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Nutrient Management in Soilless Farming Systems

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Soilless farming systems, including hydroponics, aeroponics, and substrate-based cultivation, are emerging as sustainable alternatives to conventional soil-based agriculture, particularly in urban and peri-urban areas where land and water resources are limited. Nutrient management is a critical component of these systems, as plant growth, yield, and quality largely depend on the precise supply and availability of essential macro and micronutrients. Effective nutrient management involves the preparation of balanced nutrient solutions, regular monitoring of pH and electrical conductivity (EC), maintenance of suitable root-zone conditions, and timely adjustment of nutrient concentrations according to crop requirements and growth stages. Therefore, efficient nutrient management in soilless farming systems offers considerable potential for increasing productivity, improving crop quality, and supporting food security in resource-constrained environments.

Keywords: Soilless farming, hydroponics, nutrient solution, nutrient-use efficiency, pH, electrical conductivity, sustainable agriculture

Introduction

Soilless farming is a modern cultivation technique in which plants are grown without natural soil, using nutrient solutions and suitable growing media. It includes hydroponics, aeroponics and substrate-based cultivation using materials such as cocopeat, perlite, vermiculite and rock wool. This technology is gaining popularity because it enables efficient use of water, fertilizers and growing space, particularly in protected cultivation and urban agriculture. In soilless systems, plants depend largely on the grower for an adequate supply of essential nutrients. Therefore, proper nutrient management is essential for healthy growth, better-quality produce and higher productivity. An imbalance in nutrient concentration, unsuitable pH or excessive salt accumulation can affect nutrient uptake and reduce crop performance.

Essential nutrients for plant growth

Plants require both macronutrients and micronutrients to complete their life cycle. Macronutrients, including nitrogen, phosphorus, potassium, calcium, magnesium and sulphur, are required in relatively large quantities. Micronutrients such as iron, manganese, zinc, copper, boron and molybdenum are needed in smaller amounts but remain essential for normal growth. Nitrogen promotes vegetative growth and leaf development, while phosphorus supports energy transfer and root development. Potassium contributes to water regulation, stress tolerance and produce quality. Micronutrients support enzyme activity, chlorophyll formation and other physiological processes. A balanced supply must therefore be maintained according to crop species and growth stage (Jadhav, 2023).

Important aspects of nutrient management

1. Water quality assessment

Water is the main carrier of nutrients in hydroponic systems. Before preparing a nutrient solution, the source water should be tested for pH, electrical conductivity (EC), alkalinity, hardness and potentially problematic ions. Water containing excessive salts or unsuitable

mineral concentrations may interfere with nutrient availability and cause salt accumulation in the root zone. Using good-quality water helps maintain a balanced nutrient solution and reduces the risk of nutrient disorders.

2. Maintaining pH and electrical conductivity

The pH of a nutrient solution affects the availability of essential nutrients. Many hydroponic crops perform well at a pH of approximately 5.5–6.5, although the ideal range varies with crop and growing conditions. Electrical conductivity measures the solution's ability to conduct electricity and provides an indication of its total dissolved ion concentration. A very high EC may cause salt stress and restrict water uptake, whereas an excessively low EC may indicate insufficient dissolved nutrients. However, EC cannot identify individual nutrient deficiencies or confirm that every nutrient is present in the correct proportion (Dunn & Singh, 2017). Both pH and EC should be monitored regularly and adjusted according to crop-specific recommendations.

3. Preparation of balanced nutrient solutions

Nutrient solutions should contain all essential elements in appropriate proportions. Fertiliser quantities must be calculated according to crop requirements, source-water composition, system type and growth stage. Concentrated stock solutions containing incompatible fertilisers should be prepared separately to prevent precipitation. Accurate measurement and thorough mixing help ensure uniform nutrient distribution (Penn State Extension, 2024; Pardossi *et al.*, 2017).

4. Monitoring nutrient supply and root health

Nutrient requirements change as plants develop. Young seedlings generally require a different nutrient strength from mature, fruit-bearing plants. Regular monitoring of plant growth, leaf colour, root condition, pH, EC and drainage helps identify problems early. Yellowing, leaf-edge burning, poor growth and abnormal root development may indicate nutrient imbalance, but similar symptoms can also result from diseases, unsuitable temperature or poor aeration. Therefore, nutrient adjustments should be based on measurements and careful observation rather than symptoms alone.

Table 1. Essential nutrients, their functions and possible deficiency symptoms

Nutrient	Major function	Possible deficiency symptoms
Nitrogen (N)	Leaf and vegetative growth	General yellowing, especially in older leaves
Phosphorus (P)	Water regulation and crop quality	Leaf-edge yellowing or scorching
Calcium (Ca)	Cell-wall development	Distorted young leaves and growing-point damage
Magnesium (Mg)	Chlorophyll formation	Interveinal yellowing, especially in older leaves
Iron (Fe)	Chlorophyll synthesis	Interveinal yellowing of young leaves
Boron (B)	Cell division and growing-point development	Deformed young growth and damaged growing points

Best practices for efficient nutrient management

Effective nutrient management requires regular monitoring and preventive maintenance. The following practices are particularly useful:

- Test water regularly: Assess source-water quality before preparing nutrient solutions and whenever water quality changes.

- Follow crop-specific recommendations: Use nutrient formulations suitable for the crop, variety and growth stage.
- Monitor pH and EC: Check readings regularly using calibrated meters and maintain crop-appropriate ranges.
- Inspect roots and plants: Look for abnormal root colour, poor growth, leaf yellowing and signs of salt stress.
- Maintain clean equipment: clean reservoirs, pipes, channels, filters and irrigation components to prevent blockages and contamination.
- Manage drainage and reuse carefully: Monitor nutrient accumulation in the root zone and manage recirculated solutions to avoid nutrient imbalance and disease spread.
- Avoid excessive fertilisation: Apply nutrients according to measurements and crop demand to reduce costs and minimise nutrient discharge into the environment.

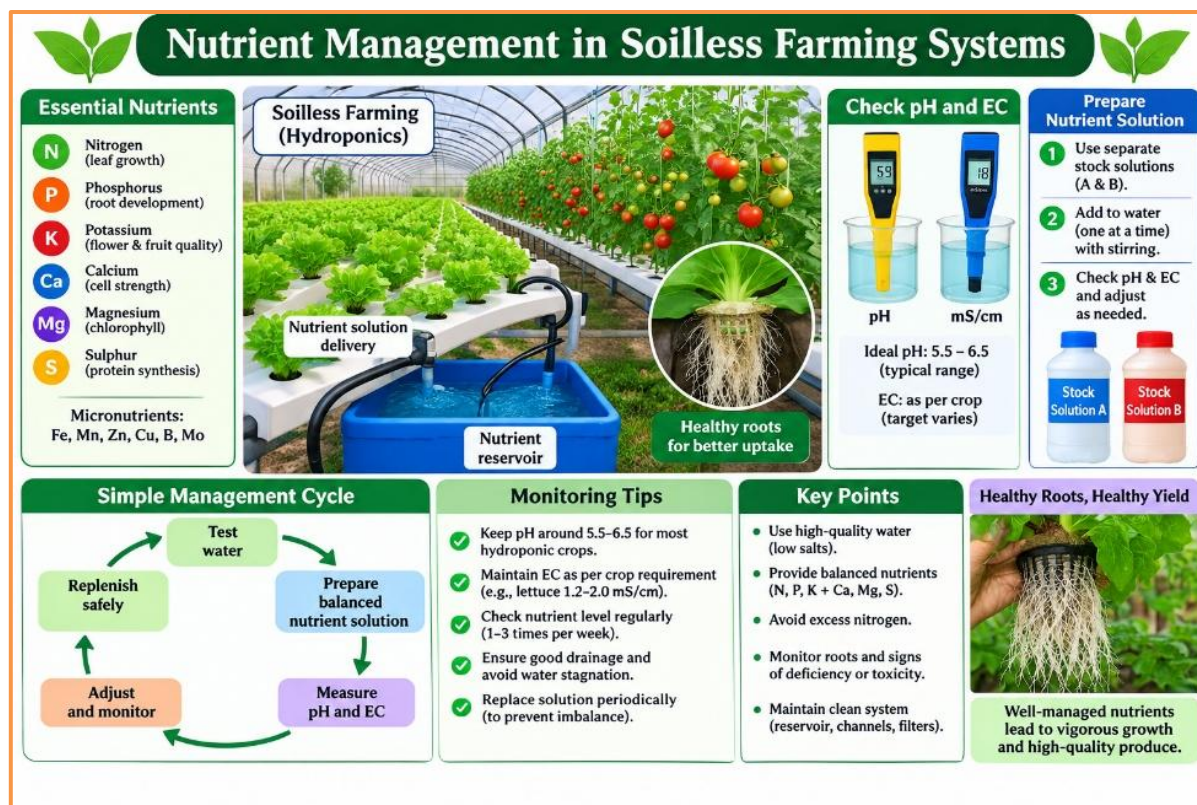


Figure 1. Nutrient management in soilless farming systems, highlighting essential nutrients, nutrient-solution preparation, pH and EC monitoring, and healthy root development.

Conclusion

Nutrient management is one of the most important factors determining the success of soilless farming systems. Maintaining balanced nutrient concentrations, suitable pH and EC, good water quality and healthy root conditions help plants absorb nutrients efficiently and achieve better growth and yield. Regular monitoring, accurate fertiliser preparation and crop-specific nutrient management can also reduce waste and improve resource-use efficiency.

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