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Study of a horizontal growth chamber aeroponics system for spinach

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Abstract

This study evaluated the effectiveness of a horizontal growth chamber aeroponics system for cultivating spinach (*Spinacia oleracea* L.) under suitable conditions. The system included components like a growth chamber, misting mechanism, and monitoring devices (EC, pH, and lux meters). Spinach seedlings were germinated and transplanted into net pots, with roots misted using a nutrient-rich solution. Growth metrics such as plant height, root length, and leaf count were recorded. Results showed consistent vegetative growth, with the maximum height of 16 cm, root length up to 48 cm, and leaf count of 26. This confirms the aeroponics system's potential as a sustainable and efficient solution for leafy green production.

Keywords: Aeroponics, spinach, soilless cultivation, horizontal growth chamber, sustainable farming

Introduction

Global population growth and diminishing arable land necessitate innovative farming technologies. Aeroponics, a form of soilless agriculture where plant roots are suspended and misted with nutrients, offers precise resource use and accelerated growth. This research investigates spinach cultivation using a horizontal aeroponic chamber to evaluate its efficacy as a sustainable alternative to soil-based methods. Spinach is rich in vitamins A, C, and K, several B vitamins, and essential minerals such as iron, calcium, magnesium, and manganese. Hydroponic cultivation within a vertical farming system is an advantageous method as urbanization continues to limit available agricultural land (Kumar *et al.* 2024) ^[4]. Higher humidity (optimally 85±2%) improves plant growth by keeping stomata open for photosynthesis, with a 10% humidity increase potentially boosting leaf length, width, and dry weight (Chia *et al.* 2022) ^[3]. Aeroponics allows for controlled environment (humidity, temperature, pH, electric conductivity) for vegetable crops, with optimal pH (5.5-6.6) and EC (1-2 mS/cm) ranges for crops like spinach and lettuce (Vamsi *et al.* 2024) ^[8]. Aeroponic systems showed higher water use efficiency (up to 67 kg/m³) and fertilizer use efficiency (up to 43.83%) compared to conventional methods (Nigadi *et al.* 2024) ^[6]. Aeroponically grown plants outperformed soil-based plants, with increased plant height, leaf number, root length, and biomass in both tomatoes and cucumbers (Bakker *et al.* 2024) ^[2]. Aeroponics promoted better growth rate and plant height in *Lilium* flowers compared to an ultrasonic system, using a modified Hoagland nutrient solution (Abbasi *et al.* 2023) ^[1]. Aeroponics involves growing plants with roots suspended in air, fed by a fine mist of nutrient-rich solution, promoting healthy root growth and nutrient uptake (Mangaiyarkarasi *et al.* 2020) ^[5]. Soilless culture, including water and substrate culture, offers sustainable options for growing various crops, with closed-loop systems gaining importance for environmental sustainability (Tuzel *et al.* 2019) ^[7].

Materials and Methods

The setup included a plywood-based chamber with 24 plant positions, nutrient tanks, misting nozzles, and a digital timer. Spinach seedlings were germinated in trays and transplanted into net pots filled with hydrotons. The misting cycle was set at 30 seconds ON and 2 minutes OFF. EC, pH, temperature, humidity, and light were monitored daily. Spinach seeds were sown in germination trays with coco peat and vermicompost for seed preparation. Water was applied twice daily, and seedlings were transplanted into the aeroponics system after 15 days.

The aeroponics system was inspected and cleaned, and a leakage issue was addressed by replacing the plastic sheet in the growth chamber. Seedlings were transplanted into net pots with hydro tons and placed in the aeroponics system, which provided a continuous flow of nutrient-rich solution. A balanced nutrient solution was prepared with macro and micronutrients, and its pH and EC levels were adjusted. Growth parameters (plant height, root length, number of leaves), environmental conditions (humidity, light intensity, temperature), and nutrient solution parameters (EC, pH, TDS) were monitored daily. Spinach was harvested after 22 days, with careful handling to avoid damage,

and prepared for distribution.

Results and Discussion

The environmental parameters were ranges as, EC (0.8-1.5 mS/cm), pH (5.8-7.7), light (950-7800 lux), and humidity (31.5-72.2%). Plants showed continuous growth over 22 days. No pest issues were observed. The data confirms robust growth under aeroponic conditions.

Table 1 reveals daily observations of EC, pH and TDS of nutrient solution in growth chamber during study period.

Table 1: EC, pH and TDS observation

Sr. No.	Date (Days After Transplant)	EC (mS/cm)	pH	TDS (ppm)
1	17-03-2025	0.8	7.1	512
2	18-03-2025	0.8	7.3	518
3	19-03-2025	0.9	7.7	576
4	20-03-2025	1.0	6.8	640
5	21-03-2025	0.9	7.3	586
6	22-03-2025	1.2	6.3	795
7	23-03-2025	1.1	6.8	705
8	24-03-2025	1.0	7.0	652
9	25-03-2025	1.2	6.9	831
10	26-03-2025	1.4	6.8	965
11	27-03-2025	1.4	6.2	971
12	28-03-2025	1.4	6.0	973
13	29-03-2025	1.4	6.4	1041
14	30-03-2025	1.4	5.8	1020
15	31-03-2025	1.5	6.2	1052
16	01-04-2025	1.5	6.6	1010
17	02-04-2025	1.4	6.4	999
18	03-04-2025	1.4	6.4	1015
19	04-04-2025	1.4	6.3	977
20	05-04-2025	1.4	5.9	995
21	06-04-2025	1.3	5.9	943
22	07-04-2025	1.1	6.4	790
Average		1.1	6.2	799

It was observed that the EC, pH and TDS of nutrient solution in growth chamber varied between range of 0.8 to 1.5 mS/cm, 5.5 to 7.7, 512 to 1020 ppm, respectively. The average of EC, pH and TDS was found to be 1.1 mS/cm, 6.2 and 799 ppm respectively. 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.

Environmental Conditions

Environmental conditions like Temperature, Relative humidity and Light intensity were carefully monitored and are shown in Table 2.

Table 2: Temperature, Humidity and Light intensity observation

Sr. No	Date (Days After Transplant)	Temperature (°C)		Humidity (%)		Light Intensity (Lux)	
		Morning	Afternoon	Morning	Afternoon	Morning	Afternoon
1	17-03-2025	26	31	59	52	1275	6260
2	18-03-2025	25.9	30	38	44	1590	7240
3	19-03-2025	28.5	31.5	39	45	4420	7590
4	20-03-2025	23.3	31	54	31.5	1270	6210
5	21-03-2025	25	31	35.5	45	1090	6980
6	22-03-2025	27.4	30.5	42.2	31.5	3230	6870
7	23-03-2025	27.2	31.7	56.5	47.5	2260	7530
8	24-03-2025	26.1	30.5	66.6	53.6	1530	7300
9	25-03-2025	23	32	70.5	49	990	7800
10	26-03-2025	27.6	32.5	62	44	1230	5650
11	27-03-2025	25.7	33	72.2	62	1550	3250
12	28-03-2025	29	34	60	49	3610	5100
13	29-03-2025	27.6	31.2	59	52	2280	4800
14	30-03-2025	26.9	32	60	51	2800	1900
15	31-03-2025	29	31.8	41	45	1950	4350
16	01-04-2025	30	34	66	52	3200	6530
17	02-04-2025	28	32	69	58	3080	7250
18	03-04-2025	26	30	70	41	2200	5430
19	04-04-2025	29.9	33	71	62	1250	4500
20	05-04-2025	28	30	64	59	1576	4760
21	06-04-2025	29.5	32	66	61	1150	3400
22	07-04-2025	29.8	32.8	71.2	63.6	950	3950

For healthy growth of spinach in the aeroponic system, it is important to maintain proper environmental conditions. During the study period, the temperature, humidity, and light intensity were regularly observed. The temperature range was observed to be between 23 °C to 30 °C in the morning and 30 °C to 34 °C in afternoon. Though, the temperature range in afternoon has been for shorter period of 1 to 2 hour but during this period plant growth were suffered negatively. Humidity was found to be

between 31.5% to 72.2% to keep the plants hydrated and prevent wilting. The light intensity was observed to be in the range of 3250 to 7800 Lux.

Growth parameters

Growth parameters like Plant height, Root length and Number of leaves were carefully monitored on alternate days and are shown in Table 3.

Table 3: Plant height, Root length and Number of leaves observation

Date	Plant No.	Plant Height (cm)	Root length (cm)	No. of Leaves
18-03-2025	1	5.8	-	15
	2	4.9	-	16
	3	3.5	-	12
	4	4.5	-	13
	5	5.7	-	12
	6	6.3	-	12
	7	5.4	-	11
	8	4	-	12
20-03-2025	1	6	-	17
	2	5	-	16
	3	3.5	-	16
	4	5	-	16
	5	6	-	16
	6	6.5	-	12
	7	5.5	-	13
	8	4.5	-	12
22-03-2025	1	6.5	0.1	17
	2	5.6	8.9	17
	3	4.1	1.1	16
	4	5.8	0.4	18
	5	6	1.4	18
	6	7.6	6.8	14
	7	5.6	2.1	16
	8	5.2	3.7	13
24-03-2025	1	7.5	0.2	20
	2	8	11	18
	3	5.5	2.5	17
	4	7	1.1	20
	5	6.5	3	18
	6	9	9	15
	7	6	3.1	18
	8	7.5	5.9	14
26-03-2025	1	7.7	0.3	21
	2	8.2	13.5	18
	3	5.5	3.1	18
	4	7.5	1.4	20
	5	6.6	3.5	18
	6	9	10.9	15
	7	6	3.8	18
	8	7.5	7.1	14
28-03-2025	1	9.3	0.5	23
	2	9.5	15	20
	3	7.5	4	21
	4	9	2	23
	5	9	4	20
	6	11	15.9	15
	7	8.5	4.5	21
	8	10	9	15
30-03-2025	1	9.5	1	25
	2	9.8	15.5	21
	3	8	6	19
	4	9.3	3.6	24
	5	9.5	6	20
	6	11.5	17.5	16
	7	8.8	4.8	20
	8	10.5	10.5	17

01-04-2025	1	10	1.5	25
	2	11	15.7	20
	3	8.9	6.5	19
	4	9.5	4.1	24
	5	10.2	10.4	18
	6	12.1	17.7	16
	7	9.5	6.2	21
	8	11.2	12.5	18
03-04-2025	1	12.2	4.6	25
	2	14.3	24	20
	3	11.7	10	16
	4	10.9	15.8	23
	5	13	3.2	16
	6	15.1	22	13
	7	10.8	19.8	19
	8	12.6	16	16
05-04-2025	1	12.6	4.8	23
	2	14.8	32	22
	3	11.9	15.5	19
	4	11.8	27.1	25
	5	13.6	39.6	18
	6	15.2	26.2	16
	7	12	25.1	21
	8	12.8	21	17
07-04-2025	1	13	5	24
	2	16	35	23
	3	12.5	16	19
	4	13	34	26
	5	14.5	48	20
	6	15.5	28	18
	7	13	29	22
	8	12.9	28	17

The spinach plants exhibited significant growth during crop duration of 22 days. In first week, average of plant height is 5.8 cm and average of number of leaves is 15. In last week, average of plant height is 12.6 cm, average of root length is 19 cm and average number of leaves is 20. Maximum plant height reaches 16 cm, root length up to 48 cm and the number of leaves up to 26, showcasing healthy vegetative development.

Conclusion

The study concludes that the horizontal growth chamber aeroponics system is effective for leafy greens like spinach, providing promising results in terms of growth rate and plant health under controlled conditions. The results highlight the potential of aeroponics as a sustainable and efficient alternative to traditional soil-based farming, especially for leafy vegetables like spinach. It was found that spinach crop was harvested in short duration of 37 days from after sowing. It is concluded that no insect attack was observed during crop growth, eliminating the need for pesticides.

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