Hydroponic Irrigation System – Feasible, Suitable and Sustainable Method

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Abstract- Hydroponic is a method of growing plants in a water based, nutrient rich solution. Hydroponic growing has received a lot of attention in recent years as future of farming. Increasing of population all over the world results in decrease in per capita land availability as well as agricultural production. As the world population is grows, the demand and need for different products, especially food products, grow as well. Therefore, land paucity is a serious predicament for the farmers because as more land is utilized by the population, it will become more difficult to produce the amount of food needed to feed the growing population. Besides this, unforeseeable climatic condition, drought prone areas, rise in temperature, contaminated water, decline in ground water table, etc. are also creating difficulty in open field agriculture farming. Under such circumstancesand to eliminate these problems hydroponic system should be adopted which is more effective, efficient and sustainable system. Therefore, hydroponic system is becoming suitable for present scenario, to overcome with these challenges. By improving and implementing innovative ideas inagriculture farming can help in growing of plants in sustainable manner.

Keywords-Hydroponic, nutrients, techniques, growing substrates, pH and EC.

I. INTRODUCTION

The earliest modern reference to hydroponic was given by the man named William Frederick, Gericke (Father of modern Hydroponics), while working at the university of California, Berkeley, he began to popularize the idea that plants could be grown in a solution of nutrients and water instead of soil. In India, hydroponic system was introduced in the year 1946, by an English scientist, W.J. Shalto Duglas, and he established a laboratory in Kalimpong area, West Bengal. He has also written a book "Hydroponic- The West Bengal System". Later on, during 1960s and 70s, commercial hydroponics farms are developed in Abu Dhabi, Arizona, Belgium, California, Denmark, German, Holland, Iran, Russian Federation and other countries. During 1980s, many automated and computerized hydroponics farms were established around the world. Home hydroponics kits became popular during 1990s.

Soil is the loose surface material consisting of inorganic particles and organic matter that covers most of the land surface. Soil provides the structural support and source of water and nutrients for plants used in agriculture.Plants growth and development largely depend on the combination and concentration of mineral available in the soil. Two classes of nutrients are considered essential for plants i.e., macronutrients and micronutrients. Some of the essential macronutrients are Nitrogen, Phosphorus, Magnesium, Potassium, Calcium and Sulphur and micronutrients are Iron, Manganese, Copper, Zinc, Boron, Molybdenum.Conventional crops growing in the soil (open field agriculture) is very difficult as it needs large space, lots of labour and large volume of water. Besides, poor fertility in some of the cultivable area, less chance of natural soil fertility build-up by microbes due to continuous cultivation, frequently drought conditions and unforeseeable of climate and weather patterns, rice in temperature, unfavorable geological or topographical conditions, etc. creates difficult for open field agriculture. Under such circumstances, hydroponic irrigation system is more convenient.

Hydroponic is a Greek word in which "hydro" means "water" and "ponos" means "labour". It literally means working with water. Hydroponic irrigation system is the irrigation system whereby crop roots receive a balanced nutrient solution dissolved in water with all the chemical elements needed for plant growth, which can grow directly on the mineral solution, or in an inert medium or substrate. Hydroponic system has been utilized as one of the standard methods for plant biology research and are also used in commercial production for several crops. Terrestrial plants may be grown with their roots in the material nutrient solution only or in an inert medium or growing media, such as perlite, gravel, or mineral wool. The media can range from sand to rockwool. A sand culture system has several inches of sand over the entire floor area. The most common growing media for hydroponic irrigation is rockwool or ground coconut husk (coco-coir) in plastic bags.

II. NUTRIENTS

Nutrients are the required elements that plants absorb carbon, oxygen and hydrogen from the air and water; the other elements required to maintain growth are nutrients and light. The nutrients provide for ideal plant growth, vigour, colour, consistency, structure and texture. Nutrients can be subdivided into two groups i.e., macronutrients and micronutrients. Macronutrients are the primary nutrients, micronutrients are the secondary nutrients, also known as trace elements. These nutrients can also be classified into further two groups i.e., stationary and mobile. Nitrogen (N), Phosphorus (P), Potassium (K), Magnesium (Mg), and Zinc (Zn) are mobile nutrients. This means that they are able to translocate and re-translocate from one area of the plant to another. Calcium (Ca), Boron (B), Chlorine (Cl), Cobalt (Co), Copper (Cu), Iron (Fe), Manganese (Mn), Molybdenum (Mb), Silicon (Si) and Sulphur (S) are stationary nutrients. This means that they are not able to re-translocate from one area of the plant to another.

Macronutrients N-P-K elements are those which plants uptake the most. The percentage volume of these elements is normally shown on the front and back of the bottled nutrient solutions. These nutrients are quite simply the base building blocks of all known life. Plants cannot thrive without them. High energy plants require high level of nitrogen, during the vegetative cycle of the plant's growth. Nitrogen is a key element in plant growth. It is found in all plant cells, in plant proteins and hormones, and in chlorophyll. High energy plants use high levels of phosphorus during the germination, young plant and flowering stages of the plant's growth. Photosynthesis relies on phosphorus to provide a mechanism for the transference of energy within the plant. Potassium is essential for plant to manufacture and move sugar and starches, as well as in growth by cell division. This element also increases chlorophyll in the plants foliage and helps regulate the opening stomata so that the plant can make good use of light, air and CO_2, and is vital for the accumulation and translocation of carbohydrates. Micronutrients or secondary nutrients (Magnesium, Calcium and Sulphur) are again used in large quantity by the plants. High energy plants are able to consume and process more secondary nutrients then a general-purpose garden centre fertilizer to able to provide. Most high energy plant growers use a two-part nutrient solution specially for hydroponics cultivation. These two and even three-part nutrient have all the macro, secondary and trace elements necessary for good plant growth.

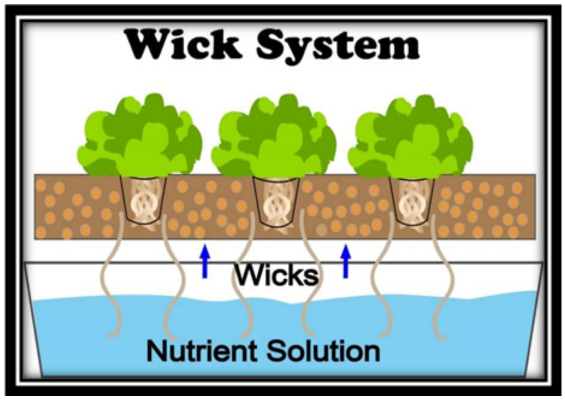
In micronutrients, magnesium help in the utilization of nutrients and magnesium also neutralizes acids and toxic compounds produced by the plant. Calcium is responsible for cell manufacturing and the growth of the plant. Sulphur is used as an indispensable element in plant cell and seed development. Zinc help in formation of chlorophyll as well as preventing its depletion. Manganese play a vital role in the chloroplast membrane system development. Iron is crucial for the transportation of electrons during photosynthesis and respiration. Boron helps in the role of cell division, differentiation, maturation and respiration. Chloride in terms open and closes stomata to regulate the moisture flow of the plant. Copper helps in carbohydrate metabolism and nitrogen fixation. Molybdenum is responsible for converting nitrate to ammonium. A definitive lack of silicon has been proved to decrease over all yields and vigour of some fruits and flowers bearing plants the two main measurements a hydroponic grower needs to make our pH and EC levels. pH is the measure of the acidity of a system and determines how plants interact with different nutrients. Every crop has a specific pH range, but most herbs and greens overlap with a range. pH should be between 5.5 and 6.5 without changing more than 0.5 per day. EC is a measure of salt in system i.e., the level of nutrients in system. EC should be kept between 1.2 and 2.0.

III. HYDROPONIC TECHNIQUESAND THEIR OPERATIONS

Hydroponic system is customized and modified according to recycling and reuse of nutrient solution and supporting media. Commonly used techniques are wick, drip, ebb-flow, deep water culture, nutrient film technique (NFT) and aeroponic. Each technique works a little differently- most use growing medium, some use pumps and timers, and certain hydroponic systems are better suited for particular gardening application and crop varieties than others. Techniques are described as follows:

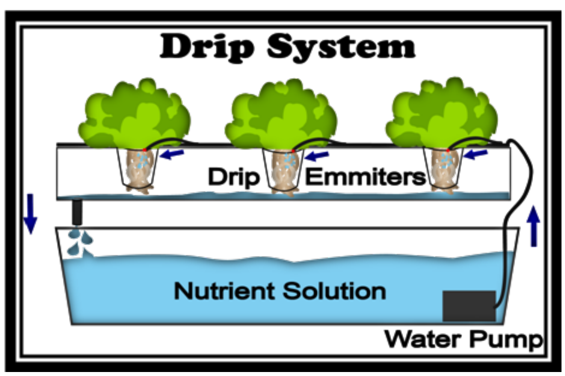
Wick – Hydroponic system

The wick system is the most straightforward and lowest cost method within the realm of hydroponics. These are very few moving parts to a basic wicking system; no pumps, timer, or electricity are utilized. Instead, most wicking systems employ some sort of nylon, cotton, or other fibrous rope material to act as the agent which draws nutrient solution to the roots of a plant. Like other hydroponic systems, a grow substrate helps to support the plant, aiding in moisture and nutrient withholding, as well as aeration to the root zone. A plant grown using the wick system may benefit from grow substrates which drain well (perlite and vermiculite) instead of those which absorb nutrient solution in abundance (like coconut fiber or rockwool).



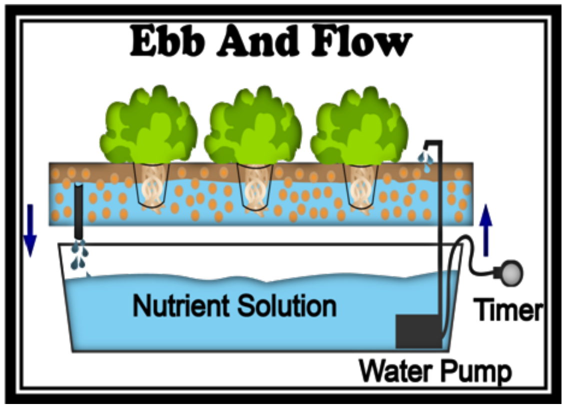
Drip system- Hydroponic system

The drip system is commonly used as a hydroponic system, both in commercial and home growing gardening. The concept is simple a slow feed of nutrient solution is dripped on to the roots or grow substrate, slowly and ceaseless supplying a plant with the health and moisture which theyneed. Recirculating drip systems reuse and recirculate the nutrient solution back to the reservoir. This ensure that the roots stay moist and health enough, but without flooding the grow medium, as is done in some other hydroponic systems. Because the nutrient solution is constantly recycled in drip systems, pH value may change with this re-circulation. It is important to monitor these levels to maintain a consistent and healthy pH. To prevent roots from drying out or becoming over saturated, slower drip systems should utilize a slow drain grow substrate (such as rockwool or coconut coir), whereas faster drip systems may benefit from quick-drying hydroponic grow substrate (such as clay pebbles or growstones).



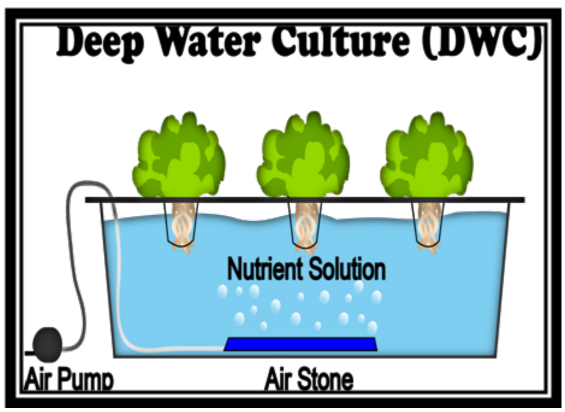
Ebb and flow (flood and drain)- Hydroponic system

The hydroponics system known as ebb and flow (also known as “flood and drain”) works by floodingnutrient solution into the growing area at specific times. Once flooded, the nutrient solution then drains slowly back into the reservoir to be reused.If the nutrients become less in that solution, then the lost nutrients get filled again in the solution. The process repeats itself with the help of a pump and timer, ensuring the plants receive optimal moisture and nutrients. Since many varieties of plants require periods of dryness (which aids in root expansion), the method of ebb and flow is quite an effective and popular hydroponic system.



Deep water culture (DWC)- Hydroponic system

One of the simplest methods of hydroponic growing involves the use of a deep-water culture (DWC) hydroponics system. Often referred to as "the reservoir method", this technique involves suspending the plant roots in oxygenated, nutrient-rich water. Air pumps or air stones are used to oxygenate the nutrient solution, which helps to prevent the roots from drenching. Most deep-water culture hydroponic systems use plastic buckets or reservoir as a base, and suspend net pots within the buckets to hold each plant.

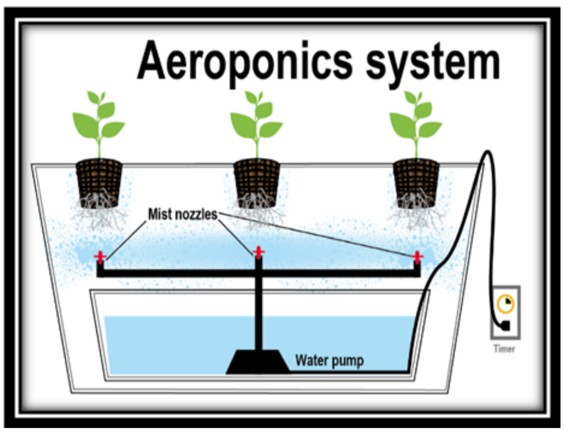


Nutrient film technique (NFT)- Hydroponic system

Nutrient film technique (NFT) is a hydroponics system wherein a continuous, shallow stream of nutrient solution is recirculated over the unclad roots of plants. A tilted, watertight groove (channel) is used, enabling a downward gravitational flow of nutrient solution over the roots. No grow substrate is required with the use of NFT, and only the tip of the roots ever touch the nutrient solution. This allow plants to obtain high level of oxygen. The main objective of using the Nutrient Film Technique in hydroponics is to instate a fast growth rate in a confined space. Larger and fruiting plants may not have worthy room for root growth using this hydroponic system, but for many, Nutrient Film Technique is an efficient method for starting plants and growing smaller plants hydroponically.

Aeroponic- Hydroponic system

Aeroponics is a hydroponic system where the roots of a plant are suspended in an air chamber (or growth chamber), and periodically misted with a nutrient solution. This hydroponic method is comical in that it requires no grow substrate, allowing for superior aeration of the roots system. These more elaborate hydroponic systems are better-suited for users wishing to grow larger and more multiple plant varieties.



IV. GROWING SUBSTRATES

The growing substrates or growing media provide moisture and oxygen to plants roots. It also supports the plant weight and holds it upright. Another role of the media is to allow plant's roots to have maximum exposure to the nutrients. And the wet media will transfer the nutrient to the root system. Some of the growing media are rockwool, pea gravel, coarse sand, sawdust, perlite, vermiculite, peat moss, expanded clay pellets, coconut fiber, growstones, oasis cubes, etc. Perlite is a very common growing medium that has been around for years. As a mined mineral, a form of volcanic glass, perlite is created under intense and rapid heat. Then countless tiny bubbles pop outs like popcorn. Therefore, it is very lightweight and porous. Perlite is good choice for the wick-type hydroponic system since it makes an excellent standing wicking action. But because of its porous and easy-to-flow nature it cannot be used for quick and strong watering systems like the ebb and flow. It can be washed away fast and easily. Coconut-coir is a byproduct of the coconut industry. Vermiculite is a form of hydrated laminar minerals with resemble mica. Just like perlite, vermiculite is processed by exposing the material to extreme heat to expand them into small clean, odorless pellets. Rockwool owns many benefits of an ideal growing material like microbe immunity, good water and air retention. This protects plants from dehydrating while giving roots continuous available amounts of oxygen. Expanded clay pellets also known as light weight expanded clay aggregate are the small round balls, about the size of marbles. They are created by heating and expanding clays to form thousands of small bubble-shaped balls. Oasis cubes are made from floral foam which is designed like a sheet form. Each of the medium's individual cell contains the right amount of nutrients as well as air and water for plant's growing. Growers use oasis cubes primarily as a starting environment for seedings or plants cutting, not as a full growing medium. Starter plugs are another effective product to start plant propagation or seed germination. To make it useful for the starting phase of planting, starter plugs are often created from materials that keep moisture well, are not easily waterlogged, and at the same time allows the roots to expand and drive through the loose bottom. Growstones are made from recycled glass from landfills or glass collecting and processing places. This medium is very lightweight, highly porous and above all, it has great air aeration, and average moisture retention to the root system. Sawdust is a by-product of sawmills and retail hardware stores. It is quite inexpensive. Sawdust is biodegradable but will decompose over time. This medium is not pH neutral. So extra care of pH monitoring for your system needs taking. Peat moss is a dead fibrous material that develops in a wet, cold, acidic, and lack-of-air environment called peat bogs. This is a good medium for soil and hydroponic planting because of its ability to retain water and hold nutrients well.

V. DESIRABLE PH RANGE OF NUTRIENT SOLUTION AND DETERMINATION OF PH VALUE

In hydroponic systems, pH is constantly changing as the plant grows. The nutrients which are added in the reservoir for plants growth, the natural reaction rise the pH value in the nutrient solution. Changes in pH of less than 0.1 unit are not significant. Thus, pH control is a necessary in hydroponic solutions. The pH range of 5.5 to 6.5 is optimal for the availability of nutrients from most nutrient solutions for mostspecies, but species differ significantly and several can grow well outside of this range. pH test paper or litmus paper is an easy, low cost method for testing the pH of a liquid solution. The pH test paper is supplied as a 5meter roll. Simply tear off a small portion of the test paper or litmus paper and dip it into the nutrient solution. The area of paper which was submersed will then change colour. Matching the paper up with the colour chart or colour ruler supplied with the test paper to establish the Ph reading. The pH should be between 5.5 to 6.5 for hydroponics. Due to constantly changing in the plant growth pH value will change frequently. Therefore, it is essential to adjust the pH value by using pH solutions. To bring pH value up and down according to nutrient solution, different pH solutions are available in the market. On the other hand, pH can be determined by using pH pen.

VI. ELECTRICAL CONDUCTIVITY (EC) MANAGEMENT

The more salts, the higher the EC. On a daily basis, EC is useful because it indicates when the nutrients or water get lost. EC depends on the pH value.Electrical conductivity measures a materials ability to conduct an electric current and conductivity of a solution id directly relate to salts dissolved in it. As pH goes up, EC goes down in that case plants are feeding and potentially raise nutrient levels.When pH goes down, EC goes up in that case plants are putting nutrient into the water rather than taking them out and nutrient level are too high. When pH stays stable, EC level stay stable in that case plants are taking equal parts of nutrients and water, therefore maximum growth occurs.

Table 1: Optimum EC and for hydroponic crops.

CROPS	EC (dSm^{-1})
Banana	1.8-2.2
Broccoli	2.8-3.5
Cabbage	2.5-3.0
Cucumber	1.7-2.0
Peppers	0.8-1.8
Spinach	1.8-2.3
Strawberry	1.8-2.2
Tomato	2.0-4.0

VII. CONCLUSION

All the research leads to conclusion that hydroponic irrigation system is a strong method for solving issues due to the unsustainability of agriculture. In the resent years hydroponics is seen as a promising strategy for growing different crops. Hydroponic irrigation is one of the alternative sources for growing plants in soil-less medium. By adopting hydroponic irrigation system will help in improving the yield and quantity of the produce which will ensure food security of our country. And also, system can contribute to environment friendly since no use of pesticides. It is a sustainable method as it is sustaining the world's food supply because of its ability to produce larger yields using a smaller amount of space. Government intervention and research institute interest can propel the use of this technology.

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