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Application of Hydroponic System

Bijaya Thapa[1*], Puspa Bhandari[2], Riya G.C[3], Yojana Acharya[4], Subash Phuyal[5]

[1]*Dept of Architecture, Kathmandu Engineering College, Nepal, E-mail:* bijayathapa7474@gmail.com
[2] *Dept of Architecture, Kathmandu Engineering College, Nepal, E-mail:* puspa.bhandari777@gmail.com
[3] *Dept of Architecture, Kathmandu Engineering College, Nepal, E-mail:* gcreeya4@gmail.com
[4] *Dept of Architecture, Kathmandu Engineering College, Nepal, E-mail:* yoj.acharya09@gmail.com
[5] *Assoc. Professor, Dept of Architecture, Kathmandu Engineering College, Nepal, E-mail:* subash.phuyal@kecktm.edu.np.com

***Abstract*— Hydroponics is a system of growing plants in a nutrient-rich solution without soil. The plants are grown in a controlled environment, such as a greenhouse, and the solution is circulated around the roots of the plants. This allows for more efficient use of water and nutrients, as the plants can absorb the nutrients they need directly from the solution. There are several different types of hydroponic systems, including deep water culture, nutrient film technique, and aeroponics. Each system has its own advantages and disadvantages, and the choice of system will depend on the specific needs of the plants being grown. One of the main advantages of hydroponics is that it allows for more efficient use of resources. Because the plants are grown in a controlled environment, water and nutrients can be delivered directly to the roots of the plants, reducing the amount of water and fertilizer needed. This can result in faster growth rates and higher yields compared to traditional soil-based methods. Another advantage of hydroponics is that it allows for more precise control over the growing conditions. The pH, nutrient levels, and temperature can all be carefully controlled to create the optimal growing conditions for the plants. This can result in healthier plants and higher quality produce.**

Keywords*— *Hydroponics, Nutrient management, Growing systems, Vertical farming, Economic viability

Introduction

Hydroponics is a type of horticulture where plants are grown in water-based mineral nutrient solutions in the complete absence of soil [1]. Commonly used mediums include rock wool, expanded clay aggregate, coconut coir, rice husks, brick shards, wood fiber and polystyrene packing peanuts. Hydroponics has been recognized as a viable method of producing vegetables like strawberries, tomatoes, cucumbers, peppers and lettuces as well as ornamental crops such as herbs, roses and foliage plants [2].

Hydroponic systems work by allowing minute control over environmental conditions like temperature and pH balance and maximized exposure to nutrients and water [3]. Hydroponic growing takes much less water and nutrients to grow, it would be possible in the future for people in harsh environments with little accessible water to hydroponically grow their own plant-based food [1].

Plants which are grown in gardens and fields are introduced to a host of variables that negatively impact on personnel's health and growth. Besides these, hydroponics produces much healthier and high-quality fruits and vegetables by eliminating pesticides. Without obstacles, plants are free to grow vigorously and rapidly [3].

Hydroponic farm, Tokha and Nepal Agricultural Research Council (NARC), Khumaltar have been taken as the case study site for the research. Hydroponic farm was found to be bigger in size and was established 8 years before while NARC was smaller in size and established 1 year ago which has helped this research to analyse the relation between area of the plant with production and cost.

Hydroponic farm, Tokha, has been spread over an area of land that is roughly 5 ropani (0.6 acre). 4 types of hydroponics systems have been installed there with 4 tunnels in farm each size 8mx16m.

NARC being research center has only 1 tunnel dedicated for hydroponic farm of size 10*18m and 3 types of hydroponic system were installed on a small scale. It was equipped with a variety of high-tech control systems.

Components of hydroponics

A hydroponic setup or a hydroponic plant requires certain components. Let us dive into each of the components separately [4].

A. Greenhouse Structure

When a greenhouse is used in conjunction with a hydroponic system, it can provide an ideal environment for optimal plant growth, yield and quality [4].

B. Reservoir

It is the container that holds the nutrient solution required for the growth of plants. It is usually a plastic or glass container. A metallic container should not be used as it can bring

* *Corresponding Author*

harmful chemicals [5].

C. Grow Tray and Net Pots

The grow tray and net pots are essential in a hydroponic setup to hold the plants. It may have valves for better gripping and sometimes also contain mediums such as coco coir, clay and pebbles [5].

D. Tubes or PVC Pipe

This tube's purpose is to connect the reservoir to the tray. The fill tube will be attached to a submersible pump with a timer that controls the water flow [7].

E. Growing Medium

A growing medium is the medium on which the plant grows, because there is no soil in a hydroponic setup. It can be vermiculite, coconut fiber, and perlite or gravel [5].

Fig. 1 GROWING medium as seen in Nepal Agricultural Research Council (NARC), Khumaltar

F. Nutrient Solution

Nutrient solution is nothing but minerals dissolved in water. A nutrient solution for a hydroponic plant is prepared by dissolving essential minerals in required dosage to feed the plants [5].

In hydroponic farms, Tokha Metal truss structures with plastics of high quality which is also known as 5 Layers (thicker than normal plastics) coverings were used. For preventing harm from insects, colour papers were used. Since no pesticides were present, these plants are healthier. A 5000 tank was installed to store water for the farm. As 200l water was required in each tunnel per day accordingly the tanks were provided. Food graded trays and pipes were installed which prevent toxification of plants through plants.

Multiple Hydroponic System with automated nutrient management system in a controlled climate environment found in Nepal Agricultural Research Council (NARC), Built in a hi-tech green house with automatic motorized central roof opening, side ventilation, Ferti bridge control fertigation for maintaining EC and PH of nutrient, different water pump with filters, water recycling system, automatic cooling system, Axial Flow Fan, RO water system, Horticulture Lights, Microprocessor based control panel, Fogger, Shading etc.[6].

Growing systems

Plants need water, mineral nutrients and oxygen to thrive. There are six different hydroponic setups, based on different ways by which these requirements are fulfilled [7].

A. Ebb and Flow System

It requires a medium such as perlite to give stability. Water and mineral solutions are periodically pumped into the tray containing plants. Plants absorb the solution and the remaining solution drains back to the reservoir [7].

B. Nutrient Film Technique (NFT)

No medium is required. Hydroponic plants are kept in wooden channels having a slope. The mineral solution is pumped to the high end of the channel and slope down water is collected and reused. Plants with large roots are grown by this method [7].

C. Drip Systems

It is similar to ebb and flow but here water goes through smaller tubes and drain on top of plants. Small plants having less developed root systems are grown using this method [7].

D. Wick Systems

This is a medium based system where perlite or rock wool is used. Nylon rope is placed at the base of each root which extends to the reservoir. It takes up minerals and water and releases it in the medium which makes it available for plants [7].

E. Aeroponics

This is a water-based system similar to NFT and doesn't require a medium. The mineral solution is sprayed onto the plants in the form of mist. This is difficult to set up but is beneficial in the large commercial setting [6].

F. Deep Water Culture (DWC)

In a container, the plant's root is suspended in oxygenated water containing minerals. An air pump is used. This is an easy method and requires low maintenance [7].

In hydroponic farm, Tokha NFT, DWC, substrate based and aquaponics systems of hydroponic system were installed whereas in NARC, all these systems except aquaponics system were installed, grow bag hydroponics with drip irrigation, EBB and flow hydroponic system was also found. In both the cases, it was found that the NFT system and

deep-water culture system was used to grow leafy greens and substrate based for tomato, brinjal, chilies, cucumber, hot pepper etc which required support to the root.

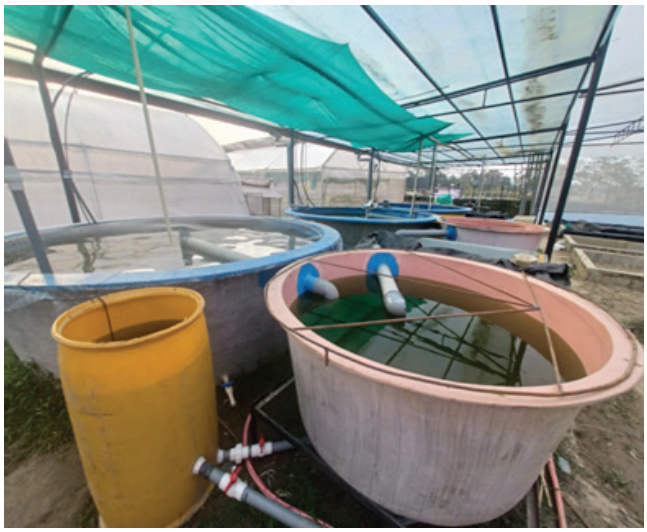

Fig: 2 Aquaponic system as seen in hydroponic farm, Tokha

Application of hydroponics in agriculture

Hydroponics allows for year-round cultivation of crops in controlled environments. It is especially useful in those areas with limited arable land or unfavourable climatic conditions. It is well suited for urban farming initiatives where space is limited. It reduces labour time of digging and cost of laborers [3].

Hydroponics produces much healthier and high-quality fruits and vegetables by eliminating pesticides. Hydroponics is a water-efficient cultivation method. In hydroponics, the nutrient-rich water solution used to feed the plants can be recirculated, reducing water consumption and wastage [4].

Application of hydroponics in architecture

A. Vertical System

A vertical hydroponic system is a type of hydroponic system in which plants are grown vertically on a wall or other vertical surface. This system is designed to maximize space utilization and increase crop yield. Overall, vertical hydroponic systems are an innovative and sustainable way to grow plants in small spaces and can be a great option for those looking to incorporate gardening into their living or working space [8].

B. Living Wall System

A living wall hydroponic system, also known as a green wall, is a type of vertical hydroponic system that is designed to create a living wall of plants. Living walls are a popular choice for green architecture and are commonly used in commercial and residential buildings. They provide a range of benefits, including improving air quality, reducing noise pollution, and enhancing the aesthetic appeal of a space [8].

C. Rooftop Hydroponic Garden

A rooftop hydroponic garden is a type of hydroponic system that is designed to be installed on a rooftop. Rooftop hydroponic gardens offer a range of benefits, including reducing the urban heat island effect and improving air quality [8].

In NARC, only the horizontal hydroponic system was installed but in Tokha both horizontal and vertical systems were installed increasing the production of crops within a small space.

Design consideration

When integrating hydroponics into architectural designs, there are several design considerations that should be taken into account. Here are some of the key design considerations for hydroponic integration [4].

A. Water and Electricity Supply

Hydroponic systems require a reliable supply of water and electricity. The system should be designed to ensure that there is adequate water supply and access to an electrical outlet [4].

B. Nutrient Delivery

Hydroponic plants rely on nutrient-rich water to grow, so we need to design a system that delivers the right nutrients in the right amounts. This can involve pumps, tubing, and reservoirs [4].

C. Lighting

Plants need light to grow, so it's important to choose the right type and intensity of lighting for the hydroponic system. LED grow lights are a popular choice for indoor hydroponics [4].

D. Climate Control

Hydroponic systems require a controlled environment to ensure optimal plant growth. The system should be designed to control temperature, humidity, and air circulation [4].

E. Maintenance and Accessibility

The system should be designed to be easily accessible for maintenance and harvesting. The design should also take into account the ease of cleaning and replacing components [4].

In both the farm about 32-35-degree temperature was maintained using greenhouse effect along with use of sensor, exhaust fan, heater. Both automated and manual systems were used to control temperature and humidity. The control panels for machinery were kept outside the production area on the buffer zone created by the double door system in NARC. In the context of Kathmandu, it isn't difficult to maintain the temperature.

NARC used a cooling pad and fan system which is another cooling system for climate-controlled high-tech greenhouse

projects. This system's main advantage is high cooling efficiency without any spraying water inside the greenhouse. A pad and fan system can also increase humidity if needed for the crop.

1. Outside air is sucked into the climate-controlled greenhouse technology through pads made from cellulose paper along the greenhouse gable side.
2. If the temperature in the greenhouse is too high, the pads are watered. As the air passes through the wet pads, the air is cooled and humidified by the water evaporating from the pad.
3. The heat needed for this evaporation is taken from the air itself. No external energy supply is needed. This is nature's own cooling process.
4. Once it's been through the climate-controlled greenhouse, the hot and humid air is removed by exhaust fans [9].

A horizontal screen system was also installed to save and control energy consumption.

Benefits of hydroponics in Nepal

A. Year- Round Production

Nepal has a varied climate with some regions experiencing harsh weather conditions. Hydroponics can provide year-round crop production, regardless of weather conditions [10].

B. Space Efficiency

Nepal is a country with a high population density and limited agricultural land. Hydroponics is a space- efficient method of agriculture, where plants can be grown in small spaces, making it ideal for urban areas [10].

C. Increased Yield

Hydroponics allows for precise control of nutrient levels and environmental factors, which can lead to increased crop yields compared to traditional soil- based methods [10].

The above-mentioned benefits were observed in both the cases along with other benefits were less labour intensive, no use of chemicals, pesticides unlike in open field cultivation, absence of open field contamination, faster harvesting time, highly nutrient product and more appealing output, etc. were observed.

Challenges of hydroponics in Nepal

A. High Initial Investment

The initial investment required for setting up a hydroponics system can be high, which may make it unaffordable for many farmers in Nepal [8].

B. Lack of a\Awareness and Knowledge

Hydroponics is a relatively new concept in Nepal, and many farmers may not be aware of the potential benefits or how to implement the system [10].

C. Power Shortages

Nepal is a country with frequent power outages, which can disrupt hydroponics systems that rely on electricity for lighting and pumps [10].

D. Availability of Nutrients

The availability of nutrients required for hydroponics systems may be limited in Nepal, which could increase the cost of implementing and maintaining the system [10].

The above-mentioned challenges were observed in both the case study but in the case of hydroponic farms, Tokha the problem of availability of nutrients was solved by purchasing the formula from Africa and now they are able to prepare their own nutrient.

NARC being a high-tech greenhouse tunnel system, all necessary backup and generators were available.

Cost and market analysis

In the hydroponic farm Tokha, Nepal, the initial investment for an 8mx16m tunnel was 1.5 million Nepalese Rupees. Among the various tunnels, the NFT system tunnel reached the breakeven point within 3-4 years after installation along with yearly benefit of 1 lakh, which highlights the significant benefits of the NFT system rather than other systems in the Nepalese context. It takes about 7-8 years to reach break-even point on a small scale and rooftop garden. Hence the NFT system is highly beneficial in the context of mass production. Based on our case studies, the hydroponic system is well-suited for cultivating leafy green vegetables in Nepal. However, due to the high investment required and a lack of public awareness, other plants and vegetables are not suitable for implementation in the Nepalese context. To maintain the viability of the farm, it is essential for the market price of the hydroponic vegetables to remain consistent throughout the year and equal to the price observed during their peak time.

The primary customers are mainly from 5-star hotels, and these products are being sold at prices equivalent to organic vegetables. Due to their visual appearance, they are sometimes perceived as artificial or plastic vegetables. Their demand rises in farmers' markets during off-seasons, as they can be cultivated throughout the year.

Conclusion

Thus, hydroponic farming is a great way to grow plants in Nepal, especially in areas with limited space or resources. It's a sustainable and efficient method that can produce high yields of fresh produce year-round. In the present context the production is limited to the 5- star hotels and farmer

market but if the nutrients and all the installation materials are produced within the country, the production rate will increase and the price will drop such that it will be available to common people. Roof gardening which adds more load to the building will be replaced for hydroponic. As the population of Nepal continues to grow, hydroponic farming will become an increasingly important method of agriculture and in near future more advanced technology including robots can be used in farming which can increase the production rate without human resource in the hydroponic system.

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