

Rootstock Revolution in Fruit Crops: The Hidden Game Changer

**Pujarani Rath¹,
Rutuja Sanjay Kadu²,
Ritthe Rupali Dattarao³,
B Tamishra⁴ and
Shibangi Ray⁵**

¹Ph.D Scholar, Department of Fruit Science and Horticulture Technology, College of Agriculture, OUAT, Bhubaneswar, Odisha

²M.Sc Scholar, Department of Horticulture (Fruit science), Dr. Balasaheb sawant konkan krishi Vidyapeeth, Dapoli

³Assistant Professor, Department of Horticulture, College of Agriculture Selu Dist. Parbhani Maharashtra (BCOA Selu).

⁴Ph.D Scholar, Department of Fruit Science and Horticulture Technology, College of Agriculture, OUAT, Bhubaneswar

⁵PhD Scholar, Department of Fruit Science and Horticulture Technology, College of Agriculture, OUAT, Bhubaneswar



Open Access

*Corresponding Author

Pujarani Rath*

Available online at
www.sunshineagriculture.vitalbiotech.org

Article History

Received: 25. 2.2026

Revised: 1. 2.2026

Accepted: 5. 3.2026

This article is published under the terms of the [Creative Commons Attribution License 4.0](https://creativecommons.org/licenses/by/4.0/).

INTRODUCTION

Fruit crops constitute an essential component of global agriculture and play a significant role in ensuring food security, nutritional balance, and rural livelihood generation. They provide essential vitamins, minerals, dietary fiber, and bioactive compounds that contribute to human health and well-being. Globally, the demand for fruits continues to increase due to growing populations, rising incomes, and greater awareness of the health benefits associated with fruit consumption. However, fruit production is increasingly confronted with multiple challenges such as climate change, soil degradation, limited availability of fertile land, water scarcity, and the prevalence of pests and diseases. These constraints significantly affect orchard productivity, fruit quality, and the long-term sustainability of fruit production systems.

To address these challenges, horticulturists have widely adopted grafting technology, which is one of the most important vegetative propagation techniques used in fruit crops. Grafting involves the union of two different plant parts: the scion and the rootstock. The scion represents the upper part of the plant that determines the fruit characteristics such as flavor, size, and color, while the rootstock forms the root system and largely determines the plant's adaptability to soil and environmental conditions. The selection of an appropriate rootstock is therefore critical because it can significantly influence the overall growth, productivity, and survival of the grafted plant.

Rootstocks have been found to affect several important traits including tree size and vigor, yield efficiency, fruit quality, nutrient and water uptake, resistance to pests and diseases, and tolerance to adverse environmental conditions.

In recent decades, the concept of rootstock selection has revolutionized orchard management practices. Modern rootstocks are specifically developed to regulate tree architecture, reduce tree size, and facilitate high-density planting systems that maximize productivity per unit area. High-density orchards allow better canopy management, improved light interception, early fruiting, and increased mechanization possibilities. Consequently, rootstocks are now regarded as a hidden but powerful tool in fruit crop improvement and sustainable orchard management.

2. Concept of Rootstock

A rootstock refers to the lower portion of a grafted plant that provides the root system and serves as the foundation for the grafted scion variety. The rootstock not only anchors the plant in the soil but also plays a critical role in determining the plant's physiological performance and adaptability to different environmental conditions. Through grafting, desirable scion cultivars with superior fruit quality can be combined with rootstocks possessing beneficial traits such as disease resistance, drought tolerance, or controlled vigor. Rootstocks significantly influence various aspects of plant growth and development, including vegetative vigor, canopy architecture, nutrient uptake efficiency, fruit yield, and fruit quality. They also determine the plant's ability to tolerate unfavorable soil conditions such as salinity, alkalinity, and poor drainage. The interaction between rootstock and scion is highly complex and involves the exchange of water, nutrients, hormones, and signaling molecules between the root system and the aerial parts of the plant.

Rootstock–scion interactions regulate several physiological processes such as mineral nutrient transport, hormonal signaling, photosynthesis efficiency, carbohydrate metabolism, and stress response mechanisms.

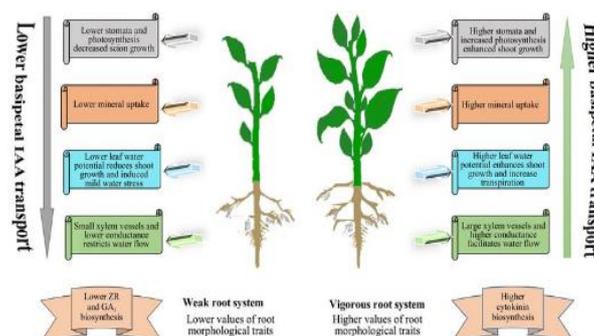
These interactions ultimately determine the overall performance and productivity of the grafted plant. Therefore, the choice of rootstock is a critical decision in orchard establishment and plays a vital role in determining the long-term success of fruit production systems.

3. Historical Development of Rootstocks

The use of rootstocks in horticulture dates back to ancient times when early farmers discovered that grafting could improve plant growth and fruit production. Historical evidence suggests that grafting was widely practiced in Mediterranean regions thousands of years ago for the propagation of fruit trees such as olives, figs, and grapes. However, the scientific understanding of rootstock–scion interactions began to develop much later with advancements in plant physiology and horticultural research.

A major milestone in the history of rootstock development occurred during the nineteenth century when European vineyards were devastated by the grape phylloxera pest. The crisis was eventually resolved by grafting European grape cultivars onto resistant American grape rootstocks, which successfully protected vineyards from the pest. This event highlighted the immense potential of rootstocks in controlling soil-borne pests and diseases.

During the twentieth century, extensive research efforts led to the development of dwarfing rootstocks, particularly in apple. These rootstocks allowed growers to control tree size, improve orchard management, and adopt high-density planting systems. In the twenty-first century, rootstock research has advanced significantly with the development of new rootstocks that offer improved tolerance to environmental stresses, enhanced nutrient uptake, and compatibility with modern intensive orchard systems. These developments have transformed rootstocks into a key component of sustainable fruit production.



4. Types of Rootstocks

Rootstocks can be classified based on various characteristics such as their method of propagation, growth vigor, and adaptability to environmental conditions. One of the primary classifications is based on the method of propagation, which includes seedling rootstocks and clonal rootstocks. Seedling rootstocks are produced from seeds and therefore exhibit genetic variability, which may lead to differences in plant growth and productivity. Although seedling rootstocks are generally vigorous and adaptable to diverse environmental conditions, their lack of uniformity may result in inconsistent orchard performance.

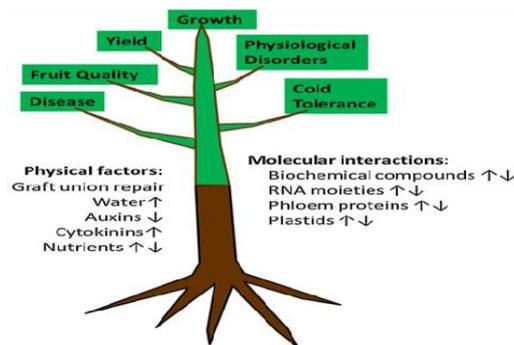
In contrast, clonal rootstocks are propagated vegetatively through methods such as cuttings, layering, or tissue culture. Because clonal rootstocks are genetically identical, they provide greater uniformity in growth, yield, and fruit quality. As a result, clonal rootstocks are widely used in modern commercial orchards.

Rootstocks can also be categorized based on their influence on tree vigor. Dwarfing rootstocks reduce tree size and promote early fruiting, making them ideal for high-density planting

systems. Semi-dwarfing rootstocks provide moderate growth and are suitable for medium-density orchards, while vigorous rootstocks produce large trees with extensive canopy growth and are typically used in traditional low-density orchards. The selection of rootstock type depends on several factors including crop species, soil conditions, climate, and orchard management practices.

5. Physiological Role of Rootstocks

Rootstocks exert a profound influence on plant physiology and play a central role in regulating the growth and productivity of grafted fruit trees. One of the most important functions of rootstocks is their ability to influence the absorption and transport of water and mineral nutrients from the soil to the aerial parts of the plant. Rootstocks differ significantly in their root architecture, root density, and nutrient uptake efficiency, which can affect the availability of essential nutrients such as nitrogen, phosphorus, potassium, calcium, and magnesium. Efficient rootstocks enhance nutrient uptake and utilization, thereby improving plant growth, yield, and fruit quality.



Another important physiological role of rootstocks is the regulation of plant hormone synthesis and transport. Hormones such as auxins, cytokinins, gibberellins, and abscisic acid are produced in both rootstocks and scions and play a crucial role in controlling plant growth and development. Rootstocks can influence the hormonal balance within the grafted plant, which in turn affects processes such as shoot elongation, flowering, fruit set, and fruit development.

Rootstocks also have a significant impact on fruit quality attributes including fruit size, color, sugar content, firmness, and storage life. Differences in rootstock characteristics can alter

the physiological and metabolic processes in the scion, leading to variations in fruit quality. For instance, studies in apple have demonstrated that different rootstocks can significantly influence fruit size, coloration, soluble solids content, and overall fruit marketability.

6. Rootstocks for Biotic Stress Resistance

One of the most valuable contributions of rootstocks to fruit crop production is their ability to provide resistance against various biotic stresses. These include soil-borne pathogens, nematodes, insects, and other pests that can severely damage the root system and reduce plant productivity. By selecting rootstocks that possess genetic resistance to specific pests or

diseases, growers can effectively protect their orchards and reduce the need for chemical pesticides.

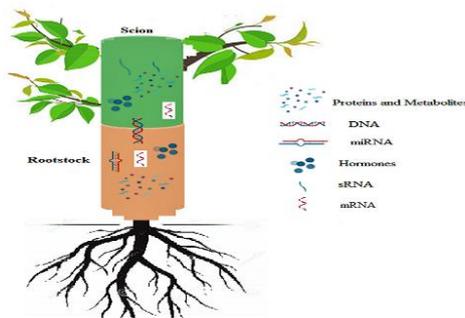
For example, certain apple rootstocks such as MM-111 exhibit resistance to woolly apple aphid, while grape rootstocks like Dogridge provide protection against phylloxera and nematodes. In citrus cultivation, rootstocks such as Cleopatra mandarin are known for their tolerance to salinity and resistance to certain soil pathogens. Similarly, mango rootstocks such as Olour are valued for their ability to withstand soil-related stresses and improve plant adaptability.

The use of disease-resistant rootstocks not only enhances orchard productivity but also contributes to environmentally sustainable agriculture by reducing reliance on chemical control measures.

7. Rootstocks for Abiotic Stress Tolerance

In addition to biotic stress resistance, rootstocks play a crucial role in helping fruit crops tolerate adverse environmental conditions. Climate change has increased the frequency and severity of environmental stresses such as drought, salinity, flooding, and temperature extremes. These stresses can significantly affect plant growth, reduce fruit yield, and compromise fruit quality.

Stress-tolerant rootstocks can improve plant resilience by enhancing water-use efficiency, maintaining physiological stability under stress conditions, and regulating nutrient uptake. For example, certain grape rootstocks are known for their drought tolerance, while citrus rootstocks have been developed to withstand saline soils. Similarly, rootstocks with improved tolerance to waterlogging can be used in areas prone to flooding or poor drainage.



The development and adoption of abiotic stress-tolerant rootstocks are therefore essential for ensuring the sustainability of fruit production in the face of changing climatic conditions.

8. Role of Rootstocks in High-Density Planting

High-density planting systems have become increasingly popular in modern fruit orchards due to their ability to maximize productivity per unit area. These systems involve planting a large number of trees per hectare while maintaining smaller tree size and efficient canopy structure. Rootstocks play a key role in enabling high-density orchards by controlling tree vigor and promoting compact plant growth.

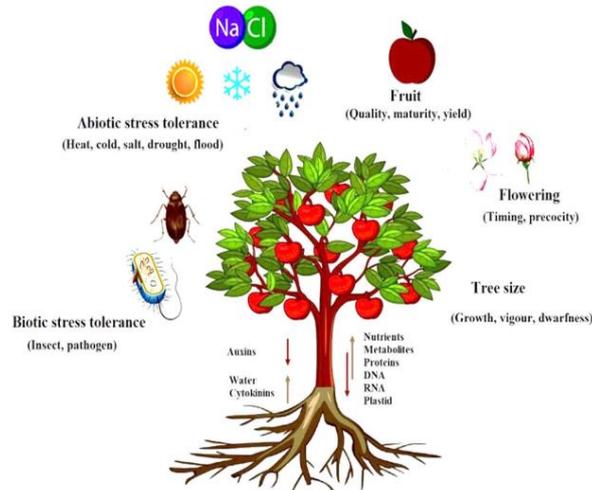
Dwarfing rootstocks are particularly important in this context because they reduce tree height and canopy spread, allowing more trees to be planted within a given area. In some intensive orchard systems, the planting density may range from 1000 to 4000 trees per hectare. High-density orchards offer several advantages including early fruit production, improved light interception, better air circulation, easier

harvesting, and enhanced suitability for mechanized operations. As a result, the use of dwarfing rootstocks has significantly transformed commercial fruit production systems.

9. Rootstocks in Major Fruit Crops

Rootstocks are widely used in several fruit crops including apple, citrus, grapes, and mango. In apple cultivation, rootstocks such as M9, M26, and MM111 are commonly used due to their ability to control tree vigor and improve productivity. M9 is a dwarfing rootstock that promotes early fruiting and high yield efficiency, whereas M26 provides semi-dwarf growth. MM111 is a vigorous rootstock suitable for traditional orchards.

In citrus cultivation, rootstocks such as Rough lemon, Trifoliate orange, and Cleopatra mandarin are widely used. Rough lemon is known for its vigorous growth, while Trifoliate orange provides cold tolerance and disease resistance. Cleopatra mandarin is particularly valued for its tolerance to saline soils.



In grape cultivation, rootstocks such as Dogridge, 110R, and 99R are commonly used to improve resistance to nematodes, drought, and soil-related stresses. Similarly, in mango production, rootstocks such as Olour, Kurukkan, and Vellaikolamban have been used to enhance nutrient uptake, improve plant vigor, and increase adaptability to different soil conditions. Research has shown that rootstocks can influence carbohydrate accumulation, nutrient distribution, and overall scion performance in mango.

10. Rootstock Breeding Programs

Rootstock breeding programs aim to develop improved rootstocks that possess desirable traits such as disease resistance, stress tolerance, controlled vigor, and compatibility with commercially important scion cultivars. Traditional breeding methods involve hybridization and selection of superior genotypes, followed by long-term field evaluation.

In recent years, modern breeding techniques such as clonal selection, marker-assisted selection, and molecular breeding have accelerated the development of improved rootstocks. Advances in plant biotechnology have also opened new possibilities for genetic engineering and genome editing, which can be used to introduce specific traits into rootstocks more efficiently.

11. Challenges in Rootstock Research

Despite their importance, rootstock research faces several challenges. One of the major challenges is the long evaluation period required to assess rootstock performance under different environmental conditions. Compatibility issues between rootstocks and scions can also limit the adoption of certain rootstock varieties. In addition, environmental variability and limited

availability of diverse germplasm resources can hinder the development of improved rootstocks. A deeper understanding of the molecular and physiological mechanisms underlying rootstock–scion interactions is therefore essential for future progress in this field.

12. Future Prospects

The future of rootstock development is closely linked to advancements in plant genetics, biotechnology, and precision agriculture. Emerging technologies such as genomic breeding, marker-assisted selection, and CRISPR-based gene editing offer new opportunities for developing climate-resilient rootstocks with enhanced productivity and stress tolerance. Furthermore, the integration of rootstock technology with modern orchard management practices and precision agriculture tools can help optimize resource use and improve fruit production efficiency.

CONCLUSION

Rootstocks have emerged as a transformative component of modern fruit production systems. By influencing plant growth, yield potential, stress tolerance, and fruit quality, rootstocks play a vital role in improving orchard productivity and sustainability. Continued research and innovation in rootstock breeding and biotechnology will further expand their potential to address future challenges in horticulture. The strategic use of improved rootstocks therefore represents a promising pathway toward achieving sustainable and climate-resilient fruit production systems.

REFERENCES

Dhurve, L., Mathew, D., Kumar, A., Joseph, A. V., & Mehara, H. (2023). Rootstocks:

- importance in fruit crop improvement. *Int J Environ Clim Change*, 13(11), 4479-4490.
- Gautier, A. T., Chambaud, C., Brocard, L., Ollat, N., Gambetta, G. A., Delrot, S., & Cookson, S. J. (2019). Merging genotypes: graft union formation and scion–rootstock interactions. *Journal of Experimental Botany*, 70(3), 747-755.
- Keller, M. (2020). *The science of grapevines*. Academic press.
- Roberto, S. R., Novello, V., & Fazio, G. (2025). New rootstocks for fruit crops: breeding programs, current use, future potential, challenges and alternative strategies, volume II. *Frontiers in Plant Science*, 16, 1718492.
- Valverdi, N. A., & Kalcsits, L. (2021). Rootstock affects scion nutrition and fruit quality during establishment and early production of ‘Honeycrisp’ apple. *HortScience*, 56(2), 261-269.
- Vittal, H., Sharma, N., Dubey, A. K., Shivran, M., Singh, S. K., Meena, M. C., ... & Sharma, R. M. (2023). Rootstock-mediated carbohydrate metabolism, nutrient contents, and physiological modifications in regular and alternate mango (*Mangifera indica* L.) scion varieties. *PLoS One*, 18(5), e0284910.
- Warschefsky, E. J., Klein, L. L., Frank, M. H., Chitwood, D. H., Londo, J. P., von Wettberg, E. J., & Miller, A. J. (2016). Rootstocks: diversity, domestication, and impacts on shoot phenotypes. *Trends in plant science*, 21(5), 418-437.