Nutrient Management in Protected Conditions including Soilless Cultivations

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ABSTRACT

Protected cultivation, including greenhouses and polyhouses, offers a controlled environment for plant growth, overcoming challenges like improper nutrition and pest infestations. Soilless cultivation methods, such as hydroponics and aeroponics, have emerged as sustainable alternatives to traditional soil-based farming, providing precise control over nutrient delivery. Fertigation, the simultaneous application of water and nutrients through the irrigation system, plays a crucial role in nutrient management, ensuring improved crop performance and resource efficiency. Various nutrient delivery systems, including drip irrigation, substrate-based systems, and automated nutrient management systems, are utilized to optimize plant growth and productivity in protected cultivation. The composition of nutrient media is carefully calculated based on plant growth stage and atmospheric conditions, with essential fertilizers and micronutrients being utilized for proper plant nutrition. Overall, protected cultivation and soilless farming methods offer innovative solutions for achieving food security and meeting the needs of a rapidly

urbanizing world.

INTRODUCTION

As the global population is forecasted to reach 9.7 billion by 2050 and arable land continues to decrease annually, expected to reduce to 0.15 hectares per person by that time (U.N., 2022), the need for efficient resource management becomes increasingly critical. In light of these challenges, the need for protected cultivation has become increasingly apparent. However, nutrient management is pivotal for optimizing plant growth and productivity within protected cultivation systems like greenhouses and polyhouses. However, continuous cultivation under soil-based media within these controlled environments presents challenges such as improper nutrition, pest infestations, and soil compaction. To address these constraints, soilless media or substrates are often utilized, allowing for precise control over nutrient levels and promoting healthier plant growth. Soilless cultivation refers to a technique for plant growth devoid of soil as a medium for root anchorage, where essential inorganic nutrients are supplied through the irrigation water (Savvas *et al*., 2013). This method involves either utilizing a porous substrate, known as substrate culture soilless, or a nutrient solution devoid of any solid phase, termed liquid-culture soilless (Tüzel *et al*, 2019). Coconut fiber, mineral wool, pumice, and perlite emerge as the prevailing neutral growing mediums (Gruda, 2019). In soilless cultivation, plants derive vital nutrients from a nutrient-rich water solution, facilitating proper growth and development. The primary objective of soilless cultivation revolves around providing plants with ideal growth conditions, encompassing nutrient concentrations, pH equilibrium, and water accessibility (Putra *et al*., 2015; Fussy and Papenbrock, 2022). Soilless cultivation methods have emerged as a sustainable alternative to traditional soil-based farming, offering precise control over nutrient delivery to plants. Therefore, effective nutrient management is essential for achieving optimal plant growth, yield, and quality in these systems. Fertigation plays a crucial role in this regard, offering precise nutrient delivery, real-time monitoring, and control, resulting in improved crop performance, resource efficiency, and flexibility. By integrating fertigation into their growing practices, growers can enhance nutrient uptake efficiency, maximize yield potential, and promote sustainable and profitable agriculture in protected environments.

Protected cultivation

Protected cultivation refers to the practice of growing crops within structures wherein the microclimate (temperature, humidity, light) surrounding the plants is controlled partially/fully (Sabir and Singh, 2013). These structures, which include greenhouses, polyhouses, and tunnels, create a controlled microclimate conducive to plant growth and productivity. Protected cultivation offers several advantages, including extended growing seasons, increased crop yields, improved crop quality, and reduced dependency on external inputs such as water and pesticides. By providing a stable environment with optimal temperature, humidity, and light levels, protected cultivation enables growers to produce a wide range of crops year-round, regardless of external conditions. This practice plays a crucial role in modern agriculture, contributing to food security, sustainable production practices, and economic viability for growers worldwide.

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Production systems in protected cultivation

In protected cultivation, various production systems are employed to maximize crop yield, quality, and efficiency within controlled environments. These systems are designed to optimize space utilization, resource management, and crop management practices. Some common production systems in protected cultivation include:

1. **Soil-Based Cultivation:**

Traditional soil-based cultivation involves growing crops in containers or raised beds filled with soil or soil mixes within the protected structure. This system allows for the use of natural soil fertility and microbial activity while providing insulation and protection from external factors.

2. **Soilless Cultivation:**

Soilless cultivation methods, such as hydroponics, aeroponics, and aquaponics, eliminate the need for soil by growing plants directly in nutrient-rich water solutions or inert substrates. Hydroponic, aeroponic and other substrates medium, such as cocopeat and compost utilize different methods for delivering nutrients to plants. Hydroponic systems circulate nutrient solutions directly to the plant roots through fertigation, while aeroponic systems mist the roots with nutrient-rich solutions. The nutrients can be delivered to other substrates medium such as cocopeat via fertigation for precise application (Pandey, 2024). These systems offer precise control over nutrient delivery, pH levels, water management, and environmental conditions, resulting in faster growth rates and higher yields.

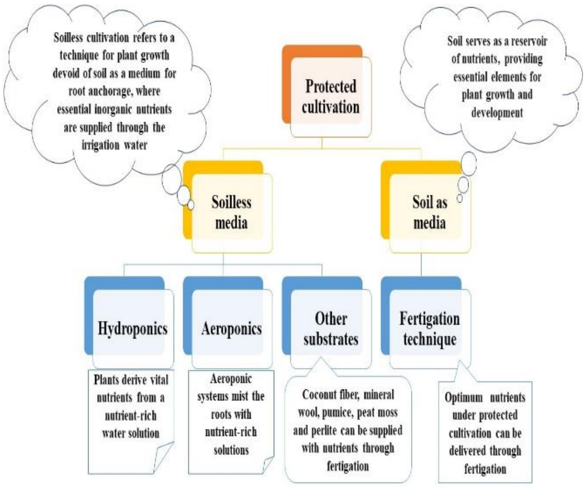

Fig. 1: Overview of different production systems and nutrient management under protected environment

Nutrient delivery system in protected cultivation

In protected cultivation, nutrient delivery systems play a crucial role in ensuring optimal plant growth and productivity. These systems are responsible for supplying essential nutrients to crops in a controlled and efficient manner. Several nutrient delivery systems are commonly used in protected cultivation, including:

i. **Fertigation Systems**: Fertigation involves the simultaneous application of water and nutrients through the irrigation system. Water-soluble fertilizers are dissolved in the irrigation water and delivered directly to the root zone of plants. Fertigation systems allow for precise control over nutrient concentrations, pH levels, and application rates, resulting in efficient nutrient uptake and utilization by plants.

Table 1: Soluble fertilizers commonly used in fertigation

Fertilizers	N – P_2O_5 – K_2O content	Solubility (g/l) at 20℃
Ammonium nitrate	34-0-0	1830
Ammonium sulphate	21-0-0	760
Urea	46-0-0	1100
Mono-ammonium phosphate	12-61-0	282
Di-ammonium phosphate	18-46-0	575
Potassium chloride	0-0-60	347
Potassium nitrate Potassium sulphate	13-0-44 0-0-50	316 110
Mono-potassium phosphate	0-52-34	230
Phosphoric acid	0-52-0	457

ii. **Drip Irrigation Systems:** Drip irrigation systems deliver water and nutrients directly to plant roots through a network of tubing and emitters. Nutrient solutions can be injected into the irrigation system using dosing pumps or venturi injectors, ensuring uniform distribution to each plant. Drip irrigation minimizes water wastage and nutrient runoff while promoting targeted nutrient delivery and root zone moisture management.

iii. **Substrate-based Systems:** Soilless cultivation systems, such as hydroponics and aeroponics, utilize inert substrates like perlite, coco coir, or rockwool to support plant roots. Nutrient solutions are continuously circulated or intermittently applied to the substrate, providing plants with essential nutrients and oxygen. Substrate-based systems offer precise control over nutrient concentrations and root zone conditions, promoting rapid growth and high yields.

iv. **Nutrient Film Technique (NFT):** NFT systems consist of shallow channels or gutters through which a thin film of nutrient solution flows, continuously bathing the roots of plants. Plants are grown in separate containers or grow tubes, with their roots suspended in the nutrient solution. NFT systems ensure constant nutrient availability and oxygenation of roots, facilitating efficient nutrient uptake and plant growth.

v. **Wicking Systems:** Wicking systems use capillary action to deliver nutrient solution to plant roots from a reservoir located below the growing medium. Growing media like peat moss or vermiculite act as wicks, drawing up nutrient solution from the reservoir to irrigate the root zone. Wicking systems are simple, low-cost, and suitable for small-scale growers.

vi. **Automated Nutrient Management Systems:** Automated nutrient management systems integrate sensors, controllers, and dosing pumps to monitor and adjust nutrient levels in real time. Sensors measure parameters such as pH, EC, and nutrient concentrations in the nutrient solution, allowing for precise control and optimization of nutrient delivery. Automated systems minimize human error, ensure consistent nutrient supply, and optimize plant nutrition for maximum yield and quality.

Nutrient management under protected cultivation

The composition of the nutrient medium is precisely calculated based on an analysis of water consumed for fertigation and adapted to the current stage of plant growth and atmospheric conditions. The nutrient media should be prepared with high concentrations of components that are completely soluble in water. The basic fertilizers used for their preparation include: calcium nitrate, $Ca(NO_3)_2$; potassium nitrate, KNO_3; magnesium nitrate, $Mg(NO_3)_2$; ammonium nitrate, NH_4NO_3; potassium sulphate, K_2SO_4; magnesium sulphate monohydrate, $MgSO_4{\cdot}H_2O$; magnesium sulphate heptahydrate, $MgSO_4{\cdot}7H_2O$; potassium monophosphate, KH_2PO_4; monoammonium phosphate, $NH_4H_2PO_4$; calcium chloride, $CaCl_2{\cdot}6H_2O$; and potassium chloride, KCl. In addition, pH correction is achieved with nitric acid (V), HNO_3, phosphoric acid (V), H_3PO_4, and hydrochloric acid, HCl, which serve as additional sources of nutrients (Mielcarek *et al.*, 2023). Iron, manganese, copper, zinc, boron, and molybdenum are introduced in the form of micronutrient fertilizers containing one, two, or more components. Apart from boron and molybdenum, these compounds are usually introduced in the form of chelates, ensuring good assimilation by plants. To address the increasing need for soilless cultivation techniques, the ICAR-Indian Institute of Horticultural Research in Bengaluru has developed a cost-effective method utilizing Arka Fermented Cocopeat (AFC) substrate. This approach, along with a standardized nutrient solution called Arka Sasya Poshak Ras, allows for the cultivation of various commonly consumed vegetables in both open fields and polyhouses. By adopting this technology, urban and peri-urban residents have the opportunity to grow their preferred vegetables to fulfil their daily dietary needs.

CONCLUSION

It can be concluded that nutrient management is essential for successful crop production in soilless cultivation systems. Nutrient management in protected environments enables year-round cultivation, leading to increased crop yields and a more stable food supply, especially in regions with challenging climatic conditions. By harnessing innovative technologies and scientific knowledge like fertigation farmers can optimize nutrient use efficiency, minimize environmental impacts, and ensure the long-term sustainability of agriculture. Continued research and collaboration are essential for advancing nutrient management practices and realizing the full potential of protected cultivation in feeding a growing global population.

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