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Market-Driven Pomological Innovations in Sweet Oranges and Mandarins Cultivation

(*Nishchala, Shashi K. Sharma, Aashima Sharma)
Department of Fruit Science, Dr. Yashwant Singh Parmar University of Horticulture & Forestry, Neri, Hamirpur, Himachal Pradesh (177 001), India
*Corresponding Author's email: nishchala123arya@gmail.com

Citrus fruits are a cornerstone of global agriculture, thriving predominantly in tropical and subtropical regions between latitudes 40°N and 40°S. Among the citrus species, sweet oranges *(Citrus sinensis*) and mandarins (*Citrus reticulata*) are particularly significant due to their economic value and widespread consumption. These fruits are not only integral to the agricultural economies of many countries but also form a crucial part of the daily diet for millions of people worldwide. Sweet oranges and mandarins, while similar in certain respects, have distinct characteristics that cater to different market niches. Sweet oranges are known for their larger size, thicker peel, and balanced sweet-tart flavor, making them popular for fresh consumption and juice production. Mandarins, on the other hand are favored for their smaller size, easy peelability, and sweet taste making them a convenient and healthy snack, particularly popular among children and health-conscious consumers.

In India, the citrus industry is predominantly driven by mandarins, followed by sweet oranges and limes. The country's citrus production plays a vital role in its agricultural sector, providing livelihoods to millions of farmers. With India's population projected to reach 1.45 billion by 2030, the demand for citrus fruits is expected to increase significantly, almost 1.5 times the current levels. This growing demand necessitates strategic interventions to ensure the sustainability and profitability of citrus cultivation. To meet the increasing market demand and enhance the profitability of citrus fruits, particularly sweet oranges and mandarins, specific pomological interventions are essential. Pomology, the science of fruit cultivation, encompasses various practices aimed at improving fruit quality, yield, and marketability. These interventions include varietal improvement, optimized cultural practices, and advanced post-harvest handling techniques, all tailored to the unique characteristics and market demands of sweet oranges and mandarins.

This article explores targeted pomological strategies to enhance their production and marketability, addressing the need for market-oriented approaches to ensure the sustained growth and success of the citrus industry. By aligning production practices with consumer preferences and market trends, growers can effectively meet the rising demand and secure a competitive edge in the global citrus market.

Global scenario of Mandarins and Sweet Oranges

The global scenario for sweet oranges and mandarins highlights distinct production and consumption trends. Sweet oranges are among the most widely cultivated and consumed fruits worldwide. Major producers include Brazil, the United States, China, India, and Mexico. Brazil leads the world in sweet orange production, primarily due to its extensive juice processing industry. However, Egypt holds the title for the largest exporter of sweet oranges. In contrast, China is the largest producer of mandarins, with a significant portion

consumed domestically. Spain and Turkey are notable exporters of mandarins, supplying substantial volumes to European markets. In India, the citrus industry is predominantly driven by mandarins, with a production of 6.35 million metric tons in 2022-2023, compared to 3.63 million metric tons of sweet oranges. The higher demand for mandarin oranges in India is evident from these production figures, making mandarins the most produced citrus fruit in the country. Regions like Maharashtra and Madhya Pradesh are major producers of mandarins, particularly the popular Nagpur mandarin variety.

Constraints in Mandarins and Sweet Oranges production

Farmers in India face several constraints in the production of sweet oranges and mandarins. Firstly, there is a lack of good quality seedlings available in sufficient quantity, which hampers the establishment of robust orchards. Additionally, the non-availability of labor during peak periods and the lack of skilled labor for training and pruning further exacerbate production challenges. Farmers also struggle with the timely availability of well-decomposed farmyard manure (FYM) and face high costs of pesticides, making pest management expensive. Inadequate or non-existent irrigation facilities compound the problem, leading to water stress in orchards. The absence of a regulated market limits farmers' ability to secure fair prices for their produce. Furthermore, a lack of the latest technical knowledge and insufficient finance and credit facilities hinder the adoption of improved agricultural practices. Finally, the non-availability of cold storage facilities results in significant post-harvest losses, reducing the overall profitability of sweet orange cultivation. Addressing these issues is crucial for enhancing productivity and ensuring sustainable growth in the sweet orange industry in India.

Market Oriented Pomological Interventions

To address these challenges and enhance the production and marketability of sweet oranges and mandarins, several pomological interventions are necessary

Micropropagation for evaluation of new citrus somatic hybrid rootstocks

Micropropagation in vitro can speed up the evaluation of new hybrids and even be used as tool for commercial propagation. The development of somatic hybridization technology by protoplast fusion in citrus has helped approaching goals that seemed unattainable using conventional breeding technologies, it helps to combine the characteristics of the best genotypes, and overcoming barriers of sexual incompatibility.

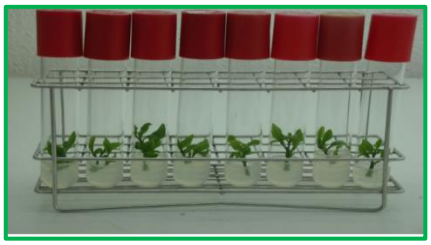

Fig.1 Micropropagation

Shoot tip grafting technique

Micrografting is a in vitro grafting technique which involves the placement of a meristem or shoots tip explant into a decapitated rootstock that has been grown aseptically from seed or micropropagated cultures.

It aims at:

- Mass production of virus free plants in citrus.
- To produce true to type precocious plants.
- Prediction of incompatibility between the grafting partners.
- Virus indexing.
- Safe Germplasm exchange between countries

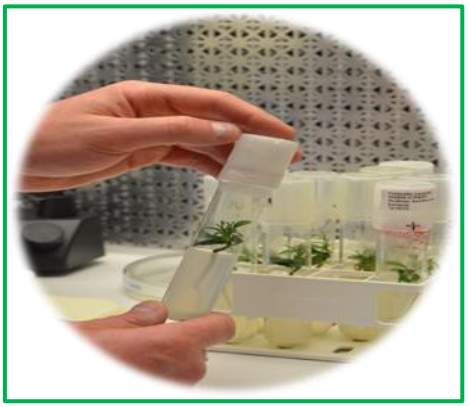

Fig.2 Shoot tip grafting

Viral dwarfing

Viral dwarfing technique is a promising approach in the search of small trees suitable for high-density planting.

Plant dwarfism has been associated with several viruses and viroids. Specifically, the citrus exocortis viroid (CEVd) appears to induce dwarfism in citrus plants by raising the hydraulic resistance aboveground. Moreover, the symptoms caused by Citrus Dwarfing Viroid (CDVd) are influenced by the rootstock, variety, and species of citrus hosts. Research on Navel Orange trees grafted onto 'trifoliate' orange rootstock has demonstrated that CDVd infection results in a stunting phenotype, reducing the canopy volume by approximately 50%.

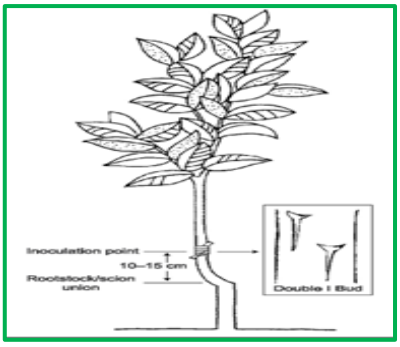

Fig.3 Viral dwarfing

Nutrient Constraints Remediation

Remediating nutrient constraints in citrus involves a systematic approach beginning with comprehensive soil and leaf analyses to identify specific deficiencies or imbalances. Once deficiencies are pinpointed, a targeted fertilization program is devised. This program includes the application of appropriate fertilizers in suitable forms and quantities, adjusted throughout the growing season to meet the trees' changing needs. Various techniques involved in Nutrient constraints remediation are fertigation, foliar fertilization, tailoring of fertilizer requirement and site specific nutrient management. Integrating these practices not only addresses current nutrient limitations but also supports sustainable orchard management for long-term productivity and health.

- **Fertigation:** Fertigation (application of nutrients through the irrigation) has still produced better results in improving the tree growth, fruit yield, quality, the reserve pool of soil nutrients, and consequently, the plant nutritional status. Besides the mobility of nutrients, fertigation has several advantages over broadcast application of granular fertilizers with respect to effective placement of nutrients and flexibility in application frequency, development of uniform root distribution, an important pre-requisite for better FUE, and improvement in fruit quality.
- **Foliar Fertilization**: Plants can sometimes grow so rapidly that their roots cannot keep up with absorbing and transporting sufficient mineral nutrients to their leaves or developing fruits. To address this, foliar sprays can be beneficial. They help maintain optimal nutrient levels in the plant throughout the growing season by enhancing nutrient mobility.
- **Tailoring of fertilizer requirement**: Utilizing soil spatial variability is essential for customizing fertilizer needs within an orchard through the variable rate application technique. In this context, efforts were made to adjust the fertilizer requirements for citrus without increasing the overall dose of fertilizers.
- **Site Specific Nutrient Management**: Site-specific nutrient management is a dynamic concept. It does not imply that every time a crop is grown, all nutrients should be applied in a fixed proportion. Instead, fertilizer application should be tailored to the crop's needs, considering the soil's capacity to meet various demands. Achieving this requires maintaining an overall nutrient balance in relation to the total crop load (Srivastava and Singh, 2016). This approach may involve applying different nutrients at specific times and in a particular sequence to maximize the benefits from the given amount of nutrients.

Photoselective Netting

Photoselective netting is an innovative intervention designed to improve the yield and quality of citrus fruits, particularly in sweet oranges and mandarins. This technique involves covering orchards with nets that selectively filter sunlight, optimizing the light spectrum that reaches

the plants. The netting modifies the light environment by reducing excessive solar radiation and altering the light quality, which can significantly affect plant physiological responses.
Benefits of Photoselective Netting:

1. Enhanced Photosynthesis
2. Temperature Regulation:
3. Reduced Water Stress
4. Protection from Pests and Diseases
5. Improved Fruit Quality

Integrated Pest Management (IPM)

Adopting IPM practices can reduce the reliance on chemical pesticides, promoting a more sustainable approach to pest control. It involves a comprehensive approach using various organic components. The primary components include Horticultural Mineral Oil (HMO), Beauveria bassiana (BB), and Azadirachtin. This integrated strategy leverages the synergistic effects of mineral oil, biological control agents, and botanical insecticides to manage pests effectively while maintaining the ecological balance and reducing reliance on chemical pesticides.

Non-Destructive Methods for Quality Assessment

In recent years, the citrus industry has increased the need for fast, accurate and non-destructive tools for online/inline fruit quality assessment, monitoring and early detection of pathological decay. Here are some non-destructive methods commonly used for quality assessment in the citrus industry:

1. **Near-Infrared Spectroscopy (NIRS)**: NIRS is a rapid and non-destructive technique that measures the interaction of near-infrared light with citrus fruit. It can analyze the internal composition of fruit, including sugar content, acidity, and moisture content, which are important indicators of quality. NIRS can be used for both online and offline quality assessment.
2. **Visible/Near-Infrared Spectroscopy (VNIR)**: VNIR spectroscopy is another spectroscopic technique that measures the reflectance or absorbance of light in the visible and near-infrared regions of the electromagnetic spectrum. It can provide valuable information about citrus fruit quality parameters such as maturity, firmness, and sugar content.
3. **Digital Imaging Techniques**: Digital imaging techniques, including color imaging and hyperspectral imaging, can be used to assess external quality attributes such as size, shape, color, and surface defects of citrus fruit. These techniques are non-destructive and can provide rapid assessment of fruit quality.

Conclusion and Future thrusts

By implementing targeted pomological strategies, growers can enhance the production and marketability of sweet oranges and mandarins. Aligning cultivation practices with consumer preferences and market trends allows growers to meet rising demand and secure a competitive edge in the global market. Future research should focus on developing high-yield, disease-resistant cultivars, improved post-harvest technologies, and sustainable agronomic practices. Emphasizing precision agriculture and enhancing infrastructure for storage and market access will further bolster the citrus industry's growth. By addressing production constraints and adopting advanced techniques, the citrus sector can achieve sustained success, benefiting producers and consumers worldwide.

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