvement

Crop	Techniques	Days to Flowering	Generations/ year	Trait Enhanced	References
Amaranth	Photoperiod and temperature	28	6	Control of plant height, flowering time	Stetter *et al*. (2016)
Tomato	Photoperiod	60-70	5-6	Drought tolerance, disease resistance	Velez-Ramirez *et al*. (2014)
Onion	Bulb dormancy breakdown, Photoperiod with far-red light, temperature	50-70	2-3	Early flowering	Khosa *et al*., (2016).
Potato	Long photoperiod	70-90	2-3	Earlier flowering, fruiting, and faster seed maturity	Sood *et al*. (2020)
Pepper	Photoperiod	60-70	3-4	Early flowering and fruiting	Jähne *et al*. (2020)

Table 4 shows the advancement of vegetable breeding as early flowering can be achieved through speed breeding.

3.5 Advantages of speed breeding

3.5.1 Speed breeding over traditional breeding methods

Breeding a new crop variety via a conventional approach requires the selection of complementary parental genotypes with desired traits, followed by crosses and a series of selection and advancement of superior progenies to release candidate cultivars that meet market demands (Shimelis & Laing, 2012). However, conventional breeding procedures can take more than 10 years to develop and release an improved variety in the absence of an integrated pre-breeding program (Ahmar *et al*., 2020). Speed breeding can be used to expedite breeding outcomes.

It can increase the number of generations per year using immature seed harvest and photoperiod response whereas conventional breeding typically takes several years (Samantara *et al*., 2022).

Breeders can more quickly identify desirable traits and create new varieties thanks to this. With speed breeding, it is also possible to screen larger numbers of plants for desirable traits, making the breeding process more efficient and effective (Temesgen, 2022).

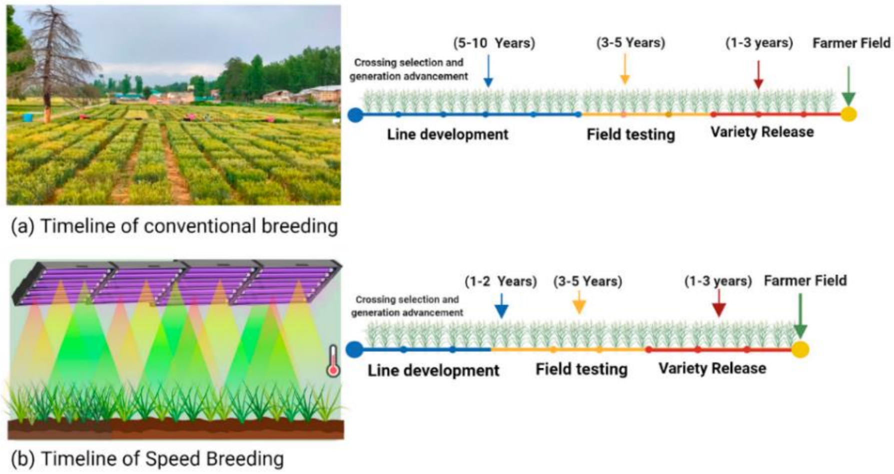

Figure 5. Timelines of varietal development with (5a) conventional breeding and (5b) speed breeding

(Source: Samantara *et al.*, 2022)

Speed breeding enables precise environmental control, allowing optimized plant growth and development which could result in more dependable and predictable plant growth. Speed breeding is far more concise than traditional breeding, which might result in a need for less land and other resources. This may also make it more accessible to breeders working on a smaller scale or with fewer resources.

Speed breeding can facilitate the introduction and selection of genetic diversity more quickly than conventional breeding, by increasing the number of plant generations cycled in one year (Temesgen, 2022). It allows for greater control over the breeding process, making it possible to select specific genetic traits with greater precision than the conventional method.

3.5.2 Rapid crop development

Speed breeding techniques allow for the rapid production of multiple generations of crops in a short time. By cutting the crop cycle in half and growing plants in highly controlled environments, breeders can generate many generations in a single year. This enables breeders to study and manipulate plant physiology and genetics more precisely than in traditional field trials. Thus, new crop varieties can be developed and released quickly and can provide solutions to challenges such as pest and disease resistance, increasing yields, and improving nutritional quality.

3.5.3 Resilient crops for a changing climate

Speed breeding techniques also have the potential to help address the challenges posed by climate change. By growing crops in highly controlled environments, breeders can simulate different environmental conditions. This helps identify crop varieties that are better adapted to changing conditions such as drought, flooding, or higher temperatures. This can help ensure food security in the face of changing climates, by developing crops that can better withstand these stresses.

3.5.4 Integrated with other modern plant breeding technologies

Speed breeding can be integrated with other modern plant breeding technologies, such as genome editing, genomic selection, and high-throughput phenotyping and genotyping. It can facilitate plant breeding and research programs with speed to feed the growing world population.

Gene editing techniques, such as CRISPR-Cas9(Clustered Regularly Interspaced Short Palindromic Repeats And CRISPR-Associated Protein 9) combined with speed breeding techniques, can greatly accelerate the process of developing new crop varieties (Haroon *et al.*, 2020). Gene editing can introduce desired traits, such as pest resistance or improved nutritional content, breeders can then use speed breeding to rapidly produce multiple generations of these edited plants. For improving the genetic benefit, speed breeding along with genomic selection is used. The main property of applying genomic selection is that it reduces the length of the breeding cycle and produces a superior quality plant variety in a very short time, which improves the genetic gain.

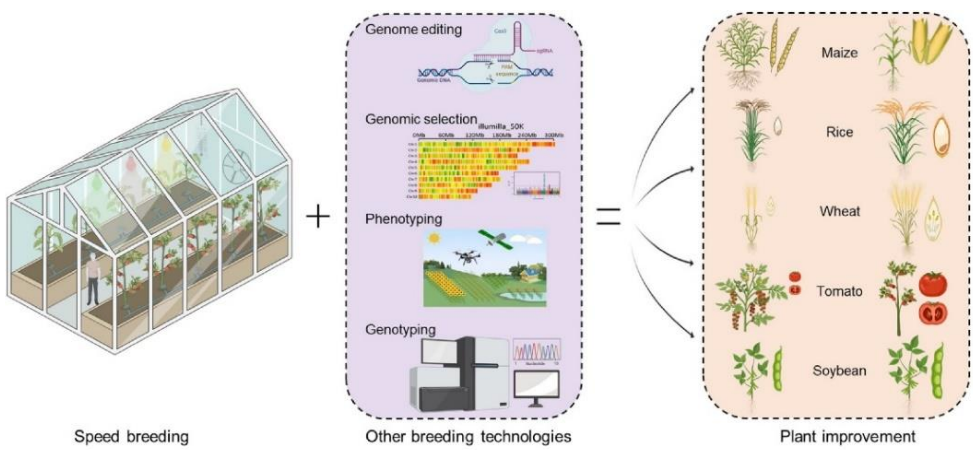

Figure 6. Integration of speed breeding with other breeding techniques accelerates plant improvement progress.

Source: (Xu *et al.*, 2022)

Phenotyping is defined as the evaluation of complex plant traits that are related to growth, development, and all the other characteristics that form the basis for complex trait evaluation (Samantara *et al*., 2022). Conducting high-throughput phenotyping under speed breeding conditions creates novel avenues for the discovery and incorporation of beneficial traits in a resource-efficient manner (Al-Tamimi *et al*., 2016). Genotyping, the process of identifying an organism's genetic makeup, is becoming increasingly important in crop breeding. It allows breeders to identify desirable genetic markers and select plants for speed breeding. This allows for a more targeted approach to crop breeding.

3.6 Challenges and limitations of speed breeding

Speed breeding has the potential to revolutionize plant breeding and contribute to sustainable agriculture. But there are several challenges and limitations to speed breeding that need to be considered:

3.6.1 A lack of trained plant breeders and breeding technicians

The absence of skilled and active plant breeders and plant breeding technicians in developing nations is a major hindrance that could prevent the public sector from implementing speed breeding (Shimelis *et al*., 2019). In some countries, legislative and administrative frameworks need to be developed to benefit plant breeders' rights, seed regulation, and the value chain from farmers to consumers (Tripp *et al*., 2007).

3.6.2 Inadequate infrastructure

Speed breeding platforms require sophisticated infrastructure to regulate environmental factors, particularly soil moisture, temperature, and photoperiod. Institutional support is limited in public plant breeding programs in many developing countries. For the selection of traits during early generation, special types of equipment are needed which is limited (Ribaut *et al*., 2010).

3.6.3 Cost

Speed breeding needs significant planning, initial investments in infrastructure, and operational costs. From an economic perspective, investments in breeding technology must consider both costs and benefits, with reversible and irreversible benefits (Lenaerts *et al*., 2019).

Table 5. Costs and benefits of speed breeding

	Reversible	**Irreversible**
Cost	Operational costs	Infrastructure investment
Benefit	Increased rate of genetic gain More responsive release of varieties	Avoid long-term detrimental impact of hunger on human development

(Source: Lenaerts *et al*., 2019)

3.6.4 Unreliable water and electricity supplies for sustainable operations

Speed breeding needs reliable water and electricity sources. As the management of temperature and photoperiod is crucial for it, unreliable electricity is a major problem here. In developing countries, it will require innovative solutions such as the use of sustainable solar power (Wanga *et al*., 2021). A small indoor speed breeding kit consisting of LED lights and temperature controls powered by a solar system with battery backup could be developed using existing technologies (Wanga *et al*., 2021).

3.7 Potential benefits of speed breeding for food security

The current population of 7.6 billion people on earth is estimated to increase to about 10 billion by 2050 (Snowdon *et al*., 2019). With this rapid population growth, the world has become increasingly urbanized, and the ratio of food producers to food consumers has significantly declined. Between 2000 and 2020, agricultural land declined by 134 million ha (FAO, 2022). But hunger is still on the rise, with almost 770 million people unnourished, 46 million more than in 2020, and 150 million more than in 2019 (FAO, 2022). It will be impossible to raise production with present crop varieties and farming methods to meet the predicted 70% growth in demand for plant-based products over the next three to four decades (Bhatta *et al*., 2021).

Developing new crop varieties with higher yields or better biotic and abiotic resistance can take one or two decades because of the many steps of breeding program. Any crop improvement program requires the following steps: (a) selection of desirable parents with complementary traits to be combined; (b) crosses involving the selected parents and the development of progenies; (c) selection and genetic advancement of the best progenies based on target traits; (d) selection of the best progenies for screening in multiple target production environments to identify the best performing and stable candidate cultivars; and (e) cultivar registration, seed multiplication, and distribution to growers (Shimelis & Laing, 2012). Technologies that reduce the length of the breeding cycle are critical for achieving this goal. Yet, a viable answer to this problem is speed breeding technology. As it produces multiple generations in a year, the total yield will be higher than in normal farming, which will ensure more food for the growing population. It can also help address climate change by producing crops that are better adapted to changing environmental conditions. Overall, speed breeding offers an innovative approach to plant breeding that has the potential to significantly improve global food security.

CHAPTER IV

CONCLUSION

Several methods of speed breeding have proven successful for different crops; faster vegetative growth was seen in crops, and anthesis was recorded approximately half as often in speed breeding conditions than in normal conditions. Improving the low-cost, homemade growth chamber conditions may increase the availability of this technology.

Speed breeding has accelerated the breeding programs of many economically important crops, like cereals, legumes, and oilseed crops, as well as different vegetable crops. Among them wheat, lentil and chickpea were the most benefitted crops as they can produce 7-8 generation per year. Vegetable crops like amaranth and tomato showed the highest potential to grow in speed breeding. Further research needs to be conducted in fruit trees. Likewise, because it allows for the development of crops that are better adapted to changing environmental conditions, speed breeding can play a critical role in mitigating the impact of climate change on agriculture.

Speed breeding has the ability to produce multiple generations of crops in a single year and breed plants with desirable traits faster. Integrating it with various modern technologies can help accelerate the breeding process, but more participation from plant breeders and adequate infrastructure are needed for implementing speed breeding on a broad scale. However, it has the potential to contribute to a more sustainable and secure food system and address global food security challenges.

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