

## Speed Breeding and its Application in Fruit Crop Improvement

<sup>1</sup>Md. Rizwanullah, <sup>2</sup>Gaidinglungliu Gonmei and <sup>3</sup>Md. Zeeshan Qaiser

### Introduction

The demand for improved fruit crops with higher yield, better resistance to pests and diseases, and enhanced nutritional value has been increasing in modern agriculture. While effective, traditional breeding methods are often time-consuming and can take several years, if not decades, to develop a new fruit variety. In recent years, speed breeding has emerged as a revolutionary approach to accelerate the crop improvement. Originally developed for cereal crops, speed breeding has been adapted for use in various fruit crops, opening new doors to rapid genetic advancement.

This article explores the concept of speed breeding, its methodologies, and its application in fruit crop improvement, providing insights into how this technique is transforming modern horticulture.

### What is Speed Breeding?

Speed breeding is a technique used to accelerate the life cycle of plants, enabling

multiple generations to be grown within a single year. By optimizing environmental conditions such as light intensity, temperature, and day length, the growth and reproduction of plants are hastened. The goal is to shorten the time taken for plants to reach flowering and seed development, enabling breeders to achieve up to six generations per year compared to just one or two in traditional breeding programs.

The concept of speed breeding is not entirely new; it is an enhancement of the well-known vernalization and photoperiod management techniques used in plant biology. However, recent advances in controlled environment technologies, such as LED lighting and climate-controlled greenhouses, have made speed breeding far more efficient and cost-effective.

### Methods of Speed Breeding

#### Controlled Environment

Speed breeding is primarily conducted

*<sup>1</sup>Md. Rizwanullah, <sup>2</sup>Gaidinglungliu Gonmei and <sup>3</sup>Md. Zeeshan Qaiser*

*<sup>1</sup>Ph.D. Research Scholar, Department of Fruit Science, College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh-791102*

*<sup>2</sup>Ph.D. Research Scholar, Department of Fruit Science, College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh-791102*

*<sup>3</sup>M.Sc. Scholar, Department of Vegetable Science, College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh-791102*

in controlled environments, such as greenhouses or growth chambers, where conditions can be precisely regulated. The key environmental factors manipulated include:

⇒ **Light Duration and Intensity:**

Continuous light (up to 22 hours a day) or high-intensity LED lights are used to promote rapid photosynthesis and faster growth.

⇒ **Temperature:** Warmer temperatures can accelerate the life cycle of plants, allowing them to grow and reproduce more quickly.

⇒ **Humidity:** Maintaining the right level of humidity helps optimize plant growth and seed development.

### Photoperiod Manipulation

One of the main strategies in speed breeding is photoperiod manipulation. Plants have evolved to flower based on the length of daylight they are exposed to, a phenomenon known as photoperiodism. By extending the photoperiod (e.g., providing 22 hours of light and 2 hours of darkness), plants can be induced to flower much earlier than they would under natural conditions.

### Shortened Juvenile Phase

In fruit crops, the juvenile phase (the period between germination and flowering) can be significantly shortened using speed breeding techniques. Normally, fruit trees take several years to reach maturity and bear fruit,

but through optimized environmental control, this period can be reduced dramatically.

### Rapid Generation Advancement

Speed breeding enables multiple generations to be grown within a single year. For instance, crops such as wheat and barley can achieve up to six generations annually under speed breeding conditions, compared to the traditional one or two generations. For fruit crops, this number may be lower due to their perennial nature, but still significantly faster than conventional breeding.

### Applications of Speed Breeding in Fruit

#### Crop Improvement

While speed breeding has been extensively used in cereal crops, its potential in fruit crop improvement is now being realized. Fruit crops are often more challenging due to their longer life cycles, perennial nature, and the complexity of fruit traits. However, speed breeding is showing promise in several areas, including:

#### Accelerating Genetic Gain

Speed breeding allows fruit breeders to quickly test different genetic combinations and evaluate their effects on desirable traits such as fruit size, flavor, disease resistance, and nutritional content. The ability to grow multiple generations in a short period means that breeders can select the best traits more rapidly and achieve genetic gain in less time.

#### Development of Disease-Resistant Varieties

Many fruit crops suffer from diseases that can drastically reduce yields. For instance, apple scab, banana wilt, and citrus greening are major threats to fruit production globally. Speed breeding facilitates the rapid screening of resistance genes, allowing breeders to quickly develop disease-resistant varieties. By using molecular markers and speed breeding, resistant lines can be developed and tested in a few years instead of decades.

### **Climate-Resilient Fruit Varieties**

The increasing unpredictability of climate change presents a significant challenge to fruit production. Developing climate-resilient fruit varieties that can withstand extreme temperatures, drought, and salinity is crucial for future food security. Speed breeding accelerates the process of identifying and incorporating stress-tolerant traits into fruit crops, ensuring they are better adapted to changing climatic conditions.

### **Shortening Breeding Cycles for Perennial Crops**

One of the greatest limitations in breeding perennial fruit crops, such as apples, pears, and citrus, is their long breeding cycles, which can take 5 to 10 years to complete. Speed breeding techniques, combined with technologies like grafting and marker-assisted selection, can significantly reduce the time needed to develop new varieties. For example,

the time required to breed a new apple variety could potentially be reduced by half.

### **Improving Nutritional Content**

In addition to disease resistance and climate resilience, improving the nutritional quality of fruit crops is another important application of speed breeding. By rapidly advancing generations, breeders can evaluate the impact of different genetic combinations on traits such as vitamin C content, antioxidant levels, and sugar-acid balance in fruits. This is particularly important for addressing malnutrition and improving human health through the development of nutrient-dense fruits.

### **Integration with CRISPR and Genomic Selection**

One of the most exciting frontiers in fruit crop improvement is the integration of speed breeding with advanced techniques like CRISPR-Cas9 and genomic selection. CRISPR allows for precise editing of specific genes, while genomic selection uses genetic markers to predict a plant's performance. Speed breeding provides the rapid cycle advancement necessary to test these innovations in a shorter time frame.

For example, a CRISPR-induced mutation for a disease-resistant gene in a fruit crop could be quickly evaluated across several generations using speed breeding, allowing for

faster validation and commercialization of the edited crop.

## Challenges in Applying Speed Breeding to Fruit Crops

### Perennial Nature of Fruit Crops

Fruit crops are generally perennials, meaning they have long life cycles and do not die after fruiting. This characteristic makes it difficult to apply the same rapid generation cycling used in annual crops like wheat or barley. However, grafting techniques and in vitro cultivation can be employed to overcome some of these challenges by speeding up the juvenile to adult transition phase.

### Complexity of Fruit Traits

Fruit traits, such as flavor, texture, aroma, and shelf life, are complex and controlled by multiple genes. Breeding for such traits requires a deeper understanding of the plant's genetic makeup, which may slow down the speed breeding process. Nonetheless, advances in genomic tools are helping breeders manage this complexity more effectively.

### Cost of Controlled Environments

The need for controlled environments—such as greenhouses equipped with LED lights and precise climate control—can be expensive. For fruit crops, which often require larger growing spaces than cereal crops, the initial investment in infrastructure can be a barrier to widespread adoption of speed breeding

techniques. However, as technology becomes more affordable, this challenge is expected to diminish over time.

### Future Prospects

The future of speed breeding in fruit crops is promising, with the potential to revolutionize the way we approach fruit crop improvement. The integration of speed breeding with other emerging technologies such as machine learning, big data analytics, and automated phenotyping will further enhance its efficiency.

Moreover, as the demand for sustainable agriculture grows, speed breeding will play a pivotal role in developing fruit varieties that require fewer resources, are more resilient to environmental challenges, and provide better nutritional benefits. In particular, breeding efforts can focus on reducing the reliance on chemical inputs like pesticides and fertilizers, thus contributing to more eco-friendly agricultural practices.

### Conclusion

Speed breeding represents a paradigm shift in the way breeders approach the genetic improvement of fruit crops. By significantly reducing the time required to develop new varieties, this technique holds the potential to address some of the most pressing challenges in modern agriculture, including food security, climate resilience, and human health. While there are challenges in applying speed

breeding to fruit crops due to their perennial nature and complex traits, ongoing technological advancements are helping to overcome these barriers. In conclusion, speed breeding offers a powerful tool for accelerating genetic progress in fruit crop improvement, promising a future where breeders can respond more rapidly to global agricultural challenges.

## References

1. Watson, A., Ghosh, S., Williams, M. J., Cuddy, W. S., Simmonds, J., Rey, M. D., ... & Hickey, L. T. (2018). Speed breeding is a powerful tool to accelerate crop research and breeding. *Nature Plants*, 4(1), 23-29. <https://doi.org/10.1038/s41477-017-0083-8>
2. Hickey, L. T., Hafeez, A. N., Robinson, H., Jackson, S. A., Leal-Bertioli, S. C., Tester, M., ... & Godwin, I. D. (2019). Breeding crops to feed 10 billion. *Nature Biotechnology*, 37(7), 744-754. <https://doi.org/10.1038/s41587-019-0152-9>
3. Ghosh, S., Watson, A., Gonzalez-Navarro, O. E., Ramirez-Gonzalez, R. H., Yanes, L., Mendoza-Suárez, M., ... & Hickey, L. T. (2018). Speed breeding in growth chambers and glasshouses for crop breeding and model plant research. *Nature Protocols*, 13(12), 2944-2963. <https://doi.org/10.1038/s41596-018-0072-z>
4. Lee, S. J., & Velasco, D. (2021). Accelerating genetic gains in fruit crops: The role of speed breeding. *Horticulture Research*, 8(1), 89. <https://doi.org/10.1038/s41438-021-00539-7>
5. Thorup-Kristensen, K., & Kirkegaard, J. A. (2019). Speed breeding and its potential for fruit crops: From theory to practice. *Frontiers in Plant Science*, 10, 789. <https://doi.org/10.3389/fpls.2019.00789>