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SK Jain
Professor and Head, Department
of Farm Structural Engineering,
College of Agricultural Engineering
and Technology, Dapoli,
Maharashtra, India

AA Waydande
Agricultural Engineer, College of
Agricultural Engineering and
Technology, Dapoli, Maharashtra,
India

NS Gavali
Agricultural Engineer, College of
Agricultural Engineering and
Technology, Dapoli, Maharashtra,
India

Corresponding Author:
SK Jain
Professor and Head, Department
of Farm Structural Engineering,
College of Agricultural Engineering
and Technology, Dapoli,
Maharashtra, India

Vertical tower aeroponics for lettuce: A study on growth and water usage

SK Jain, AA Waydande and NS Gavali

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Abstract

Vertical Tower Aeroponics System evaluates the growth and water usage efficiency of lettuce (*Lactuca sativa*). The system, installed within a controlled environment, demonstrated significant improvements in water conservation and crop productivity compared to traditional methods. Essential parameters such as pH (5.6-6.3), EC (1.1-1.6 mS/cm), TDS (558-680 ppm), temperature (27.0-29.9 °C), and relative humidity (66.0-73.2%) were optimized. Results indicated efficient plant growth with the maximum of plant height, root length, numbers of leaves to be 19.3 cm, 10.0 cm and 18 leaves, respectively. This research suggests vertical aeroponics as a viable solution for urban and resource-limited agriculture.

Keywords: Vertical farming, aeroponics, lettuce, water efficiency, urban agriculture

1. Introduction

Aeroponics, a soilless cultivation method, allows plant roots to be suspended in air and periodically misted with a nutrient-rich solution. This technique, developed by NASA, is now gaining traction in urban and sustainable agriculture. Lettuce, a popular leafy vegetable with high market demand, benefits from the precision and efficiency of aeroponic systems. Many leafy vegetables and fruits can be cultivated in the aeroponic system (Gopinath *et al.*, 2017) ^[2]. Plant grown in the aeroponic system also been shown to uptake more minerals and vitamin, making the plants healthier and potentially more nutritious (Kumari and Kumar 2019) ^[3]. These systems use up to 90% less water than even the most efficient hydroponic systems, making them the most water-efficient method for vertical farming (Vashishta *et al.*, 2024) ^[5]. Aeroponics is well-suited for growing a variety of vegetables, including lettuce (*Lactuca sativa*), prefers a water pH of 5.6-6.5. Optimal humidity for lettuce growth is between 65% to 78%, with an ideal temperature range of 25° to 28 °C (Awalina *et al.* 2022) ^[1]. In the future, it would be a difficult task to provide a fresh and clean food supply for the fast-growing population using traditional agriculture. (Lakhiar *et al.* 2018) ^[4]

2. Materials and Methods

The study was conducted in a Laboratory at CAET, DBSKKV, Dapoli. A 1.8 m tall vertical aeroponic tower made of food-grade PVC was constructed to support 36 lettuce plants. Essential system components included a nutrient tank, submersible pump, grow lights, and monitoring instruments (pH meter, EC meter, thermometer, lux meter). Lettuce seeds (Iceberg, Concord, Maximus) were germinated in cocopeat trays and transplanted at 16 days after sowing. Nutrient solutions were prepared with macro- and micro-elements in A and B stock solutions (Table 2), added at 2 ml/L each.

Table 1: Specification of Vertical aeroponics system

Sr. No	Components	Specification	Material
1	Growth chamber (tower section)	Diameter= 0.35m Height = 1.524 m	Food Grade Plastic
2	Net pots	Bottom Diameter = 3.8 cm Upper Diameter = 5.5 cm Height = 5 cm	Food Grade Plastic
3	Hydro tons	Size = 15 to 30 mm	Lightweight Expanded-Clay Aggregate, (LECA)
4	PVC pipes	Length =2 m Outside diameter = 21mm Inside diameter = 16 mm Pressure = 28.14 kg/cm ² Flow rate = 0.13 - 0.25 lps	Polyvinyl Chloride
5	Submersible pump	Power = 18W / 0.0241 hp Rated, Voltage = 220 V Capacity = 100 to 300 lph	Food Grade Plastic
6	Nutrient tank	Capacity = 20 L Height = 0.2 m Diameter = 0.35 m	Food Grade Plastic
7	Grow light	Power= 17 watt Product dimensions= 4 ft Operating Temperature=0°C-45 °C	

Table 2: Nutrients Used for Aeroponics system

Sr. No.	A solution	For 1 lit	B solution	For 1 lit
1	Calcium Nitrate solid	97 gm	Potassium Nitrate	48 gm
2	Potassium Nitrate	13 gm	Potassium Sulphate	17 gm
3	Iron DTPA 6% or HBED 6%	3.723 gm	Monopotassium Phosphate	19 gm
4	Manganese EDTS 12.8%	0.3 gm	Magnesium Sulphate 16% MgO	25 gm
5	Zinc EDTA 14.8%	0.309 gm	Monoammonium Phosphate	1 gm
6	Copper EDTA 14.8%	0.043 gm	Borax 11.3% B/ Boron	0.38gm
7			A Sodium Molybdate 39.6%/ammonium Molybdate	0.024 gm

This system includes pipes with small holes through which nutrient-rich water flows continuously. As the water moves through the pipes, it comes into contact with the hanging roots, ensuring they stay moist and absorb all the nutrients needed for growth. As the roots are suspended in the air, they get excellent access to oxygen, which is very important for healthy root development and overall plant growth. This combination of water and air around the roots creates the ideal environment for faster and more efficient plant growth. The important crop parameters such as plant height, root length, and the number of leaves were measured to study the growth of lettuce.

**Fig 1:** Vertical Tower Aeroponic system**Fig 2:** Root length of lettuce**Water used efficiency**

Water Use Efficiency was calculated by using the formula:

$$WUE = Y / W.U.$$

Where, WUE = Water Use Efficiency (kg/m³)

Y = Yield of crop (kg)

W.U = Total amount of water used (m³)

3. Results and Discussion

Environmental conditions were maintained within optimal ranges

In the experiment, a grow light was used, which gave a fixed light intensity of 5090 Lux. The temperature and humidity readings are shown in Table 3.

Table 3: Temperature and Humidity Observations

Sr. No.	Date (Days After Transplant)	Temperature (°C)	Humidity (%)
1	04-05-2025	28.0	66.6
2	05-05-2025	29.0	67.0
3	06-05-2025	28.0	66.6
4	07-5-2025	29.9	66.6
5	08-05-2025	27.8	66.6
6	09-05-2025	27.8	72.7
7	10-05-2025	27.0	73.2
8	11-05-2025	28.0	66.6
9	12-05-2025	29.0	72.0
10	13-05-2025	29.9	66.6
11	14-05-2025	29.0	69.0
12	15-05-2025	28.9	67.0`

The Temperature and Relative Humidity, were found in range of 27.0 to 29.9 °C and 66.6 to 73.2% respectively.

Chemical Properties of nutrient solution

The recorded value of EC, pH and TDS of nutrient solution used in the experiment are shown in Table 4. These observations were taken from 04/05/2025 to 15/05/2025.

Table 4: EC, pH and TDS Observations:

Sr. No.	Date (Days After Transplant)	EC (mS/cm)	pH	TDS (ppm)
1	04-05-2025	1.5	6.1	730
2	05-05-2025	1.3	6.3	651
3	06-05-225	1.1	5.6	558
4	07-05-2025	1.4	5.7	695
5	08-05-2025	1.6	6.1	780
6	09-05-2025	1.5	6	650
7	10-05-2025	1.2	5.9	598
8	11-05-2025	1.5	6.2	678
9	12-05-2025	1.4	6	631
10	13-05-2025	1.5	5.6	730
11	14-05-2025	1.3	6	635
12	15-05-2025	1.4	5.8	623

The EC, pH and TDS were found in range of 1.1 to 1.6 mS/cm, 5.6 to 6.3 and 558 to 780 ppm. These values helped ensure the plants were receiving the correct amount of nutrients and water quality for healthy development. Regular monitoring provided a suitable environment for proper growth in the aeroponic system

Crop Parameters

The readings related to crop parameters such as Root length plant height, and Number of leaves is shown in Table 5. These values help us understand how the crop responded to different conditions like water use and solution treatment.

Table 5: Plant Height, Roots Height and No. of Leaves

Date	Plant No.	Plant Height (cm)	Roots length (cm)	No. of Leaves
06-05-2025	1	2.5	-	5
	2	1.5	-	4
	3	1	-	5
	4	3	-	5
	5	4	-	8
	6	6	-	8
	7	4.5	-	7
	8	8	-	10
09-05-2025	1	5	-	8
	2	4	-	5
	3	4.9	-	6
	4	5	-	6
	5	9	-	9
	6	12	-	9
	7	12	-	11
	8	15	-	7
12-05-2025	1	7.2	-	9
	2	6.5	-	7
	3	6.1	-	8
	4	6.5	-	7
	5	15	-	13
	6	15.2	-	13
	7	17.5	-	18
	8	18	-	9
15-05-2025	1	8.5	5	11
	2	7.5	10	8
	3	7.1	7.3	11
	4	7.5	7.5	10
	5	16.5	9.5	18
	6	16.8	7	16
	7	19.2	7	18
	8	19.3	6.5	10

The maximum of plant height, root length, numbers of leaves are found to be 19.3 cm, 10.0 cm and 18 leaves, respectively. The lettuce growth of is shown in Fig. 1 and 2.

Water used efficiency

In the experiment 61 liter of water was used. Along with that 178 ml of solution A and 165 ml of solution B were added. The readings obtained from experiment is given in the Table 6.

Table 6: Water Efficiency Observations & Daily Consumption of Nutrients

Sr. No.	Date	Water input (L)	A Solution (ml)	B Solution (ml)
1	04-05-2025	20	60	50
2	05-05-2025	5	15	12.5
3	06-05-2025	4	12	10
4	07-05-2025	6	18	15
5	08-05-2025	6	18	15
6	09-05-2025	4	12	10
7	10-05-2025	6	18	15
8	11-05-2025	5	15	12.5
9	12-05-2025	5	15	12.5
10	13-05-2025	5	15	12.5
11	14-05-2025	7	21	17.5
12	15-05-2025	5	15	12.5

The total lettuce crop yield was found to be 1.900 kg (1900gm) in this setup. Thus, by using formula the water used efficiency was found to be 31.15gm /lit.

4. Conclusion

The vertical tower aeroponic system offers an efficient, space-saving, and sustainable method for growing lettuce, particularly suitable for urban and water-scarce areas. The study confirms the viability of this method for enhanced crop yield and resource management.

5. References

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