

Low cost-hydroponics systems for urban and peri-urban farming

Urbanization and rapid industrialization are shrinking natural resources, while the ever-growing population suffers from malnutrition instead of enjoying guaranteed food security for every citizen of India. This situation necessitates adopting innovative approaches to ensure food and nutritional security. Hydroponics, a soilless farming technology, offers significant advantages, such as higher water-use efficiency, pesticide-free production, and suitability for limited spaces. While high-tech hydroponics systems are often capital-intensive, low-cost hydroponic models using locally available materials—such as plastic bags, scrap containers, PVC pipes, polythene tubes, and coconut coir—can be effectively adopted for urban horticulture. ICAR-CISH Lucknow has developed low-cost designs using inexpensive materials in liquid and aggregate hydroponics, enabling year-round production of vegetables, herbs, and small fruits on rooftops and balconies. Promoting low-cost hydroponics can transform urban horticulture, enhance livelihoods, and contribute to a sustainable urban food system.

Keywords: Nutrient solution, Rooftop gardening, Soilless cultivation, Urban horticulture, Vertical farming

URBANIZATION is accelerating at an unprecedented pace, transforming the way food is produced, distributed, and consumed. Expansion of cities and diversion of fertile agricultural land for development have intensified the pressure to produce more from shrinking land resources. Rising rural-to-urban migration has further increased the urban population, placing stress on conventional food supply chains. While government programs have helped improve food security, they alone cannot address persistent issues of hidden hunger and malnutrition. Conventional peri-urban vegetable belts face land conversion, water stress, and contamination risks.

Urban populations demand a balanced diet rich in fresh, safe, and nutritious vegetables, yet current systems largely depend on rural cultivation and rapid transportation, both of which are energy-intensive and vulnerable to disruptions. Changing consumer preferences are also reshaping demand patterns, with health-conscious urban residents increasingly preferring pesticide-free vegetables that are fresh and rich in natural antioxidants.

Meeting this demand requires innovative, resource-efficient, and environmentally sustainable production systems. Hydroponics—the technique of growing crops without soil by supplying essential nutrients through water—offers such a possibility. Traditionally viewed as a technology requiring sophisticated greenhouses and high capital investment, hydroponics can, in fact, be adapted into low-cost systems suitable for urban settings. Low-cost hydroponics, using water and nutrients, offers a compact,

resource-efficient solution that fits rooftops, balconies, and community spaces, strengthening both nutritional security (year-round access to fresh, diverse vegetables) and environmental security (lower resource footprints, reduced pollution).

Simple hydroponic units, such as nutrient film technique (NFT), deep-water culture, and grow-bag systems, can be constructed using locally available materials like PVC pipes, buckets, or trays. Nutrient solutions can be prepared with water-soluble fertilizers and managed with basic monitoring of pH and electrical conductivity. Beyond household adoption, hydroponics also presents opportunities for community gardens, school learning modules, rooftop farming, and start-up ventures. For urban households, it ensures year-round access to safe vegetables; for entrepreneurs, it creates opportunities to establish small-scale units catering to niche consumers such as restaurants, hospitals, and wellness centers. At the community level, hydroponics strengthens food resilience and reduces dependence on long-distance supply chains.

This article discusses low-cost hydroponics designs, nutrient solutions, suitable crops, and the opportunities presented by low-cost hydroponics for urban horticulture, along with examples of successful implementation. Thus, low-cost hydroponics holds immense potential to complement traditional agriculture, conserve resources, and support healthier diets for the growing urban population.

Hydroponics systems have three main components:

(i) System design, (ii) Crop-specific nutrient formulation, and (iii) Crop management

Designs of Hydroponics Systems

Hydroponic system design varies according to available space, crop type, resource availability, and other factors. In India, most hydroponic designs are imported and primarily used by affluent individuals. However, these users often discontinue after a short period due to limited technical know-how, high initial investment, and the high cost of nutrient formulations—factors that significantly impede technology adoption in the country.

To address these challenges, ICAR-CISH has developed low-cost hydroponic models for a variety of crops in both liquid and solid systems. Solid hydroponic designs are particularly well-suited for growing vegetables, herbs, and soft fruits in areas with irregular or erratic power supply.

CISH triangular vertical NFT hydroponics

This system is designed using food-grade PVC pipes as grow channels, an iron angle frame, and paint buckets as nutrient tanks, with an 8-watt water cooler motor for nutrient circulation. Nutrient flow is regulated through a switch timer. The A-shaped design allows maximum light exposure to each plant and maximizes yield per unit area by efficiently utilizing vertical space. The system accommodates 80 plants and saves 60–70% of water and 40% of nutrients due to its closed-loop nutrient circulation. It is ideal for short-stemmed crops such as leafy vegetables, herbs, and strawberries, and is suitable for balconies, rooftops, and indoor spaces. The system costs ₹3,500/unit and is patented under Indian patent law.



CISH vertical double row NFT hydroponics

The system was developed for rooftop gardening, indoor gardening, and areas where soil is unavailable. It is ideal for short-stemmed crops such as lettuce, broccoli, red cabbage, Swiss chard, kale, coriander, *methi*, mint, basil, and fruits like strawberries. The system features an automated nutrient circulation system operated by a timer-based electric switch. It can accommodate 192 plants and costs ₹12,700/unit. The double-row design allows 25% more plants and provides wider gaps to permit light to reach the lower layers of the plants. The design is patented.



CISH hybrid hydroponics nutri-garden model

The design is a hybrid of liquid and aggregate hydroponics, suitable for growing all commonly consumed vegetables, including root vegetables, fruit vegetables, and herbs. It accommodates 224 plants and costs ₹6,600/unit..



CISH pyramid aggregate vertical model

The system uses a solid growing medium, making it suitable for locations with erratic electricity supply. It accommodates 75% more plants per unit area and is ideal for growing short-stature vegetables, herbs, and strawberries. The system includes a drainage setup for nutrient recycling and an automatic irrigation system with a timer. Leafy greens such as lettuce, broccoli, red cabbage, Swiss chard, kale, coriander, *methi*, mint, and basil; fruits like strawberries and blueberries; and ornamental plants like marigold, carnation, chrysanthemum, and roses are all suitable for this hydroponic system. It can accommodate 72 to 140 plants and costs ₹3,000/unit.



CISH X shape vertical model

The system uses a solid growing medium, making it suitable for locations with erratic power supply. It can accommodate 75% more plants per unit area and is ideal for growing vegetables, herbs, and strawberries. Automated drip fertigation reduces labor costs. The cost is ₹3,000/unit.



CISH drip bag hydroponics

The system is designed for rooftops or unproductive soils and is suitable for indeterminate varieties of tomato, cherry tomato, capsicum, cucumber, summer squash, bottle gourd, bitter gourd, rose, and coronation, among others. It uses 10 kg UV-stabilized double-layered bags (white outside, black inside) with four holes. Nutrients are circulated by gravitational force, with the tank placed on a 1.5 m platform and operated manually daily or on alternate days as needed. The cost is ₹6,500 for 100 bags, including the drip system.



CISH deep flow system

The CISH Deep Flow System is designed for rooftops, balconies, and indoor gardening with natural light. It is suitable for leafy greens, tomato, capsicum, and cape gooseberry. The system accommodates 48 plants and costs ₹2,400/unit.



Crop specific nutrient solution formulation

The high cost of nutrients in the market is a major limitation of hydroponics. ICAR-CISH developed a low-cost A and B nutrient solution at 3X strength (1 litre dissolved in 300 litres of water) for solanaceous vegetables, leafy vegetables, strawberries, and cucumber using commercially available fertilizers. Some elements are incompatible at higher concentrations and may precipitate when combined in stock solutions. Therefore, nutrient stock solutions are typically prepared separately. They do not precipitate when diluted and can be used together without issue. Compatible nutrients are combined and labeled as A and B solutions. Stock solutions are available in three strengths: 1X, 2X, and 3X, with the general recommendation that strength should not exceed 3X. Common macronutrients include potassium nitrate, calcium nitrate, and potassium phosphate, while micronutrients such as magnesium sulfate, iron, manganese, copper, zinc, boron, chlorine, and nickel—



Nutrients and their acceptable concentration in a hydroponic solution:

Element	*ppm in solution	
	Limits	Average
Nitrogen	150-1,000	300
Calcium	300-500	400
Magnesium	50-100	75
Phosphorus	50-100	80
Potassium	100-400	250
Sulphur	200-1,000	400
Copper	0.1-0.5	0.5
Boron	0.5-5.0	1.0
Iron	2.0-10	5.0
Manganese	0.5-5.0	2.0
Molybdenum	0.001-0.002	0.001
Zinc	0.5-1.0	0.5

*Parts per million (1 mg in 1,000 ml water)

sometimes with chelating agents to keep iron soluble—are added to supply essential elements. The concentration of the solution varies according to crop type. In ICAR-CISH hydroponic solutions, the selection and blending of nutrient components prevent precipitation of cations and anions at higher concentrations in A and B solutions, ensuring efficient nutrient uptake by plants.

The CISH Leafy Vegetables Hydroponic Nutrient Solution serves as a universal nutrient solution for all leafy vegetables. Its high 3X strength requires less space and reduces transportation needs. Similarly, the CISH Solanaceous Vegetables Hydroponic Nutrient Solution is suitable for all solanaceous vegetables. Both solutions are economical, being prepared from commercially available water-soluble fertilizers. The average cost of the CISH hydroponic nutrient stock solution is ₹85/liter, which is significantly lower than the cost of similar solutions available in the market.

Crop Management in Hydroponics

Crop selection, environmental conditions, water quality, substrate physiochemical status, irrigation frequency and doses, crop management, and light quality all have an impact on crop yield and quality in hydroponics.

Crops: Hydroponic systems should cultivate high-value, high-yielding, and multi-harvest crops. Suitable crops include tomatoes, capsicum, cucumber, leafy greens such as lettuce, broccoli, red cabbage, Swiss chard, kale, coriander, fenugreek (methi), mint, basil, fruits like strawberries and blueberries, and ornamentals such as marigold, carnation, chrysanthemum, and roses.

Water: Hydroponically grown plants prefer slightly acidic conditions. The pH of the nutrient solution regulates nutrient uptake, with most nutrients optimally available at pH 5.5–6.5. Therefore, neutral to slightly acidic water is recommended for hydroponic systems.

Nutrients: Nutrient solution strength is measured using an EC (electrical conductivity) meter, which indicates overall nutrient concentration but does not detect imbalances in individual nutrients. Low EC indicates insufficient nutrients, leading to poor growth, while excessively high EC can damage plants. Optimum EC should be maintained for each crop to maximize productivity. In automated hydroponic systems, EC is controlled by adding nutrient solution to the tank, whereas in manual systems, daily monitoring is required to ensure proper nutrient levels.

pH: The pH of the nutrient solution should be

The optimal pH, EC, and TDS range for subtropical regions has been established (20 -25 oC)

Crop	pH	EC (mS/cm)	TDS(ppm)
Capsicum	6-6.5	1.8-2.2	1,250-1,540
Tomato	5.5-6.5	2-5	1,000-2,500
Lettuce	5.5-6.5	0.8-1.2	400-850
Pak Choi	6.5-7.0	1.5-2	1,050-1,400
Cucumber	6.0-6.5	1.7-2.4	1,150-1,750

maintained within the acceptable range. If pH adjustments are required more than once a day, especially after adding fresh nutrient solution to the tanks, corrective measures should be taken. Sulfuric acid, nitric acid, phosphoric acid, citric acid, and acetic acid can be used to lower the pH, whereas potassium hydroxide, sodium hydroxide, and sodium bicarbonate (NaHCO_3) are used to raise the pH.

Temperature: The temperature of the growing media significantly influences crop growth. For leafy and exotic vegetables, an ideal range is 15–18 °C, although they can tolerate temperatures as low as 7 °C. For cucumber, the optimum range is 15–32 °C, and for tomato and capsicum, it is 18–27 °C. Growth is limited if the nutrient solution temperature falls below 10 °C or rises above 35 °C. A chiller or other temperature control system may be required to maintain optimal conditions.

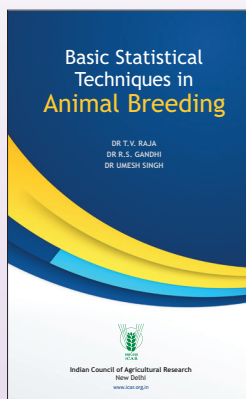
Oxygen: Roots require sufficient oxygen to absorb water and nutrients. Plants do not thrive in waterlogged conditions that lack aeration. In hydroponic systems, aeration through circulation or bubbling is essential, as the solubility of oxygen in water is very low (0.004%).

CONCLUSION

Low-cost hydroponics provides a practical, resource-efficient, and scalable solution to strengthen urban and peri-urban food systems. By utilizing locally available materials and simplified designs, ICAR-CISH models make hydroponic cultivation affordable, technically feasible, and suitable for diverse spaces such as rooftops, balconies, and community areas. These systems enable year-round production of safe, pesticide-free vegetables while conserving water, nutrients, and land. Cost-effective nutrient formulations further reduce operational expenses and encourage wider technology adoption. With rising urbanization and growing demand for fresh, nutritious produce, low-cost hydroponics can play a transformative role in ensuring food and nutritional security, promoting green cities, and supporting sustainable urban agriculture.

For further interaction, please write to:
ICAR-CISH Rehmankhara, Lucknow 226 101, Uttar Pradesh
Corresponding email: srajparmar@gmail.com

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Business Unit

ICAR-Directorate of Knowledge Management in Agriculture
Krishi Anusandhan Bhawan – I, Pusa, New Delhi 110012

Tel: 011-25843657; email: businessuniticar@gmail.com

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