__Original Research Article__

Design and Comparison of Vertical and Horizontal Hydroponic Systems for Coriander and Spinach Growth

Abstract

Understanding the differences in growth performance between these two systems will provide valuable insights for optimizing hydroponic farming practices, particularly in regions with harsh climates and limited water access, where sustainable and efficient food production is crucial for addressing future food security challenges.As the global population continues to grow and climate stress intensifies, indoor/vertical farming is to complement traditional agricultural practices by enhancing sustainable food production and ensuring high-quality produce.The study demonstrated that the horizontal hydroponic system was significantly more effective for growing coriander than the vertical system. In summary, the horizontal hydroponic system consistently outperformed the vertical system for both spinach and coriander, with particularly pronounced results for coriander.Since the shoot is the main economic part of both spinach and coriander, the vertical hydroponic system outperforms the horizontal system, offering significant advantages for economic production. These findings highlight the importance of using vertical hydroponic systems to achieve higher and more profitable yields of these crops.

Keywords: sustainable food production, hydroponics,Vertical farms, fish farming

UNDER PEER REVIEW

1. Introduction

Vertical farms are innovative farming systems where plants grow in a controlled environment using artificial lighting to replace sunlight. These farms use soilless cultivation methods such as hydroponics (roots in nutrient-enriched water with substrates like perlite or rockwool), aeroponics (roots in air/mist), and aquaponics (combining fish farming with hydroponics). These methods allow plants to be stacked in multiple layers, either horizontally or vertically, maximizing space and efficiency. This controlled environment and advanced growing techniques enable optimal plant growth and development, independent of traditional soil and weather conditions (Avgoustaki*et al*.,2020). As the global population continues to grow and climate stress intensifies, indoor/vertical farming is to complement traditional agricultural practices by enhancing sustainable food production and ensuring high-quality produce.

Hydroponics offers several advantages, i.e it doesn't need soil, it is faster than traditional farming, it requires less space and can be grown anywhere, it is not affected by seasonal changes, it needs little or no pesticides and herbicides, plants receive a complete range of nutrients in the exact amounts needed, plants are protected from diseases and pests, it can be used to isolate crops for experiments (Raviv*et al.*, 2007; Dutta *et al.*, 2023) and in some crops such as coriander and Spinach it was found to have better yield under under hydroponics compared to soil cultivation (Kulkarni *et al.*, 2018).

Unlike field cultivation, hydroponically grown plants are typically cultivated in greenhouses or controlled environment agriculture (CEA) setups, using inert media. This controlled environment allows for the precise management of growth conditions, leading to optimized plant health and yield. Commonly grown hydroponic crops include tomatoes, peppers, cucumbers, strawberries, lettuces, and cannabis, primarily for commercial purposes [7,8].

Given the advantages of hydroponics, this research paper aims to compare plant growth under vertical and horizontal hydroponic systems. Vertical and horizontal hydroponic systems each have unique benefits, depending on the space and crops involved. Vertical hydroponics is very efficient with space, stacking plants in layers to use vertical room effectively. This makes it especially useful in cities where ground space is limited. However, it can be harder to ensure all plants get enough light, often requiring extra lighting. Maintenance can also be more difficult since reaching plants on higher or lower levels can be challenging, though automation can help [9,10]. Horizontal hydroponic systems, on the other hand, place plants on a flat surface, which allows for even light distribution and easier access for maintenance. While these systems use more ground space and are less space-efficient, they are easier to set up and manage. Horizontal systems are also more versatile, making them suitable for a wider variety of crops, including larger ones. They generally cost less to set up, but they need more land, which could be a drawback in areas with limited space. In summary, vertical systems are great for maximizing yield in small spaces but are more complex and expensive, while horizontal systems are simpler and more versatile but require more space (Cabanás*et al.,* 2020).

Understanding the differences in growth performance between these two systems will provide valuable insights for optimizing hydroponic farming practices, particularly in regions with harsh climates and limited water access, where sustainable and efficient food production is crucial for addressing future food security challenges.

2. Materials and methods

2.1 Study Area

The research was conducted at BRSM College of Agricultural Engineering and Technology & Research Station in Mungeli, Chhattisgarh. The study area is located at 22°03’59” N latitude and 81°38’32” E longitude, with an average elevation of 288 meters (944 feet) above sea level.

2.2 Design of Hydroponics system

- PVC was chosen as a basic structure that could support the weight of the hydroponic system and the plants.
- Holes were drilled along the framework at regular intervals.
- In a horizontal hydroponic system, the structure was pyramidal, whereas in a vertical hydroponic system, it was u-shaped.
- PVC tubing was cut to lengths slightly longer than the height of the structure.
- A hole was made at the top of the structure for one end of the tubing, which hung down to the bottom, and this was repeated for every hole.
- All of the tubing at the bottom of the structure was connected with a manifold or connector and half-inch pipes.

UNDER PEER REVIEW

- This allowed the nutritional solution to flow through the entire tube evenly and continuously.
- The nutrient solution was prepared using NPK fertilizer (19:19:19).
- pH and TDS were identified as two important indicators for a hydroponics system which was measured using pH meter and TDS meter.
- The plants chosen were spinach and coriander

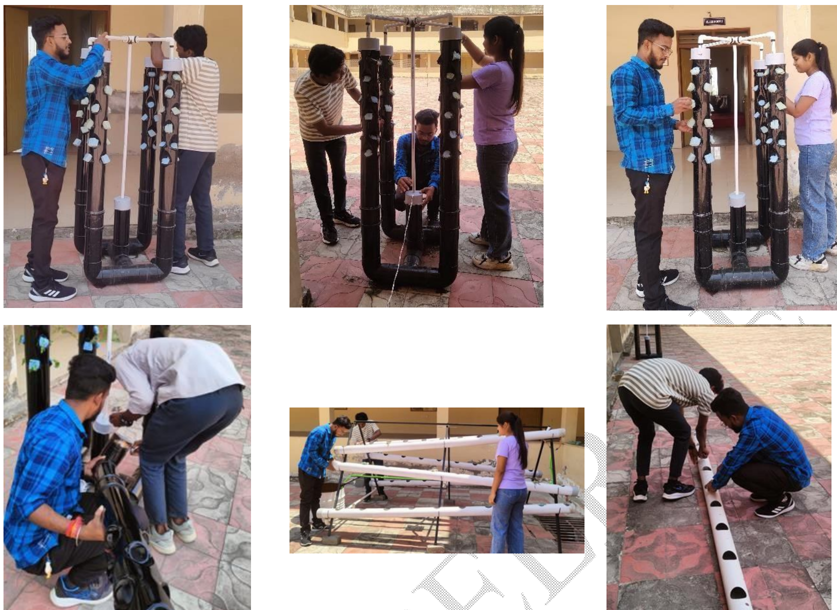


Fig.1: Construction of hydroponics systems

2.4 Specifics of the arrangement

- Vertical Hydroponic System

  Length of pipe: 100cm/1m

  Diameter of pipe: 101mm/10.1cm

  Area of cylindrical pipe: 3333.2cm^2/0.333m^2

  Hole diameter: 5cm

  Total number of plants grown: 72

- Horizontal Hydroponic System

  Length of pipe: 100cm/1m

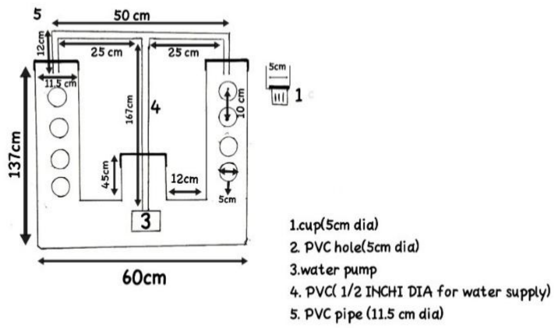
  Diameter of pipe: 101mm/10.1cm

  Area of cylindrical pipe: 3333.2cm^2/0.333m^2

UNDER PEER REVIEW

Hole diameter: 8cm

Total number of plants grown: 60



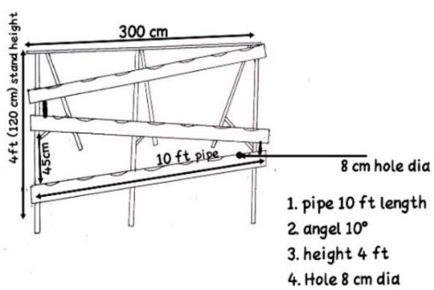


Fig.2: Design of Vertical and Horizontal Hydroponic System

2.3 Statistical analysis

The t test was conducted to compare the performance under vertical and horizontal hydroponics systems. The analysis was conducted using the statistical software R. The methodology began with data collection, ensuring that the sample sizes were adequate and the data met the necessary assumptions. Once the data was collected, the mean and standard deviation for each sample were calculated. For an independent two-sample t-test, the null hypothesis typically stated that there was no significant difference between the means of the two groups, while the alternative hypothesis stated that there was a significant difference. Using R, the t-test was performed by inputting the data and specifying the type of t-test. The software calculated the t-value and the corresponding

UNDER PEER REVIEW

p-value. If the p-value was less than the chosen significance level (usually 0.05), the null hypothesis was rejected, indicating a significant difference between the group means. The results were then interpreted to understand the practical implications of the findings (Moore *et al*., 2020).

3. Results and Discussions

Table 1: The results of t test conducted

Particulars	Crop	Hydroponics System	Mean	SD	p value
Shoot length	Spinach	Vertical	20.31	0.54	0.000
		Horizontal	17.93	0.59	
	Coriander	Vertical	18.99	0.57	0.035
		Horizontal	18.34	0.54	
Root length	Spinach	Vertical	12.31	0.54	0.047
		Horizontal	12.93	0.59	
	Coriander	Vertical	10.99	0.57	0.000
		Horizontal	12.34	0.54	

3.1 Root Length

The analysis of crop root length for spinach and coriander between vertical and horizontal hydroponic systems revealed significant findings. For the spinach crop, the mean root length in the horizontal hydroponic system (12.925 cm) was slightly higher than in the vertical system (12.3125 cm), with standard deviations of 0.587367 and 0.5356905, respectively. The t-test result showed a p-value of 0.04704241, indicating a statistically significant difference at the 5% significance level. This suggested that the horizontal hydroponic system performed better for growing spinach compared to the vertical system. Similarly, for the coriander crop, the mean root length in the horizontal hydroponic system (12.3375 cm) surpassed that of the vertical system (10.985 cm), with standard deviations of 0.5396758 and 0.5717892, respectively. The p-value from the t-test was 0.000252307, which was much smaller than the conventional alpha level of 0.05, indicating a highly statistically significant difference. This demonstrated that the horizontal hydroponic system was significantly more effective for growing coriander than the vertical system. In summary, the horizontal hydroponic system consistently outperformed the vertical system for both spinach and coriander, with particularly pronounced results for coriander.

3.2 Shoot Length

The analysis of the spinach crop revealed that the mean shoot length from the vertical hydroponic system was 20.31 cm, with a standard deviation of 0.54, whereas the horizontal hydroponic system had a mean shoot length of 17.93 cm and a standard deviation of 0.59. The t-test results showed a p-value of 7.19×10^{-77}indicating that the difference in shoot lengths between the two systems was statistically significant. This suggested that the higher

UNDER PEER REVIEW

shoot length observed in the vertical hydroponic system was unlikely to be due to random variation, demonstrating a clear advantage of this system for growing spinach.

For the coriander crop, the vertical hydroponic system also showed a higher mean shoot length of 18.99 cm with a standard deviation of 0.57, compared to the horizontal system, which had a mean shoot length of 18.34 cm and a standard deviation of 0.54. The p-value for the t-test was 0.035, which was below the 0.05 threshold, indicating that this difference was statistically significant. While the evidence was not as strong as for the spinach crop, it still suggested that the vertical hydroponic system was more effective in producing a higher shoot length of coriander compared to the horizontal system.

In summary, both spinach and coriander crops had higher shoot lengths in vertical hydroponic systems than in horizontal systems. The shoot is the economically important part of both spinach and coriander. The vertical hydroponic system shows clear benefits for these crops. It produces longer shoots, which means higher yields and better market value. This makes the vertical system a better choice for growers who want to increase their profits from spinach and coriander. Similarly Cabanás*et al.,* (2020) found out that, vertical hydroponics system were more effective compared to horizontal systems for Basic crop productivity due to optimization of light source distribution.

Conclusion

In this study, vertical and horizontal hydroponics systems were designed. The study also compared the growth of spinach and coriander in vertical and horizontal hydroponic systems. For root length, the horizontal hydroponic system showed an advantage for both crops. Spinach and coriander both had longer roots in the horizontal system, indicating it is better for root growth. On the other hand, the vertical hydroponic system was better for shoot length. Spinach grown in the vertical system had a significantly longer mean shoot length, and coriander also had longer shoots in the vertical system. These results suggest that vertical systems are better for shoot growth, likely due to better light exposure and space efficiency. Since the shoot is the main economic part of both spinach and coriander, the vertical hydroponic system outperforms the horizontal system, offering significant advantages for economic production. These findings highlight the importance of using vertical hydroponic systems to achieve higher and more profitable yields of these crops.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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UNDER PEER REVIEW

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