

Vertical farming under protected cultivation for enhancing farmers' income in Bundelkhand

Vertical farming refers to the growing of crops, mostly vegetables and herbs on stacks of shelves indoors using artificial light and nutrient solutions, eliminating the need for sunshine and soil. It often incorporates controlled-environment agriculture, which rules out the adverse effects of climate change and focuses on optimizing plant growth conditions by employing soilless farming techniques. A comparison with the conventional/horizontal farming reveals the needs, constraints, implementation opportunities and possible alternative approaches, highlighting the potential of vertical farming technology as a viable option for food and nutritional security in India. This innovative approach involves indoor farming, leveraging cutting-edge technologies to create new paradigm in agriculture.

IN India, vertical farming is still in nascent stage but has a potential to be speciality agriculture by growing foods such as micro greens, leafy greens and high value food crops. It is not going to replace mainstream arable agriculture but can make its place as an innovative form of growing foods. Vertical farming can become a remunerative option of growing food. The vertical farming industry will be driven by numerous new and advanced technologies, making it more profitable through the adoption of high-value crops and reduced capital investment. This method enables intensive crop production under fully or partially controlled conditions.

In India, states such as Karnataka, Madhya Pradesh and Andhra Pradesh are the main producers of tomato under protected condition. India is the second largest producer of tomato after China. This crop is easier to grow compared to other vegetable crops and can be successfully cultivated year-round in poly-houses. It contains the valuable pigment lycopene, along with a significant amount of essential vitamins, making it highly sought after by the processing industry.

Protected cultivation technology has great potential if implemented in a planned manner. It is a well-established fact that the harsh and challenging climatic conditions (extreme heat and cold waves) significantly reduce the crop production and productivity. In North India, particularly in Bundelkhand, open-field vegetable cultivation is extremely challenging during the summer and winter seasons, making protected cultivation a vital alternative. In this regard, the vertical farming techniques like hydroponics, aeroponics and aquaponics are gaining popularity among the urban farming systems.



Cole crops under the indeterminate tomato

Cultivation practices

The indeterminate growth habit of tomato is suitable for greenhouse cultivation. The maximum space utilization with vertical growth of the plant increases the yield, quality and colour. Tomato hybrids are grown up to a height of 5-6 meter, utilizing the vertical space in greenhouse. For vertical farming of tomatoes, nursery sowing is done in July-August followed by transplanting in August-September (hybrid variety NS-4266). It results in an increase in harvest period that extends up to March-April. The nursery of



Indeterminate tomato intercropping with white cauliflower, coloured cauliflower, khol-khol and cabbage

cauliflower (Bishop-RZ), cabbage (Marcello-RZ, KPS 99 champ and Improved Bahar), broccoli (Tahoe-RZ), and coloured cauliflowers (Carotena & Valentena) are sown in mid-October and transplanted between two tomato plants in the month of November. Beds of 90-100 cm width and 15-20 cm height are prepared leaving 45-50 cm footpath between the beds. Well decomposed organic manure at the rate of 10-15 kg per square meter of the bed is added and mixed thoroughly before fumigation.

The two inline drip laterals (16 mm in diameter), spaced 50 cm apart are laid on each bed at 50 cm spacing with a discharge rate of 2 LPH. The tubes are placed at each planting row on the bed prior to planting. Plastic mulching is done on transplanting beds, providing several advantages such as 20-30% yield increase, earlier fruiting, weed control and soil moisture retention. Black/silver polyethylene mulch film 100-micron (400 gauges)

thickness having 1.2 m width is used to cover the planting beds and securing the edges of the sheet by burying in the soil. Pre-irrigation to the field capacity is done for better establishment of seedlings, before transplanting. Only the best 25-30 days old, vigorous and uniform size (15-20 cm in height) seedlings are selected for transplanting. Seedlings are transplanted at planting distance of 50 cm × 50 cm on drip irrigation system for efficient use of water and fertilizers. The beds are drenched with copper oxy chloride (@ 3 g/L) if seedling mortality observed due to damping off.

Fertigation

Fertigation commences after transplanting, with the following schedule:

- *First flowering*: N: P: K (19:19:19) at 250 g/500 square meter
- *Flowering to fruit set*: N: P: K (19:19:19) at 100 g, 46:0:0 at 175 g, and 0:0:50 at 275 g
- *Fruit set to peak harvesting*: Water-soluble fertilizers N: P: K (19:19:19) at 100 g, 46: 0: 0 at 250 g, and 0:0:50 at 275 g
- *Crop end*: N: P: K (19:19:19) at 50 g, 46:0:0 at 125 g, and 0:0:50 at 150 g

Fertigation is done twice a week, starting 25 days after transplanting. Pruning involved retaining a single stem and removing side shoots or suckers that develop between leaf petioles and side branches, beginning 20-30 days after transplanting at weekly intervals.

The main stem of tomato plants branches into two after the first flower cluster. Plant is supported by separate plastic twine hanging from an overhead GI wire trellis support system 3 m above the ground level, so that the branches do not break due to weight of the foliage and fruits.

Vertical farming of tomato with cauliflower, broccoli, and cabbage in NVPH

A demonstration of mixed farming was conducted, where tomato hybrid NS-4266 was transplanted on August 15, 2021, and served as an umbrella crop for the following varieties transplanted on November 17, 2021: white cauliflower (Bishop-RZ), coloured cauliflower (Carotena and Valentena), broccoli (Tahoe-RZ), and cabbage (Marcello-RZ, KPS 99 Champ, and Improved Bahar).

Single plant of tomato gave 7.5 kg fruit, whereas under the tomato umbrella, the white cauliflower hybrid (Bishop-RZ) produced compact curd weighing 0.900 kg. The coloured cauliflower such as Valentina and Carotena recorded 0.800 kg and 0.950 kg, respectively. Broccoli, hybrid Tahoe-RZ produced 0.750 kg compact curd. The cabbage hybrids, i.e. the hybrids Marcello-RZ, KPS-99 Champ, and Improved Bahar produced 1.05 kg, 0.900 kg, and 0.850 kg per head.

Vertical farming with indeterminate tomato and garlic in insect proof net house

The tomato hybrid (NS-4266) was transplanted on August 25, 2021 and garlic variety Yamuna Safed-3 (G-282) was sown between indeterminate tomatoes on



Healthy garlic

Healthy garlic crop in between two tomato rows for green leaves in insect proof net house



Bunches of garlic for sale in market



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Higher officials visited vertical/mixed farming site at BUAT, Banda

Table 1. Final cost of cultivation of hi-value vegetable crops in 200m²

Protected structure	Name of crop	Fruit yield	Cost of cultivation with structure (₹)	Gross income (₹)	Net income (₹)	B: C Ratio
Natural Ventilated Polyhouse (NVPH)	Coloured Capsicum	2,160	48,376.80	101,400	53,023.20	1:2.09
	Indeterminate Tomato	5,200	51,629.16	104,000	52,370.84	1:2.01
	English Cucumber	3,360	35,803.20	100,800	64,996.80	1:2.81
Insect Proof Net House	Coloured Capsicum	1,760	44,483.52	82,800	38,316.48	1:1.85
	Indeterminate Tomato	4,720	47,526.16	94,400	46,473.84	1:1.98
	English Cucumber	2,640	32,775.20	79,200	46,424.50	1:2.41
Green Shade Net House	Coloured Capsicum	1,540	44,243.52	72,400	31,596.48	1:1.63
	Indeterminate Tomato	4,120	47,256.16	82,400	35,143.84	1:1.74
	English Cucumber	2,280	32,775.20	68,400	35,624.80	1:2.08

October 31, 2021. The single plant of tomato gave 7.0 kg fruit, whereas under the tomato umbrella, the good green quality garlic plants were uprooted and made a bunch of 10-15 plants and sold in the market @ ₹ 15/bunch.

SUMMARY

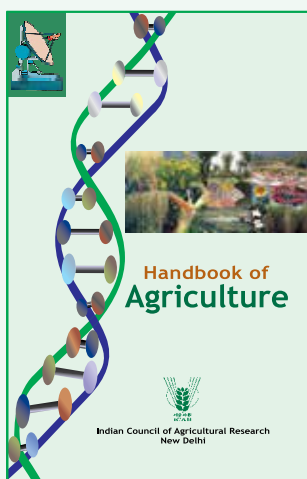
In the era of urbanization, industrialization and climate change, the vertical farming holds a great promise to enhance the vegetable productivity by using hydroponic or aeroponics systems. Today, approximately 60% of the global population resides in the urban areas which are expected to reach a mark of 68% by 2050. Simultaneously, the global population is estimated to reach a figure of 10 billion by 2050. Vertical farming is one of the most effective solutions to meet out the growing demand of

healthy and nutritious vegetables. The vertical farming of vegetables can provide round the year fresh vegetables. Vegetable growing under vertical farming systems can enhance vegetable production and productivity globally and can be a potential system to tackle the challenges imposed by climate change. Further, the vertical farming may provide job opportunities in the area of engineering, biotechnology, infrastructure, biochemistry, research and development.

For further interaction, please write to:

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TECHNICAL SPECIFICATIONS

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