

Evaluating Water Savings in Vertical and Horizontal Hydroponic Systems Using Nutrient Film Technique

Aanchal Chandrakar^{1,*}, Narendra Agrawal²

Abstract

A study conducted at SVCAET, IGKV, Raipur, focuses on water conservation in hydroponics using the nutrient film technique (NFT). The research evaluated both vertical and horizontal hydroponic systems. Initially, plants were grown in a nursery before being transplanted into either the vertical or horizontal system. In these systems, nutrient-rich water was continuously circulated over the plant roots. The study assessed water usage and the remaining water in the system on alternate days. Vertical hydroponic systems, characterized by stacked plants, were found to make better use of space and save water by reusing the fertilizer solution across different levels. This stacking method allows the nutrient-rich water to trickle down from one level to the next, optimizing resource use. In contrast, horizontal systems, where plants are arranged in rows, tend to use more water because each row requires its own nutrient supply. This setup does not facilitate the reuse of water and nutrients as efficiently as vertical systems. Results indicated that the water use efficiency was significantly higher in vertical hydroponic systems compared to horizontal. Vertical NFT systems require less water while still supporting more plant growth, making them more water efficient. This efficiency is crucial for sustainable hydroponic practices, especially in regions where water conservation is vital. These findings suggest that adopting vertical hydroponic systems could lead to more sustainable and resource-efficient agricultural practices. By reducing water consumption and making better use of available nutrients, vertical hydroponics can contribute to the development of more environmentally friendly farming methods. This study highlights the potential for vertical NFT systems to enhance water conservation efforts in hydroponic agriculture.

Keywords: Vertical hydroponics, horizontal hydroponics, nutrient film technique (NFT), water use efficiency, plant

INTRODUCTION

The rapid development of the world's population and urbanization have increased the demand for sustainable agriculture practices. Traditional soil-based farming methods frequently result in inefficient water use, necessitating the development of new agricultural approaches. Many challenges arise with traditional farming, including physical ploughing, weeding, pests, and climate. It also necessitates extensive usage of land. All these issues are handled in hydroponic farming. Hydroponics farming produces crops faster, healthier, with less water, in a smaller space, and without illnesses, pests, or weeds. It is like traditional agriculture systems, thus the background required to apply this system will be the same in most cases, such as maintaining adequate nutrient levels, utilizing suitable irrigation techniques, caring for the plant, and so on. Other vital information will be related to the creation of a

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Received Date: October 23, 2024

Accepted Date: December 03, 2024

Published Date: December 17, 2024

Citation: Aanchal Chandrakar, Narendra Agrawal. Evaluating Water Savings in Vertical and Horizontal Hydroponic Systems Using Nutrient Film Technique. International Journal of Nutritions. 2025; 2(1): 1–8p.

proper and reliable network with a fail-safe mechanism [1, 2]. This farming technology feeds plants with nutrient-rich water rather than soil. As technology progresses and people's living standards rise, hydroponic plants become an increasingly important element of our daily lives. Not only do hydroponic plants enhance the environment, but they also make you happy [3].

There are many types of hydroponic systems including the wick system, nutrient film technique (NFT), aeroponic system, and deep flow method [4]. In the NFT technique, the water that contains nutrients circulates through plant roots. The advantage of employing this approach is that plant development is more easily controlled [5]. Vertical and horizontal systems have different benefits and problems with ease to maintain, space-saving, and increasing yield. Plants grown in vertical hydroponic systems are especially advantageous in urban environments with limited space each plant receives ample light [6]. However, horizontal systems spread plants over a larger horizontal surface area, which could make access easier [1].

Water usage efficiency (WUE) is defined as the amount of water utilized by plants or plant systems in relation to the amount of biomass generated [7]. For example, higher water use efficiency suggests that less water is necessary to reach a specified level of agricultural output, implying more efficient use of existing water resources. Water is an essential resource for plant growth; thus, its availability and quality have a substantial impact on crop quality and output. Growers in controlled environment agriculture (CEA), particularly in locations prone to drought or water constraints, want sustainable and efficient strategies to grow crops for high-profit margins. Using NFT, assess the water-saving capacity of vertical and horizontal hydroponics systems, providing insights into their efficiency and sustainability for urban farming applications [8].

This study was conducted to compare the water use efficiency and growth parameters of vertical and horizontal setups using the nutrient film technique. The purpose of this study is to optimize hydroponic systems for greater water savings by analyzing variables, such as plant growth performance, evaporation rates, and water recirculation.

MATERIALS AND METHODS

Study Area

The research was conducted at SVAET & RS, IGKV Raipur. It was in central Chhattisgarh in latitude 21°14'9" N and longitude 81°42'10" E, at an elevation of 302 metres above mean sea level. The area has a humid subtropical climate with an average annual rainfall of 1260 mm, primarily from the south-west, followed by the north-east monsoon. The experimental site has clay loam soil. The meteorological parameters of temperature, relative humidity, and light intensity were measured at the experimental site.

Materials Used Hydroponics Structure

- *Vertical Hydroponic System:* PVC pipes (diameter: 4 inches), water reservoir (50 liters), submersible pump (flow rate: 500 liters per hour), NFT channels (2 meters in length), the support structure (metal or plastic).
- *Horizontal Hydroponic System:* PVC pipes (diameter: 4 inches), water reservoir (50 liters), submersible pump (flow rate: 500 liters per hour), NFT channels (2 metres in length).

Plants and Net Pots

Spinach (*Spinacia oleracea*) seedlings, plastic net pots.

Nutrient Solution and Growing Media

Commercial hydroponic nutrient solution, growing media (cocopeat and vermiculite).

Monitoring Equipment

EC (electrical conductivity) meter, pH meters, water flow meters, temperature and humidity sensors, water level sensors, timer for the pump.

METHODOLOGY

System Setup

- *Vertical System:* Using the PVC pipes arranged in a vertical pipe arrangement, set up a vertical hydroponic system. Make sure the submersible pump is attached to each pipe that connects to the water reservoir. From the top pipe, the nutrient solution should cascade through each pipe below it before returning to the reservoir.
- *Horizontal System:* Set up a horizontal hydroponic system with the PVC pipes laid out horizontally. Connect the pipes to the water reservoir with the submersible pump, ensuring a continuous flow of nutrient solution through the channels.

There were hydroponics systems available in the study area, both vertical and horizontal.

Planting

In plastic pro-trays, spinach crop seeds were planted with a soilless media made of a 3:1 mixture of coco peat and vermiculite. To keep the seedlings healthy and disease-free, they were raised in a playhouse with natural ventilation. Place the seedlings in the NFT channels of both hydroponics systems after transplanting them into net pots (Figure 1).



Figure 1. Germinated plant.

Nutrient Solution Preparation

The water-soluble NPK 19-19-19 is an essential component of the hydroponic nutrient solution, which is used in both vertical and horizontal systems. The nutritional solution is made by combining solution A (NPK and Epsom salt) and solution B (calcium nitrate) with water. Adjust the EC to 1.2–1.8 mS/cm and the pH to 5.5–6.5. Transfer the prepared fertilizer solution into each system's water reservoir.

System Operation

A pump constantly circulates the nutrient solution through the channels in both vertical and horizontal NFT systems, ensuring a consistent flow rate that ensures uniform distribution to plant roots. To

maintain the ideal conditions for plant growth, it is essential to regularly evaluate the pH and electrical conductivity (EC) of the nutrient solution and make necessary adjustments to the nutrient concentrations. To ensure that the plants receive the right ratio of nutrients. Additionally, the growth environment's temperature and humidity were regulated and maintained to establish a steady and favorable atmosphere for plant development. Because they affect growth rates, nutrient uptake, and crop performance overall.

Water Use Efficiency

The water use efficiency obtained for each treatment was divided by the quantity of water used consumptively for the respective system. Water use efficiency was worked out and expressed in kg per cubic meter of water used.

$$WUE = \frac{T_p}{T_w}$$

where,

- WUE = Water use efficiency (kg/liter).
- T_p = Total production (kg).
- T_w = Total water use (liter).

Data Collection

Growth Parameter

- *Plant Height*: Measure the height of the plant from the base of the stem to the tip of the highest leaf using a measuring tape. Plant height was measured 7 days after transplanting and measured every week.
- *Number of Leaves*: Count the total number of leaves per plant manually. Number of leaves measured 7 days after transplanting and measured every week.
- *Stem Diameter*: Measure the stem diameter at a standardized height using calipers. Stem diameter was measured 7 days after transplanting and measured every week.

Water Usage and Savings

Water Used

Measure the volume of nutrient solution delivered to each system using flow meters. Measure total water usage over specific intervals.

Water Savings

Collect runoff water and measure its volume. Calculate water savings by comparing the volume of nutrient solution used to the runoff collected, determining the percentage of water conserved by each system.

RESULTS

Data Observed

- *Data Observed in Both the System*: Measurements were taken for three plants (R1, R2, and R3) in each hydroponic system at 7, 14, 21, and 28 days after transplanting (DAT). The data includes plant height, number of leaves, and average stem diameter. The plant growth data in vertical and horizontal hydroponics systems are shown in Table 1.

Comparison of Growth Parameter in Vertical Hydroponics and Horizontal Hydroponics

Plant Height

Figure 2 shows that vertical hydroponic systems have more height than horizontal hydroponic systems. Because several things can be attributed to the difference in height. Plants in a vertical structure grow upward because they receive light from the top [9]. As a result of this structure, plants can get taller as they attempt to reach the light source above. In a vertical system, the cascading flow of nutrients

from top to bottom ensures that plants at each stage receive a new supply of nutrients, promoting rapid growth [10].

Table 1. Plant growth data in vertical and horizontal hydroponic systems.

Parameter		7 DAT			14 DAT			21 DAT			28 DAT		
		R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3
Plant height (cm)	VS	4.3	4.9	4.8	5.8	6.2	6.3	7.6	8.2	8.1	10.7	11.5	11.4
	HS	4.1	3.8	4.5	6.6	6.5	5.7	8.1	8.5	7.9	10.5	10.	10.4
Number of Leaves	VS	2	3	3	4	3	4	5	5	6	8	7	8
	HS	2	3	4	4	4	5	6	7	7	8	9	9
Stem Diameter (cm)	VS	0.03	0.03	0.04	0.12	0.14	0.13	0.31	0.3	0.31	0.4	0.42	0.44
	H S	0.05	0.04	0.05	0.14	0.15	0.16	0.35	0.38	0.32	0.43	0.47	0.45

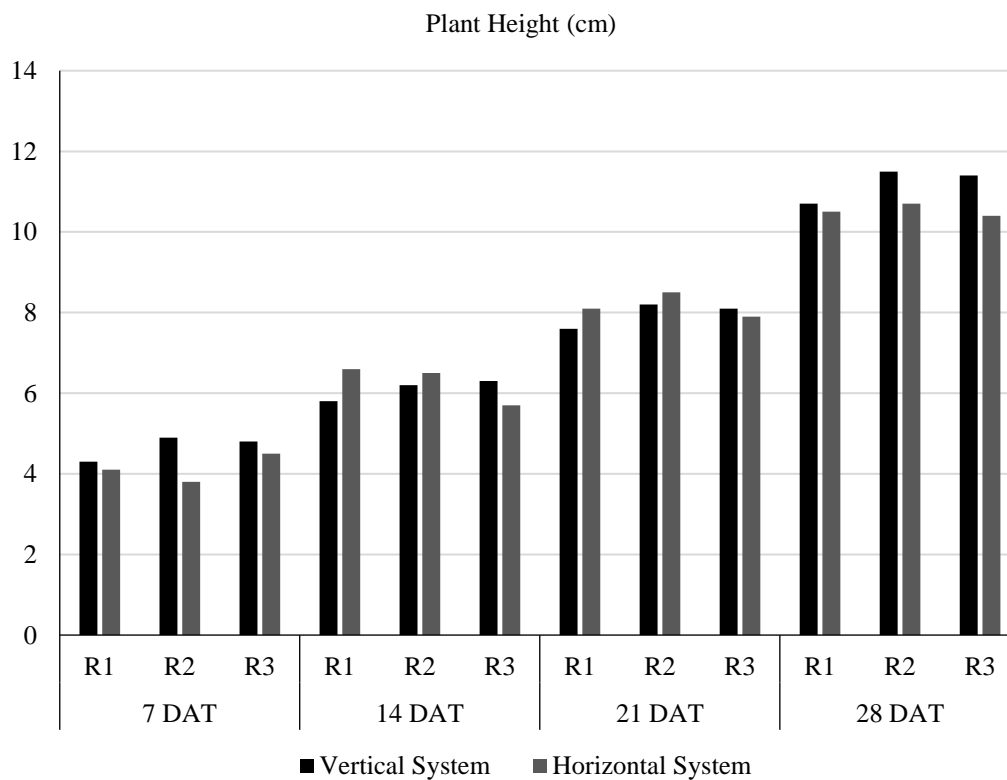


Figure 2. Plant height in vertical and horizontal hydroponic systems.

Number of Leaves

Figure 3 shows that a horizontal hydroponic system produces more leaves than a vertical hydroponic system. The capacity of the plant to absorb light and carry out photosynthesis can be improved by having more leaves. The photosynthetic layer of a plant grows by more leaves, which enables the plant to create more energy and develop faster. More leaves can develop be a result of the horizontal system's steady delivery of nutrients, signifying robust and fruitful plants. By ensuring that every plant receives enough light and nutrients, the horizontal arrangement encourages the growth of more leaves [11].

Stem Diameter

Figure 4 shows that a horizontal hydroponic system produces more stem diameter than a horizontal hydroponic system. Because more dense stems on plants produced in a horizontal hydroponic system indicated improved structural development. There are several factors that thicker stems could be beneficial. More foliage may be held up by thicker stems, which additionally offer the plant more

structure and improve its ability to withstand mechanical stress [2]. Uniform growth and thicker stem development may result from the horizontal arrangement's potential to provide a more uniform and even distribution of nutrients throughout the root zone. By distributing light more evenly throughout the plant canopy, the horizontal arrangement encourages balanced growth and stronger stems.

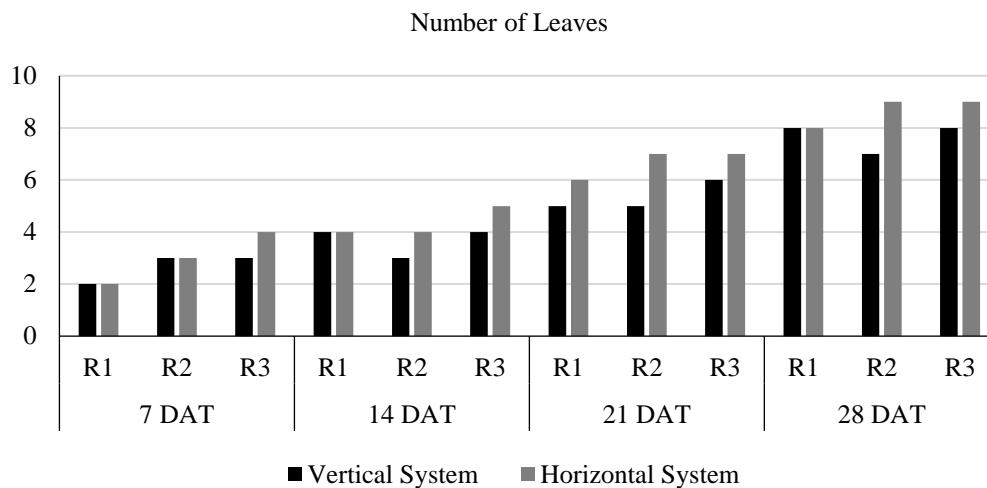


Figure 3. Number of leaves in vertical and horizontal hydroponic systems.

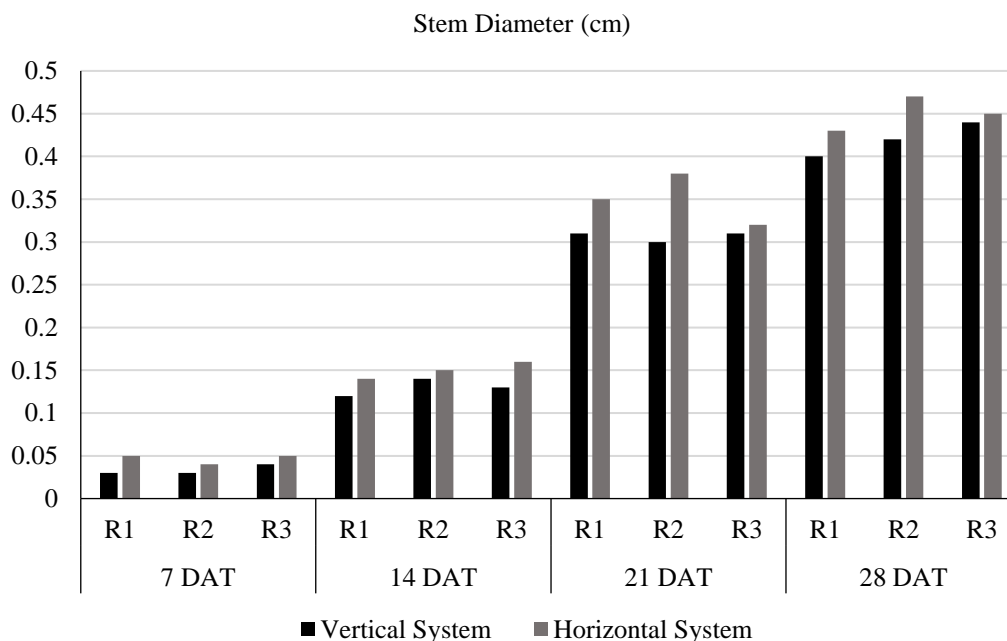


Figure 4. Stem diameter in vertical and horizontal hydroponic systems.

Comparison of Water Used Efficiency in Vertical Hydroponics and Horizontal Hydroponics System

A comparison of water used in vertical and horizontal hydroponic systems is shown in Table 2.

Table 2 compares the effectiveness of vertical and horizontal hydroponics systems with a focus on water usage, total yield, and water use efficiency. A total of 19 kilograms of crops were produced in the vertical system using 1100 liters of water. On the other hand, the horizontal system produced 16 kg less but used 1500 liters of water more than the vertical system. One important indicator of how well water

is used to produce crops is water use efficiency or WUE. By dividing the total production by the total amount of water utilized, it is computed. With a much higher water use efficiency of 0.0173 kg/L, or 0.0173 kilograms of crops produced for every liter of water utilized, the vertical system was seen. The horizontal system, however, exhibited a lower water use efficiency of 0.0107 kg/L (Figure 5).

Table 2. Water usage in vertical and horizontal hydroponic systems.

Parameter	Vertical System	Horizontal System
Total water used (liters)	1100	1500
Total production (kg)	19	16
Water use efficiency (kg/L)	0.0173	0.0107

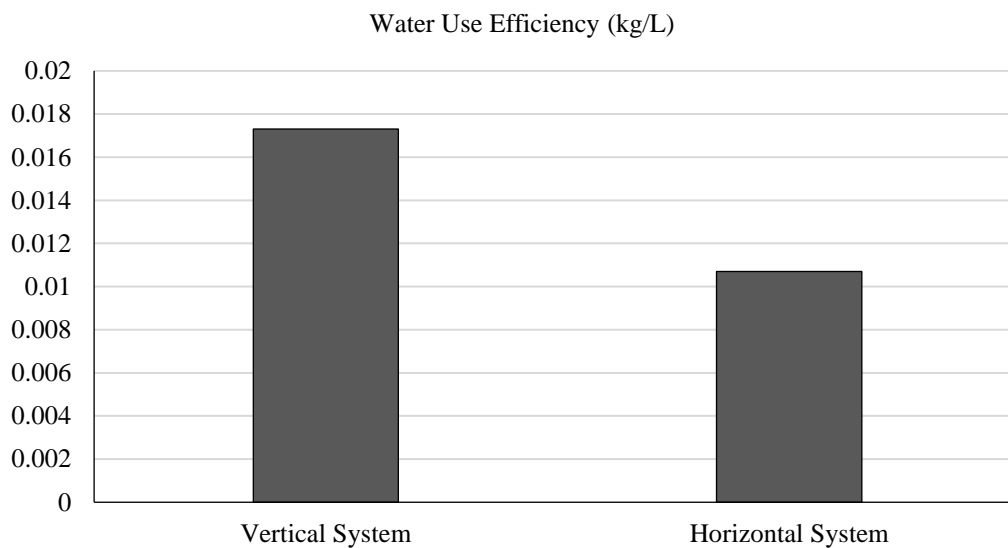


Figure 5. Water use efficiency in vertical and horizontal hydroponic Systems.

The graph shows that higher water uses the efficiency of 0.0173 kg/L, or 0.0173 kilograms of crops produced for every liter of water utilized, the vertical system was seen. The horizontal system, however, exhibited a lower water use efficiency of 0.0107 kg/L. The horizontal system, however, exhibited a lower water use efficiency of 0.0107 kg/L. These numbers highlight how much more effectively the vertical hydroponics system uses available water. Because the vertical system maximizes plant development and production while conserving water by generating a larger yield with less water. Because of its efficiency, gardeners looking to maximize produce while consuming the least amount of water may consider the vertical hydroponics system as a more sustainable and productive alternative. The finding was the same as [11–14].

CONCLUSIONS

The objective of this study was to evaluate water use efficiency and plant development characteristics through a comparative study on water savings in vertical and horizontal hydroponic systems. The result shows that it was discovered that the vertical hydroponic system used less water than the horizontal system. The vertical system fared better than the horizontal system, which had a water use efficiency (WUE) of 0.0107 kg/L. The vertical system's WUE was 0.0173 kg/L. This showed that less water was needed in the vertical system compared to the horizontal system giving a higher amount of yield. The vertical hydroponics system allows for the reuse of nutrient solutions. This uniform flow of nutrients also promotes the growth of the plant and gives greater plant height in the vertical system compared to the horizontal system. The horizontal structure required more water and yielded slightly less, but it allowed for quicker and more consistent nutrient delivery. Plant growth data showed that the horizontal system produced more leaves and had thicker stem diameters, but the vertical system increased plant

height more than the horizontal system. The trade-offs between the two systems are highlighted by these variations. The vertical system is especially well-suited for urban farming and regions with limited water resources because of its space-efficient design and increased water savings. The study's overall findings highlight the possibilities of vertical hydroponic systems as an effective and sustainable substitute for urban agriculture that maximizes water use without sacrificing plant development and yield.

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