

Vertical hydroponics: A future technology for urban horticulture

People have been forced to adopt a reliable crop-growing system that could provide ample opportunities to supplement fresh, safe, and healthy, pesticide-free, natural antioxidant-rich produce due to increased health consciousness, high incidence of fatal diseases due to excessive chemical use in horticultural crops, and inclination toward green living. Instead of helping to face the uncertain climatic challenges in crop production, hydroponics, a technology of growing crops in nutrient solution, offers an opportunity for efficient use of natural resources, mitigation of malnutrition, more quality produce per unit area and time, where conventional farming is not possible due to water scarcity, degraded and sick soils.

THE availability of land per capita is decreasing as a result of faster industrialization and diversion of agricultural lands for development and city expansion. Food, nutrition, health, and environmental security are all threatened by high population pressure, rising food prices, and socio-economic and environmental stresses. Hydroponic technology may play an important role in maximising food production while minimising insect pest risks. Hydroponics is a highly productive technology that can also be automated, making it ideal for areas where conventional farming is impossible due to water scarcity, degraded or sick land. In metropolitan cities, it has proven its worth on roof top and indoor gardening.

Technological advancements have led to the development of hydroponic gardening which is a method of growing plants in nutrient solutions. There are different hydroponic designs to choose from. Liquid culture of

plants uses a liquid medium for root growth and is divided into Nutrient Film Technique (NFT) including deep flow techniques and non-circulating methods, which include root dipping, floating, and capillary action techniques.

The roots are grown in a solid medium culture method. Hanging bag techniques, grow bag techniques, trench techniques, and pot techniques are some of the



Drip system hydroponic



Tomato under nutrient film technique



Lettuce in aeroponics



Swiss chard in Ebb flow system

examples of this category. In Aeroponics culture system, roots grow in the dark in the air, with nutrients delivered to them via misting or fogging in the air.

Crop production in hydroponics has three main components namely (i) system design, (ii) crop-specific nutrient formulation and (iii) crop management.

Hydroponic designs

Design varies according to space, crop type, resource availability, and so on. Most hydroponics technology in India is imported and used by affluent members of society who leave after a short period of time due to a lack of technical know-how and higher production costs due to the high initial cost of the system and the high cost of nutrient formulation, which is a major impediment to technology adoption in India.

The ICAR-CISH, Lucknow initiated standardising the cultivation of vegetables, herbs, and strawberries in subtropical climates. The Institute demonstrated four hydroponic systems, namely an aeroponic system, an ebb and flow system, an NFT system, and a drip hydroponic system. The drip hydroponic system was appropriate for indeterminate tomato, cherry tomato, parthenocarpic cucumber, nutrient film techniques of leafy vegetable, indeterminate tomato, and capsicum; Ebb and flow system for growing leafy vegetables and seedlings.

Problem faced on above imported designs, ICAR-CISH has developed over ten models for various crops in liquid and solid hydroponic systems. Solid hydroponics are better suited for growing vegetables, herbs, and soft fruits in areas with erratic power supply.

CISH Triangular Vertical NFT Hydroponics

- It has been designed to maximise output per unit area by utilising vertical space. The design accommodates 80 plants as opposed to 32 plants in the conventional production system.

- It saves 60-70% of the water and 40% of the nutrients due to nutrient circulation.
- The system is ideal for short-stemmed crops such as strawberries and leafy vegetables. It is timer-based and can be powered by a solar panel.
- Suitable for water-scarce areas, degraded and sick lands, roof tops, and building interiors.

CISH Vertical Double Row NFT Hydroponics

- The system was created for roof top gardening, indoor gardening, and in areas where there is no soil available.
- The system is ideal for short-stemmed crops such as strawberries and leafy vegetables.
- It has an automated nutrient circulation system that is timer-based and can be powered by a solar panel.
- It can accommodate 192 plants as opposed to 32 in the standard system.

CISH Vertical Single Row NFT Hydroponics

- The system was created for roof top gardening and indoor gardening, and it is ideal for short stature crops that require more light and aeration.
- It has an automated nutrient circulation system that is timer-based and can be powered by a solar panel.
- It can accommodate 160 plants as opposed to 40 in the standard system.
- It saves 70% of the water and 40% of the nutrients.

CISH Pyramid Aggregate Vertical Model

- System use solid growing medium hence suitable for places where electric supply is erratic.
- It accommodates 75% more plant per unit area.
- System is suitable growing short stature vegetables, herbs and strawberry.
- It has drain system for nutrient recycling and auto irrigation system with timer.



CISH Triangular Vertical NFT hydroponics



CISH Vertical Double Row NFT hydroponics



CISH Vertical Single Row NFT

CISH X Shape Vertical Model

- Because the system uses a solid growing medium, it is appropriate for locations with erratic power supply.
- It can fit 75% more plants per unit area.
- The system is ideal for growing vegetables, herbs, and strawberries.
- Drip fertigation with automation saves money on labour.

CISH designs are popular among urban vegetable growers due to their low cost and ease of operation. The institute has provided over 100 structures in Lucknow and Kanpur, as well as some resource poor landless families, with a complete package for growing vegetables in order to ensure their nutritional security. Policymakers have expressed an interest in technology and have emphasised the importance of popularisation in the state.



CISH X Shape Vertical Model

Crop specific nutrient solution formulation

Because some elements are incompatible with each other when concentrated and cause precipitation when combined, stock solutions of all nutrients are typically prepared separately. They do not precipitate when diluted and can be used together without issue. As a result, elements that are compatible with one another are combined. Many use various chemical combinations to achieve similar total final compositions. Potassium nitrate, calcium nitrate, and potassium phosphate are common macronutrient chemicals. Magnesium sulphate, iron, manganese, copper, zinc, boron, chlorine, nickel, and sometimes chelating agents used to keep Fe soluble are micronutrients added to hydroponic solutions to supply essential elements. Compatible nutrients are combined and labelled as A and B solution. Stock solutions are available in three strengths: 1×, 2×, and 3×. In general, stock solution strength should be less than 3×. The concentration of the solution combination varied from crop-to-crop.

Table 1. Nutrients and their acceptable concentration in a hydroponic solution:

Element	*ppm in solution	
	Limits	Average
Nitrogen	150-1000	300
Calcium	300-500	400
Magnesium	50-100	75
Phosphorus	50-100	80
Potassium	100-400	250
Sulphur	200-1000	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 1000 ml water).



CISH Pyramid Aggregate Vertical Model

The high cost of nutrients in the market is a major flaw in hydroponics. ICAR-CISH developed a low-cost A and B nutrient solution with 3× (dissolve one litre in 300 litres of water) strength for solanaceous vegetables, leafy vegetables, strawberries, and cucumber.

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: Hydroponics farming crops should be high-value, high-yielding, and multi-harvesting. Tomatoes, capsicum, cucumber, leafy greens like lettuce, broccoli, red cabbage, swish chard, kale, coriander, methi, mint, basil, fruits like strawberries and blueberries, and ornamental like marigold, carnation, chrysanthemum, and roses are all suitable hydroponic horticultural crops.

Water: Plants grown hydroponically prefer slightly acidic growing conditions. The pH concentration regulates crop nutrient uptake. The majority of nutrients become available to the hydroponic plant between pH ranges of 5.5 to 6.5. As a result, neutral water is preferred for use in the system.

Nutrients: The strength of a nutrient solution is measured using an EC metre, but it only measures the total strength of the solution and does not indicate whether one or more nutrients are out of balance. Low conductivity implies low nutrient concentration, which results in poor plant growth. Higher conductivity leads to higher yield but may harm the plant; therefore, the optimum conductivity for each crop should be maintained for maximum productivity. The nutrient solution EC is automatically maintained in an auto hydroponic system by adding the nutrient solution to the tank. However, in manual measurement, the EC must be checked daily to see if the strength has increased or decreased.

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

Crop	pH	EC (mS/cm)	TDS (ppm)
Capsicum	6-6.5	1.8-2.2	1250-1540
Tomato	5.5-6.5	2-5	1000-2500
Lettuce	5.5-6.5	0.8-1.2	400-850
Pak Choi	6.5-7.0	1.5-2	1050-1400
Cucumber	6.0-6.5	1.7-2.4	1150-1750

pH: The pH of the nutrient solution should not be allowed to rise or fall outside of the acceptable range. The pH of the solution needs to be adjusted twice a day, especially after adding a new nutrient solution to the nutrient tanks. Sulphuric acid, nitric acid, phosphoric acid, citric acid and acetic acid are used to lower the pH of media, whereas potassium hydroxide, sodium hydroxide, and bicarbonate of soda (NaHCO_3) are used to raise the pH.

Temperature: A favourable temperature of the growing media influences crop growth. The temperature range of 15-18°C is ideal for leafy and exotic vegetables, though they can tolerate temperatures as low as 7°C. Temperatures between 15 and 32°C for cucumber and 18 and 27°C for tomato and capsicum are ideal for crop production. Growth is limited if the temperature of the nutrient solution falls below 10°C or rises above 35°C. A chiller plant will be required to keep the temperature of the solution constant, or another source could be used to keep the temperature of the solution constant. The roots require a certain amount of oxygen in order to absorb water and nutrients. Plants do not grow well in waterlogged soil that lacks air space, and most plants do not grow well in water culture unless the solution is aerated by circulating or bubbling air into it. The solubility of oxygen in water is low (0.004%) and decreases as temperature rises.

For further interaction, please write to:

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