A HYDROPONIC SYSTEM FOR INDOOR PLANT GROWTH

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Abstract - ***Growing certain plants and vegetables in remote areas such as deserts and the north and South Pole can be a challenge because of the extreme outside weather. Very few species of plants thrive in such situations and are often not used as a food source. [1] In this study, we created a system that can grow common plants and vegetables and can operate without depending on the outside climate. We achieved this by using a technique called Hydroponics. Hydroponics is a method of growing plants without using soil. System parameters can be maintained and controlled by a sensor such as pH sensor, water temperature sensor and air temperature/humidity sensor. For adequate management of water and nutrients in the hydroponic system the electrical conductivity, pH dissolved oxygen and temperature should be measured because ion concentrations in the nutrient solutions change with time, resulting in a nutrient imbalance. In closed hydroponic systems real time measurement of all nutrients are required but such measurements are not available due to technical problems.***

***Key Words:* Nutrient solution, Horizontal Cylinder Hydroponics, Continuous flow solution culture, NFT, Flow rate**

1. INTRODUCTION

1.1 WHAT IS HYDROPONICS?

"Hydroponics is a method of growing certain plants and vegetables without soil instead of plants are grown in solution composed of nutrients in water solvents."

1.2 NEED OF HYDROPONICS

The production of agriculture and livestock sector is very seasonal and the climate is the main cause. In order to make the production as continuous as possible the application of new production techniques is required. Thus, a hydroponic [3] system for indoor plant growth and fodder production allows that there is a food supplement for human beings in daily life and animals on a farm, continuously and at any time of the year.

The purpose of the project is to expand and improve the utilization of hydroponics as well as to create an environmentally independent system for indoor plant growth. In a hydroponic system, a plant is placed in a solution composed of soluble nutrients and water as opposed to soil. In most conventional hydroponic systems, parameters such as EC and pH of the water solution are set to the desired value while setting up the system [4], [5]. In this project we built a system that grows plant without use of soil. In general, the process goes as follows: create a nutrient solution based on the plant being grown, apply this solution to a bed of water, and place a germinated plant into the water such that the exposed roots are touching the solution. If the parameters are maintained within optimum levels, the plant should grow faster and healthier than its natural growth. Typically hydroponic systems require human interactions when it comes to the regulation of certain elements that allow the plant to grow [6].

2. LITERATURE SURVEY

The earliest published work on growing terrestrial plants without soil was the 1627 book *Sylva Sylvarum* by Francis Bacon, printed a year after his death. Water culture became a popular research technique after that. In 1699, John Woodward published his water culture experiments with spearmint. He found that plants in less-pure water sources grew better than plants in distilled water. By 1842, a list of nine elements believed to be essential for plant growth had been compiled, and the discoveries of German botanists Julius von Sachs and Wilhelm Knop, in the years 1859-1875, resulted in development of technique of soilless cultivation. Growth of terrestrial plants without soil in mineral nutrients solutions are called solution culture. It quickly became a standard research and teaching technique and is still widely used. Solution culture is now considered a type of hydroponics where there is no inert medium. [7] Growth of terrestrial plants without soil in mineral nutrients solutions are called solution culture. It quickly became a standard research and teaching technique and is still widely used. Solution culture is now considered a type of hydroponics where there is no inert medium.

In 1929, William Frederick Gericke of the University of California at Berkeley began publicly promoting that solution culture be used for agriculture crop production. [8][9] He first termed it aquaculture but later found that aquaculture was already applied to culture of aquatic organisms. Gericke created a sensation by growing tomato with use of nutrient solution rather than soil. [10] He introduced the term hydroponics in 1937, proposed to him by W.A. Setchell. Reports of Gericke's work and his claims that hydroponics would revolutionize plant agriculture prompted a huge number of requests for further information. He denied the use of Universities greenhouse for his experiments due to the administration's skepticism. He published the book, *Complete Guide to Soil less Gardening,* after leaving its position.

One of the earliest successes of hydroponics occurred on Wake Island, a rocky atoll in the Pacific Ocean used as refueling stop for Pan American Airlines. Hydroponics used there was in 1930s to grow vegetables for the passengers. Hydroponics required in a Wake Island because there was no soil and it was prohibitively expensive to airlift in fresh vegetables.

In the1960s, Allen Cooper of England developed the Nutrient film technique. The land Pavilion at Walt Disney World's EPCOT Center opened in 1982 and prominently features a variety of hydroponic techniques. In recent decades, NASA has done extensive hydroponic research for its Controlled Ecological Life Support System (CELS). Hydroponic intended to take place on mars are using LED lighting to grow in a different color spectrum with much less heat.

Plants which are not traditionally grown in a climate would be possible to grow using a controlled environment system like hydroponics. NASA has also looked to utilize hydroponics in the space program.

Ray Wheeler, a plant physiologist at Kennedy Space Center's Space Life Science Lab, believes that hydroponics will create advances within space travel. He terms this as a bioregenerative life support system. [11]

3. OBJECTIVE

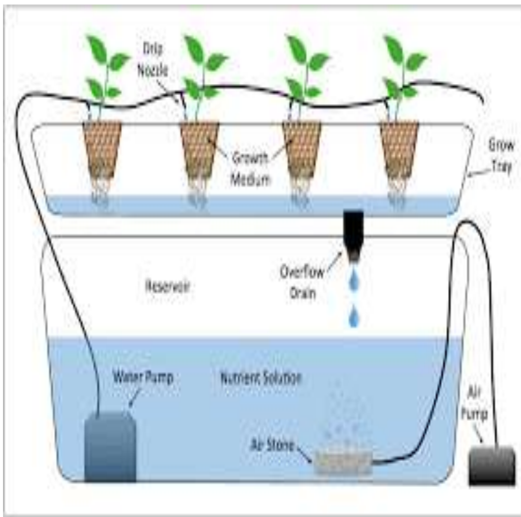
The main objective of hydroponic is to supply the ideal environment for optimum plant performance. Although technically not a portion of hydroponic, growers typically try to provide ideal environmental factors also. Plant performance may be further optimized by controlling the climate and lighting. Employing a greenhouse provides natural lighting can also guarantee the optimal season for optimum plant performance. Advances in technology in lighting, nutrient delivery and environmental control, will further improve plant productivity and performance.

4. WORKING METHODOLOGY

4.1CONTINUOUS-FLOW SOLUTION CULTURE

In continuous-flow solution culture, the nutrient solution constantly flows past the roots. It is much easier to automate than the static solution culture because sampling and adjustments to the temperature and nutrient concentrations can be made in a large storage tank that has potential to serve thousands of plants. A popular variation in the nutrient film technique or NFT, whereby a very shallow stream of water containing all the dissolved nutrients required for plant growth is recirculated past the bare roots of plants in a watertight thick root mat, which develops in the bottom of the channel and has an upper surface that, although moist, is in the air, Subsequent to this, an abundant supply of oxygen is provided to the roots of the plants.

As a general guide, flow rates for each gully should be 1 liter per minute. At planning, rates may be half this and the upper limit of 2L/min appears about the maximum. Flow rates beyond these extremes are often associated with nutritional problems. Depressed growth rates of many crops have been observed when channels exceed 12 meters in length. According to studies while oxygen level has been remaining adequate, nitrogen may be depleted over the length of the gully. As a consequence, channel length should not exceed 10-15-meter length. In situations where it is not possible, the reductions in growth can be eliminated by placing another nutrient feed halfway along the gully and having the flow rates through each outlet.



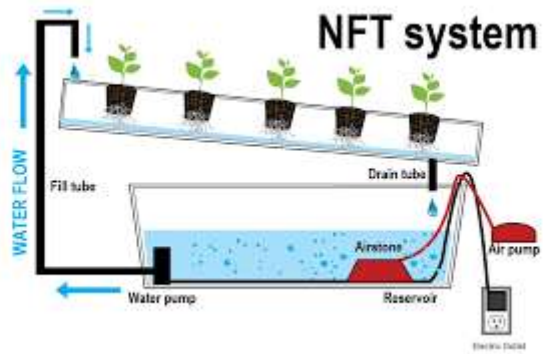


Fig. 4.1.1 Above figure shows overall view about the hydroponics NFT system.

4.2 HORIZONTAL CYLINDER TYPE HYDROPONICS (ROTARY)

A rotary hydroponic garden is a style of commercial hydroponics created within a circular frame which rotates continuously during the entire growth cycle of whatever plant is being grown.

While system specifics vary, systems typically rotate once per hour, giving a plant 24 full turns within the circle each 24-hour period. Within the center of each rotary hydroponic garden can be a high intensity grow light, designed to simulate sunlight, often with the assistance of a mechanized timer.

Each day, as the plants rotate, they are periodically watered with a hydroponic growth solution to provide all nutrients necessary for robust growth. Due to the plants continuous fight against gravity, plants typically mature much more quickly than when grown in soil or other traditional hydroponic growing systems. Due to the small foot print a rotary hydroponic system has, it allows for more plant material to be grown per square foot of floor space than other traditional hydroponic systems.

Fig. 4.2.1 rotary hydroponics system

5. DESIGN OF THE PROJECT

5.1 CALCULATION OF THE PROJECT

i. **DESIGN OF SHAFT**

Consider the material of the shaft assumed to be – MS C40 STEEL

S_y = 330 MPa

W.K.T by maximum shear stress theory

$S_{sd} = 0.5\ S_y$

∴ $S_{sd} = 0.5*330$

∴ S_{sd} = 165 MPa

Let the power of motor is given by,

Given, P = 145 W

$$P = \frac{2\pi NT}{60}$$

$$145 = \frac{2 \times \pi \times 10 \times T}{60}$$

$$T = 138.46 \times 10^3 \text{ Nmm}$$

By torsion equation,

$$\tau = \frac{16 \times T}{\pi \times d^3}$$

$$145 = \frac{16 \times 138.46 \times 10^3}{\pi \times d^3}$$

$$d = 16.22\ mm$$

∴ dia of the shaft choosen as d = 22 mm

ii. **TO DETERMINE SPEED OF THE HORIZONTAL CYLINDER**

Let we know that the speed ratio can be determined by

$$\frac{N2}{N1} = \frac{D1}{D2}$$

Where,

N1 = speed of the larger wheel which is to be determined

N2 = speed of the smaller dia shaft i.e. speed of motor = 1440 rpm

D1 = dia of the larger wheel = 774.7 mm

D2 = dia of the smaller shaft = 16 mm

$$\frac{1440}{N1} = \frac{774.7}{16}$$

$$N1 = 29.74\ rpm$$

5.2 MODELLING OF THE PROJECT

The design for the given project is based on the actual existing system with enlarged scale. The modeling for the given project is done on the SOLID EDGE ST5 software.

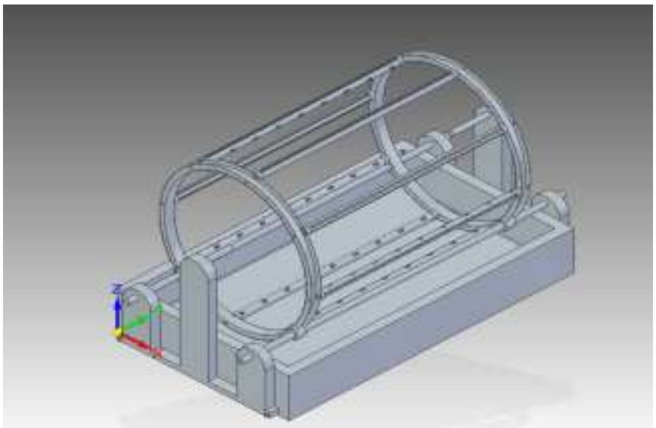


Fig. 5.2.1 3D model of project

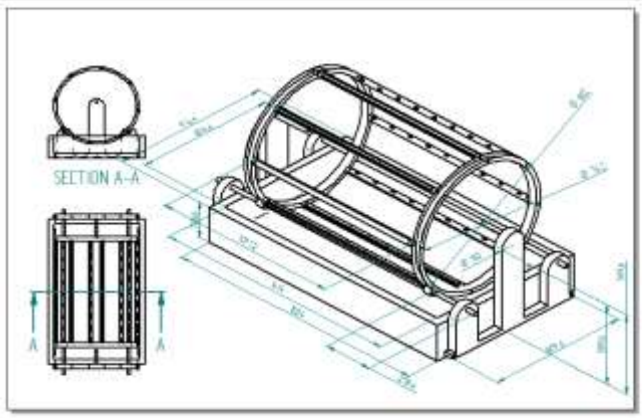


Fig. 5.2.2 sectional front view, top view & isometric view

5.3 SPECIFICATION OF THE MODEL

Specification for the given hydroponics system is described as below.

i. Total length of model = 1440 mm
ii. Total width of model = 809.6 mm
iii. No. of PVC pipes used = 8
iv. Dia. Of PVC pipe = 75 mm
v. Dia. Of circular ring = 762 mm
vi. Thickness of circular ring = 25mm
vii. Dia. Of shaft = 22 mm
viii. Total length of shaft = 1440 mm
ix. AC motor = 145 W (1Qty.)
x. T5 Tube light = 1

6. FABRICATION OF THE PROJECT

Fig. 6.1 final assembly of project

7. A HORIZONTAL CYLINDER TYPE HYDROPONIC SYSTEM

The system we developed for hydroponics is a horizontal cylinder type system in which full assembly is done on the horizontal support (shaft) which makes frictional contact and driven by ac motor with speed control regulator. We further see which is the plant to be chosen for given system and what is the exact proportion of the nutrient solutions for the system?

7.1 GREEN LETTUCE

Fig. 7.1.1 green lettuce plant

For the present report we are using green lettuce seeds which are to be grown by hydroponic system first take a look over the detail of green lettce.

Lettuce (*Lactuca sativa*) is an annual plant of the daisy family, Asteraceae. It is most often grown as a leaf vegetable, but sometimes for its stem and seeds. Lettuce is most often used for salads, although it is also seen in other kinds of food, such as soups, sandwiches and wraps; it can also be grilled. One variety, the *woju*, or asparagus lettuce (celtuce), is grown for its stems, which are eaten either raw or cooked. In addition to its main use as a leafy green, it has also gathered religious and medicinal significance over centuries of human consumption.

7. 2 ROCKWOOL (MINERAL WOOL)

Fig. 7.2.1 rockwool used for hydroponics

Mineral wool is any fibrous material formed by spinning or drawing molten mineral or rock materials such as slag and ceramics. Applications of mineral wool include thermal insulation (as both structural insulation and pipe insulation, though it is not as fire-resistant), filtration, soundproofing, and hydroponic growth medium.

Mineral wool products can be engineered to hold large quantities of water and air that aid root growth and nutrient uptake in hydroponics; their fibrous nature also provides a good mechanical structure to hold the plant stable. The naturally high pH of mineral wool makes them initially unsuitable to plant growth and requires "conditioning" to produce a wool with an appropriate, stable pH.

7.3 NUTRIENT SOLUTION

Fig.7.3.1 major components for nutrient solution mixture containing major composition of magnesium, zinc & calcium

As we know in hydroponics system the plant growth is based on the nutrient solution proportion. So for any of the plant growth it is essential to select the required proportion of nutrients. Main nutrients for any of the plant growth are nitrogen, potassium, phosphorous, calcium, magnesium & sulphur.

7.4 T5 TUBE LIGHT

Fig. 7.4.1 T5 tube light

T5 grow lights are one of the best types of lights you can use to grow any kind of plant, from vegetables to the most delicate flowers. This is because T5s are extremely efficient, allowing you to save money on electricity while still providing bright, powerful light. They also have features you can customize to build the perfect set-up for any size and type of indoor garden. Many indoor growers are already familiar with the virtues of T5s, but even if you know your T5 fixtures and more or less know how they work, you might need help with some things, because specifics like color temperature, hanging height and light cycles might not be as easy to figure out.

First things first, for those of you who do not know the basics, a T5 grow light is a tube-shaped fluorescent light that is 5/8-inch in diameter. In terms of the light's name, the "T" is for tube shape, and the "5" is for the 5 in the 5/8-in. unit of measurement. These lights are mainly used as additional or full-on artificial lighting for plants to re-create the natural light spectrum. They can be used in many different environments and conditions, from greenhouses to indoor gardens. Here are some tips on how to use them to your full advantage.

8. OBSERVATION & RESULTS

The efficiency of the given hydroponic system is based on the plant growth in the minimum possible days. From the above study based on the plant growth for the green lettuce following observations are to be made and results are analyzed.

8.1 PLANT GROWTH ANALYSIS ON EACH DAY

8.1.1 DAY 1

Fig. 8.1.1 (a) seeds inserted in rockwool (Date – 01/05/2019)

In the very first day the seeds of the required plant (green lettuce) are inserted in the rockwool. The main function of the rockwool is to provide mechanical support to the seed the watering is done along with a mix of nutrient solution once in a day. Before taking the plant on the system the same procedure continued until the seeds start germinating it will take around one week.

8.1.2 DAY 3

Fig. 8.1.2 (a) initial germination from seed (DATE - 03/05/2019)

The above figure shows the stage at which germination begins it will take a day to start germination.

Fig. 8.1.3 (a) initial stage plant growth (DATE – 13/05/2019)

It will take around a week to grow full stabilized plant which is taken in to the system for further growth this will ensure that rockwool holds the plants roots with a sufficient strength.

8.1.4 DAY 15

Fig. 8.1.4(a) plant growth on the system (DATE - 20/05/2019)

Since the total life cycle to grow green lettuce plant is around 40 days. With the present hydroponic system we'll get full efficient, fully grown lettuce plant within another 15 days till then we have to continue with the same procedure i.e. system is allowed to complete the full revolution within the specified time with specified number of cycles per day.

8.1.5 DAY 20

Fig. 8.1.5 (a) plant growth (DATE – 25/06/2019)

8.1.6 DAY 30

Fig. 8.1.6 (a) plant growth

9. CONCLUSIONS

From the above study its clear that yes, its been possible to grow plants without soil completely and hence leads to more quality, improved and more nutritious plant growth with help of designed hydroponic system. Also by providing artificial light it supplements to the excessive amount of sunlight that the plants can get for fully grown height. And also system can contribute to environment friendly since no use of pesticides.

Hence we can conclude that hydroponics is the future of farming.

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BIOGRAPHIES

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