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Hydroponic: A Step Ahead for Soil and Water Conservation

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Introduction

Soil is usually the most important growing medium for any plant. It is the most important media to provides anchorage, nutrients, air, water, etc. for successful plant growth [·]. However, Soils do pose serious limitations for plant growth due to the presence of disease-causing organisms and nematodes, unsuitable soil reaction, unfavourable soil compaction, poor drainage, degradation due to erosion, etc.

Moreover, with the advent of civilization, open field/soil-based agriculture is facing some major challenges; most importantly a decrease in per capita land availability. In 1960 with 3 billion population over the World, per capita land was 0.5 ha but presently, with 6 billion people it is only 0.25 ha and by 2050, it will reach 0.16 ha[·]. Under such circumstances, in the near future, it will become impossible to feed the entire population using the open field system of agricultural production only. Naturally, soil-less culture is becoming more relevant in the present scenario, to cope-up with these challenges. In soil-less culture, plants are raised without soil. Improved space and water-conserving methods of food production under soil-less culture have shown some promising results all over the World.

Soil-less culture mainly consists of the techniques of Hydroponics and Aeroponics. The term Hydroponics was derived from the Greek word's hydro' means water and ponos' means labour [·]. In this method a plant growing by using mineral nutrient solutions without soil. This system most useful to face the challenges of climate change and also helps in production system management for efficient utilization of natural resources and mitigating malnutrition. In India, first ever Hydroponics was introduced in year 1946 by an English scientist, W. J. ShaltoDuglas.

How Hydroponics Works and It's Function

Soilless culture is a man-made suggests that of providing plants with support and a reservoir for nutrients and water. In this the soilless culture can be defined as "any method of growing plants without the use of soil as a rooting medium, in which the inorganic nutrients absorbed by the roots are supplied via the irrigation water". Hydroponics is a Biotechnology of soilless cultivation of plants which is carried out in controlled culture conditions, in an artificial media but does not oppose to customary methods of intensive agriculture [·]. Plants don't need soil, but they do need the vitamins and minerals that soil can provide for them. Plants also need light, water, carbon dioxide and oxygen at the root zone. In hydroponics, plants are grown in an inert medium such as rocks or coco coir fibre, and they are fed a solution containing a perfected mix of primary, secondary and micro-nutrients. Almost any kind of plant can be grown hydroponically, including veggies, herbs, fruits and flowers.

The function of soilless cultivating method i.e. hydroponic is stimulating plant growth while controlling the quantities of water, mineral salts and most important, dissolved oxygen. The basic concept is quite simple. When roots are suspended in moving water, they absorb food and oxygen rapidly. If the oxygen content is insufficient, plant growth will be slow. But if the solution is saturated with oxygen, plant growth will accelerate. Therefore, the grower's task is to balance the combination of water, nutrients, and oxygen, with the plan's needs, in order to maximize yield and quality [·]. For the best results, a few important parameter need to be taken into account; temperature, humidity and CO_2 levels, light intensity, ventilation, pH and the plant's genetic make-up. All nutrients and fertilizer required for plant growth are mixed into water, which passes through the medium several times a day. An active hydroponic system uses a pump to move water, while passive systems rely on wick or the medium's ability to absorb water.

Hydroponic System Types:

Wick system:

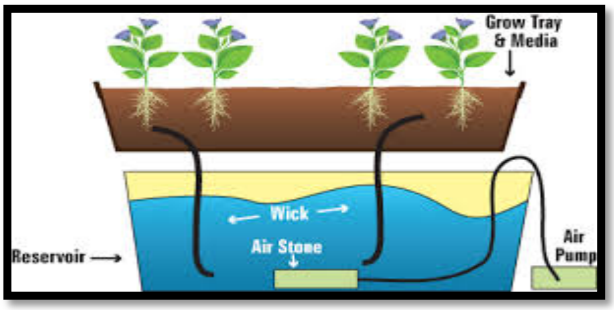

Figure 1: The Wick system

The wick system (Figure 1) is the simplest of all types of hydroponic systems. It is known as passive hydroponics because traditionally it doesn't have any moving parts, thus it doesn't use any pumps or electricity. However, the wick is the connecting part between the potted plant and food solution in the existing reservoir. Because it doesn't need electricity to work, it's also quite useful in places where electricity can't be uses, or is unreliable. Good choices include coconut coir, perlite, or vermiculite. Wick systems are good for smaller plants that don't use up a lot of water or nutrients. Larger plants may have a hard time getting enough of either via a simple wick system.

Deep Water Culture (DWC):

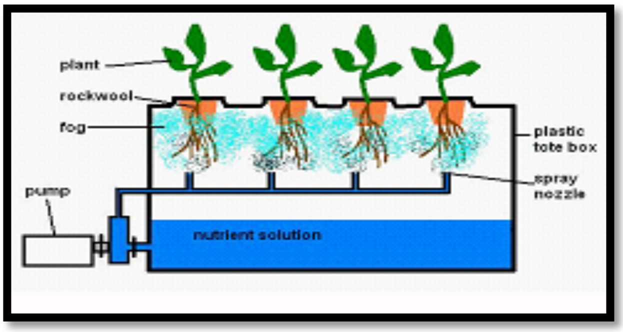

Figure 2: Deep Water Culture (DWC)

In a DWC system the roots of your plants are suspended in that solution so they get a constant supply of water, oxygen, and nutrients. To oxygenate the water, use an air pump with an air stone to pump bubbles into the nutrient solution. This prevents your roots from drowning in the water A water culture system can easily be set up in glass basins, (fish ponds), plastic boxes, ice boxes, Concrete basins or in engraved basins covered with polypropylene sheets. Since the plants are floating and continuously in contact with the nutrient solution, there is no risk of damage to plants in the event of a power outage or stop the air pump. The most convenient plants in this system are Lettuce, strawberries, and herbs grow particularly well in this system.

Nutrient Film Technique (NFT):

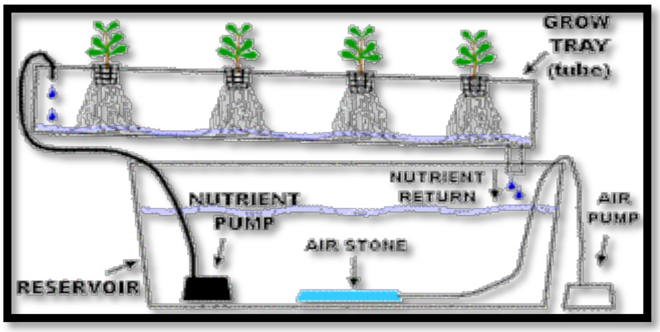

Figure 3: Nutrient Film Technique (NFT)

The nutrient film technique (Figure 3) is recirculated design to run highly oxygenated dissolved nutrients continuously over the roots of plants through a set of channels, typically grown in baskets hanging in a PVC pipe. The solution is pumped from a holding tank, through irrigators at the top of every sloping pipe and the run-off from the bottom of the channels is returned to the tank. Thus, the nutrient solution is continuously recycled. It is possible to make the angle of the pipe smaller and add an overflow pipe similar to what's in an off and flow system. This would serve to provide a reservoir of nutrients that would remain in the event of a power or pump failure. Because of the confined space of a PVC pipe and the requirement for nutrients to continuously flow over the roots, the nutrient film technique is particularly well suited to plants that have small root balls such as lettuce, strawberries and herbs.

Ebb and Flow (Flood and Drain):

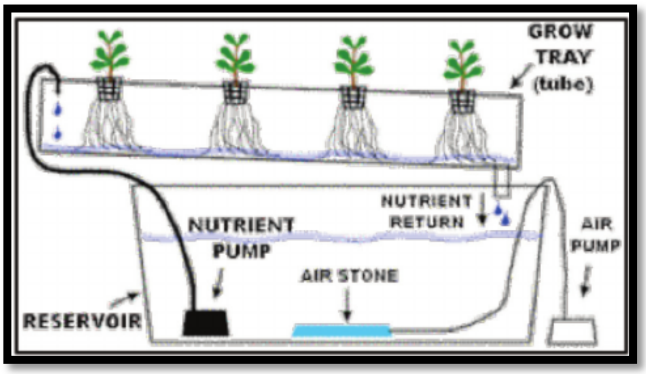

Figure 4: Ebb and Flow (Flood and Drain)

Ebb and Flow systems, which are also known by the name Flood and Drain, are a less-commonly seen system. But they're still quite effective and can be the best choice depending on your situation. The setup contains two containers, the one on top containing the plants in pots with substrate, and the one on the bottom containing the nutrient solution. Rather than the nutrient solution being passed slowly to drippers at the stem of each plant, the nutrients are pumped in large volumes into the top container, flooding the container. An overflow pipe determines the height of the nutrients, typically to where the roots begin at the base of the stem, with excess liquid being recirculated through the overflow pipe back to the bottom container. Plants with large root balls are also particularly suited to off and flow systems.

Drip system:

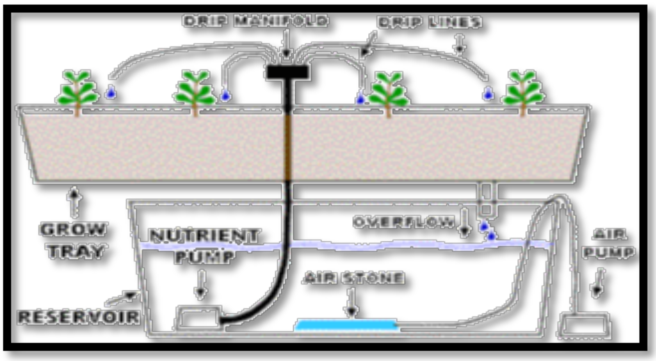

Figure 5: The Drip System

Drip hydroponic system (Figure 4) is at least two containers, one on top or higher than the other. Plants are located in the top container, while the nutrient solution is in the bottom container. The nutrient solution is pumped up to drips located by the stem of each plant with a water pump, and an aquarium air stone is used to oxygenate the water. The nutrients filter down to the plant roots and are passed back to the bottom container. Typically, both the water and air pumps run continuously with this type of system. A crop of almost any plant will grow well with this system. Plants with large root balls are particularly suited to drip systems. However, the plants are grown in supportive mediators.

Substrate Culture (Growth Medium):

Growth medium is the substitute for soil in soilless culture systems. The functions of growth medium are to provide the roots with oxygen bring the water and dissolved nutrients in contact with roots via irrigation system through the media, allowed to run to waste to recirculate the solution through the system and to steady the plants as supportive mediators so that they do not fall over. There are various substrates that used as growth medium are consisting of inorganic (natural; expanded clay, glasswool, gravel, perlite, pumice, rockwool, sand, sepiolite, vermiculite, volcanic tuff and zeolite or synthetic; foam mats, hydrogel and plastic foam) or organic (bark, coconut coir, coco soil, fleece, marc, peat, ruffia bark, rice husk, sawdust and wood chips) [·].

Supply of Nutrients to the Plants:

In hydroponics, because of limited nutrient-buffering capacity of the system and the ability to make rapid changes, careful monitoring of the system in necessary. Sources of nutrient elements with their characteristics are given in table:

Source	Element	Characteristics
Potassium nitrate (KNO_3)	N, K	Very soluble salt
Potassium phosphate monobasic KH_2PO_4	P, K	Corrects phosphorus Deficiency
Magnesium sulfate $MgSO_4$	S, Mg	Cheap, highly soluble, pure salt
Iron chelate	Fe Cit	Best sources of Iron
Boric acid H_3BO_3	B	Best source of Boron
Calcium nitrate $Ca\ (NO_3)_2$	N, Ca	Very soluble salt

Sources of nutrient elements with their characteristics

The frequency and volume of the nutrient solution applied depends on the type of substrate used, the size of the container, the crop and irrigation systems used and the prevailing climatic conditions. Plants should be fed daily. The best time to administer the nutrient solution is between 6.00 and 8.00 am. The solution should be applied to the roots, trying to avoid wetting the leaves to prevent damage and the appearance of diseases. It is generally recommended that you apply only water to the plants once a week, in order to flush away any excess salts that have remained. Use double the amount of water normally applied, but without adding nutrients. Between 20 and 50% of the solution should be drained-off to prevent the accumulation of toxic ions and an excessive increase of electrical conductivity in the root area. The excess nutrient solution that is drained away from containers during daily watering can be reused in the next watering.

Advantage

There are many advantages of growing plants under soil-less culture over soil-based culture. This system produced healthiest crops with high yields. Plants may be grown closer, and only 1/5th of overall space and 1/20th of total water is needed to grow plants under soil-less culture in comparison to soil-based culture [·]. There is no chance of soil-borne insect pest, disease attack or weed infestation too. Overall soil-less culture provides efficient nutrient regulation, higher density planting, and leading to increased yield per acre along with better quality of the produce. It is also effective for the regions of the World having scarcity of water or fertile land for agriculture.

Limitations

Hydroponic systems are relatively expensive, required proper preparation of containers, good quality water, careful maintenance of the pH of the nutrient solution, careful monitoring of the nutrient solution, and either changing or adding additional nutrients to meet the needs of the plants. Sanitation practices are required to eliminate toxic substances from the containers or solution. Control of disease and insect pests is necessary. Wind protection is required to reduce the evaporation of the solution and prevent mechanical damage to the plants. Intensive labour is required to promote and maintain proper conditions for crop production.

Conclusion

Due to rapid urbanization and industrialization as well as the melting of icebergs (as an obvious impact of global warming), arable land under cultivation is further going to decrease. Again, soil fertility status has attained a saturation level, and productivity is not increasing further with an increased level of fertilizer application. Besides, poor soil fertility in some of the cultivable areas, less chance of natural soil fertility build-up by microbes due to continuous cultivation, frequent drought conditions and unpredictability of climate and weather patterns, rise in temperature, river pollution, poor water management and wastage of huge amount of water, decline in groundwater level, etc. are threatening food production under conventional soil-based agriculture. So, that there is no option to adopting soil-less culture to help improve the yield and quality of the produce so that we can ensure the food security of our country. However, Government intervention and Research Institute interest can propel the use of this technology.

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