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Substrate Selection and Nutrient Supply for Greenhouse Strawberry Yield Optimization

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Abstract This study focuses on the combined effects of substrate selection and nutrient supply in greenhouse strawberry production, and provides a systematic analysis. It mainly discusses how different substrate types and nutrient management strategies influence plant growth, yield formation, and fruit quality. An ideal substrate should maintain a balance in physical structure, chemical buffering capacity, and biological activity, so as to ensure root aeration, water supply, and stable nutrient release. Coconut coir, peat, and their mixed substrates with perlite, vermiculite, and vermicompost show clear advantages in improving the rhizosphere environment, enhancing nutrient use efficiency, and optimizing fruit quality. Integrated water and fertilizer management based on dynamic regulation at different growth stages is a key measure to achieve high yield and good quality. By reasonably adjusting the proportions of elements such as N, K, and Ca, yield can be increased significantly, and the sugar-acid ratio and vitamin content can be improved. Sensor-based precise water and fertilizer management, together with recycling systems, can greatly improve water and nutrient use efficiency while reducing environmental pressure, without reducing yield. Substrate and nutrient supply should be optimized together, and combined with regional resource conditions and sustainability requirements, to build an efficient, stable, and environmentally friendly greenhouse strawberry production system.
Keywords Greenhouse strawberry; Soilless cultivation; Substrate optimization; Nutrient management; Water-fertilizer integration

1 Introduction

Strawberry (*Fragaria × ananassa* Duch.) is one of the most economically valuable soft fruits in modern horticulture, combining high economic returns with excellent nutritional and sensory quality. Strawberries are rich in vitamin C, polyphenols, and antioxidant compounds, making them an important part of a healthy diet and increasingly promoted as a functional food. Over the past two decades, global strawberry cultivation area and production have increased rapidly, and in many countries it has become one of the most profitable horticultural industries (Rahim Doust et al., 2023). Protected cultivation systems, including greenhouses, high tunnels, and other controlled environments, have played a key role in this expansion. These systems provide frost protection, extend the harvest period, stabilize yields, and improve control over major diseases and abiotic stresses, thus supporting industry growth (Samtani et al., 2019). Within these systems, the development of advanced cultivation techniques—especially soilless culture—has turned strawberry into a representative crop for intensive and urban horticulture, enabling high-density planting, off-season production, and more efficient use of resources (Nichols, 2021; Kouloumprouka Zacharaki et al., 2024).

Consumers now expect strawberries to be available year-round, with not only good appearance—uniform size, consistent color, and attractive shape—but also high sensory quality such as sweetness, aroma, and firmness, along with strong nutritional and functional value (Hernández-Martínez et al., 2023; Cardarelli et al., 2024). This shift in market demand has pushed breeding and production systems to focus more on varieties and cultivation practices that combine high yield with high internal quality. Key targets include improving soluble solids, organic acids, polyphenol content, and antioxidant capacity (Sturzeanu et al., 2025). By optimizing fertilization and water management, it is possible to enhance soluble solids, organic acid levels, color, and bioactive compounds while maintaining yield (Raffaelli et al., 2025).