

Optimizing orchid cultivation:

Strategies for enhancing production and profitability

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Orchidaceae, one of the largest and most diverse flowering plant families, comprises approximately 28,000 species and over 100,000 cultivated hybrids, thriving in ecosystems ranging from tropical rainforests to arid regions. Orchids exhibit remarkable ecological adaptability, growing as epiphytes, lithophytes, or terrestrials, and rely on specific mycorrhizal fungi and specialized pollinators for survival and reproduction. This ecological specialization highlights their crucial role in maintaining biodiversity and ecosystem balance.

Keywords: Ecological adaptability, Ecosystem balance, Flowering plant

THE global market of orchids is a dynamic and rapidly expanding segment of the ornamental plant industry, driven by the exceptional diversity, adaptability, and aesthetic appeal of orchids. Their intricate floral structures and captivating beauty have cemented their status as one of the most valued groups of flowering plants, widely used in traditional and modern industries.

The market thrives on cultivating diverse varieties and

hybrids, catering to an increasing consumer preference for rare and exotic species, alongside standardized commercial varieties. The Asia-Pacific region dominates global orchid production and export, with Thailand, Taiwan, and China leading the industry. Thailand, in particular, has established itself as a major exporter, specializing in the mass cultivation of Dendrobium and other commercially significant species. Taiwan and Malaysia also play pivotal roles in supplying high-quality potted and cut orchids to international markets. In Europe, the Netherlands serves as a critical hub for orchid trade, excelling in the production, distribution, and re-export of both cut flowers and potted plants. Consumer trends indicate a growing interest in unique and exotic orchids. This rising preference is further supported by advancements in tissue culture and hybridization technologies, which enable large-scale production of uniform, disease-free plants and the development of novel hybrids with enhanced traits such as vibrant colours, prolonged shelf life, and resilience to environmental stresses.

India's position in the global orchid market

India has increasingly recognized orchids as a high-value crops, presenting significant economic opportunities, particularly in the northeast region. The rising demand for medicinal orchids in states like Sikkim and other north eastern States underscores their potential in both traditional and commercial markets. While India harbours a vast diversity of



orchid species, many with unique medicinal properties, their commercialization remains limited. Sustainable practices and conservation efforts must be prioritized to ensure biodiversity protection while fostering economic growth. Over the past decade, India has made substantial progress in orchid cultivation. The area under orchid farming expanded from just 10 hectares in 2012–2013 to 3,040 hectares in 2022–2023. Similarly, orchid cut flower production surged from 180 metric tonnes (MT) to 10,730 MT over the same period. Initially, orchid cultivation was concentrated in the northeast, with states like Assam, Mizoram, Meghalaya, and Sikkim covering 43 ha and producing 5,480 MT of cut flowers in 2013–2014. However, in recent years, cultivation has extended to Karnataka, Kerala, Madhya Pradesh, Telangana, Goa, and West Bengal, where orchids are grown for both cut flower and loose flower production.

While India has made notable contributions to orchid taxonomy, species discovery, and academic research, these efforts have not yet translated into substantial economic benefits. Unlike other nations that have successfully leveraged their orchid resources for large-scale commercial trade, India's orchid sector remains underdeveloped. To bridge this gap, a stronger focus on market-driven cultivation, large-scale commercial production, and integration into the global supply chain is essential. Without strategic interventions in breeding, tissue culture, and export infrastructure, India's orchid industry will continue to lag despite its rich biodiversity. By prioritizing research-driven innovation and aligning cultivation practices with international market standards, India has the potential to emerge as a significant player in the global orchid trade.

Selection of suitable orchid species and hybrids

- **Stress and climate adaptability:** Selection of orchids with resilience to abiotic and biotic stresses, ensuring sustainable cultivation across diverse environmental conditions.
- **Market and economic viability:** Selection based on demand for cut flowers, potted plants, and medicinal applications, with emphasis on high-yielding and commercially valuable species.
- **Growth, flowering, and post-harvest performance:** Preference for species with rapid growth, frequent blooming, extended shelf life, and high transportability.

Commercially viable orchid species

Orchids for cut flower production: *Cymbidium eburneum*, *Cymbidium ensifolium*, *Paphiopedilum hirsutissimum*, *Paphiopedilum insigne*, *Paphiopedilum venustum*, *Paphiopedilum villosum*, *Vanda coerulea*, *Vanda stangeana* and *Vanda tessellata*; along with intergenic hybrid groups such as *Mokara*, *Aranda* and *Arachnis*.

Orchids for potted plant industry: *Phalaenopsis*, *Oncidium*, *Miltonia*, *Cymbidium*, *Paphiopedilum*, *Dendrobium*, *Cattleya*, *Ascocenda*, *Vanda*, *Brassia*, *Epidendrum*, *Lycaste*, *Rhyncostylis*, *Renanthera*.

Optimal light and temperature requirements for orchids

Orchids have diverse light and temperature requirements depending on their genus.

- **Light requirements:** Cymbidiums thrive under bright morning sunlight and require varying light intensities across seasons, with mature plants needing 50–55% shade in hot weather. Dendrobiums prefer warm, bright light with at least 12–14 h of exposure daily, while Phalaenopsis can be cultivated indoors under artificial light, requiring 1000–1500 foot candles in winter and lower intensities in summer. Cattleyas and Oncidiums require moderate to bright light with 30–50% shade, whereas Vanda orchids demand high light levels, with shading requirements varying by leaf type. Paphiopedilum orchids grow best under low to medium light (60–70% shade).
- **Temperature:** Plays a crucial role in orchid growth and flowering. Cymbidiums tolerate temperatures as low as 7°C, with flowering initiated at 10–15°C, while Dendrobiums exhibit varied preferences based on species, ranging from cool-growing types (10–24°C) to warm-growing ones (22–32°C). Phalaenopsis thrives best at 26–27°C during growth and 19–21°C for flowering, with a minimum of 15°C in winter. Cattleya, Oncidium, and Paphiopedilum orchids have adaptable temperature ranges, though most require moderate warmth, with some Paphiopedilum hybrids tolerating up to 36°C. Vanda orchids, highly sensitive to cold, need warm temperatures year-round, with cylindrical types requiring a minimum of 16–17°C at night and flat-leaved types preferring 10–12°C in winter.
- **Humidity and watering requirements for orchids:** Proper water management is crucial for orchid cultivation, as overwatering leads to root rot and disease susceptibility. Most orchid species prefer water with a pH range of 5.0–6.5, with rainwater being optimal. Watering frequency varies with environmental factors, pot size, and substrate type. High humidity (50–80%) is essential for optimal growth and flowering, with misting, fogging, and companion plants aiding in humidity maintenance. Cymbidium requires year-round watering, while Dendrobium and Phalaenopsis perform best at 50–70% humidity. Oncidium watering depends on root morphology, with fleshy-rooted species requiring less frequent irrigation. Paphiopedilum requires 65–75% humidity, with gradual reduction in winter. Vanda orchids demand high humidity (70–75%) and frequent irrigation, especially in warmer months.

Potting media, containers, and repotting strategies

The selection of appropriate potting media, containers, and repotting techniques plays a crucial role in optimizing orchid growth, health, and productivity. Orchids thrive in well-draining, aerated substrates such as bark, sphagnum moss, charcoal, perlite, and coconut husk, which facilitate proper root respiration

and prevent waterlogging. The choice of media should align with species-specific requirements, environmental conditions, and cultivation systems. Equally important is the selection of containers, which should ensure adequate drainage and airflow. Regular repotting is necessary to replenish nutrients, remove decomposed media, and accommodate root expansion, ensuring sustained plant vigour and optimal flowering. Proper repotting techniques, including the use of sterilized tools, minimal root disturbance, and careful handling, contribute to faster recovery and growth.

Advanced cultivation techniques for yield optimization

Advancements in bioreactor-based micropropagation for orchid mass multiplication: Bioreactor technology has revolutionized large-scale orchid propagation by providing a controlled, sterile environment that enhances micropropagation efficiency. Temporary Immersion Bioreactor Systems (TIBs) have proven particularly effective in optimizing nutrient uptake, minimizing contamination risks, and ensuring uniform plantlet development. This approach accelerates the production of high-quality, market-ready plantlets while reducing labour and production costs. To maximize the benefits of bioreactor systems, future research should focus on species-specific optimization of key parameters such as nutrient composition, immersion cycles, and aeration strategies. The development of customized culture media tailored to different orchid species is crucial for improving seed germination and *in vitro* propagation. Refining protocols for recalcitrant species will enhance explant survival and genotype-specific responses, addressing challenges associated with their propagation.

Precision-controlled environment cultivation for orchid production: Polyhouse cultivation offers a controlled environment by regulating temperature, humidity, and light, ensuring optimal growth conditions for orchids. Automated irrigation and fertigation systems enhance resource efficiency by delivering precise amounts of water and nutrients, minimizing waste and improving plant health.

The integration of IoT-based real-time monitoring enables continuous tracking of environmental parameters, facilitating data-driven decision-making for cultivation optimization. Microclimate control strategies, including misting, shading, and ventilation, play a crucial role in maintaining stable growing conditions, reducing plant stress, and maximizing productivity.

In commercial orchid production, precision and digital farming technologies are instrumental in improving sustainability and efficiency. Real-time monitoring through remote sensing and drone-based assessments enables precise management of key environmental factors, directly influencing plant growth and yield. Advanced precision irrigation systems, supported by soil moisture sensors, ensure water is applied efficiently, optimizing plant hydration while



Phalaenopsis Orchid Biowall at ICAR-NRC for Orchids, Pakyong, Sikkim

preventing overwatering. Automated climate control systems further stabilize growth conditions, reducing labour requirements and mitigating environmental stress. AI-driven data analytics refine breeding strategies and resource management, while GIS-based mapping aids in strategic planning for both commercial expansion and conservation initiatives.

High-density planting: High-density planting and space optimization techniques enhance orchid cultivation efficiency by maximizing available space. Vertical farming systems allow orchids to be grown in stacked layers, optimizing land use. Multi-layered rack cultivation is particularly beneficial in controlled environments, increasing productivity per unit area. Hanging baskets are effective for epiphytic orchids like Vanda, promoting better aeration and growth. Additionally, emerging soilless cultivation methods such as aeroponics and hydroponics improve root aeration and nutrient uptake efficiency, further enhancing plant health and yield.

Nutrient management

Proper nutrient management is essential for optimal orchid growth and development. A balanced supply of nitrogen (N), phosphorus (P), and potassium (K) is required at different growth stages to support foliage, root, and flower development. The use of biofertilizers enhances soil microbiota, promoting nutrient absorption and sustainable cultivation. Slow-release fertilizers provide a steady nutrient supply, preventing excessive leaching and ensuring long-term plant health.

Post-harvest management and value addition

Effective post-harvest management is critical for maintaining quality and extending the marketability of orchids. Harvesting at the optimal bud initiation stage significantly prolongs vase life, preserving floral aesthetics and commercial value. Cold chain logistics, including vacuum pre-cooling and refrigerated transport, play a crucial role in minimizing post-harvest

losses by reducing ethylene production and microbial spoilage.

Beyond fresh flower markets, orchids offer significant potential for value addition. The extraction of bioactive compounds from orchids supports the development of perfumes, essential oils, and nutraceutical products, expanding commercial applications. Further, ongoing research into the pharmacological properties of highlights their potential applications in medicine, particularly in the development of novel therapeutics. Strengthening post-harvest protocols and value-chain strategies will enhance the economic sustainability of orchid cultivation while fostering innovations in product diversification.

Market-driven strategies for enhancing orchid trade:

Expanding the domestic orchid market requires strategic interventions to strengthen trade networks and improve market accessibility. Targeting high-demand regions such as Europe, Japan, and the Middle East can significantly enhance global market penetration. Establishing direct sales channels through supermarkets, florists, and e-commerce platforms streamlines distribution, ensuring better price realization for producers.

Furthermore, the adoption of fair-trade certification improves consumer confidence and facilitates entry into premium markets, aligning with sustainability and ethical trade standards. Digital marketing and branding play a crucial role in enhancing market visibility and consumer engagement. Leveraging e-commerce platforms and social media campaigns can increase accessibility and global outreach, fostering direct interaction with consumers. Strengthening

these market-driven approaches will boost trade opportunities, enhance profitability, and establish a sustainable commercial model for orchid cultivation.

SUMMARY

The future of orchid cultivation relies on the integration of advanced technologies, sustainable practices, and market-driven strategies to enhance productivity and profitability. Smart farming solutions, such as AI-based analytics, precision irrigation, and automated climate control, optimize resource utilization while improving efficiency. Biotechnological advancements, including micropropagation, somatic embryogenesis, and targeted breeding using genomic tools, accelerate the development of superior hybrids with desirable traits. Innovations in post-harvest management, such as advanced packaging, eco-friendly preservatives, and optimized cold storage, ensure extended vase life and reduced post-harvest losses. The adoption of digital marketing, e-commerce platforms, and participation in international trade fairs strengthens market reach, enabling better access to global consumers. Additionally, integrating value-added products like orchid-based perfumes, nutraceuticals, and floriculture tourism diversifies revenue streams, making orchid cultivation a more lucrative and sustainable enterprise. By optimizing production techniques and aligning with evolving market demands, the orchid industry can achieve greater efficiency, profitability, and long-term growth.

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