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Research Article

# Hydroponics (Soil-Less Cultivation): A Space Effective and Water Efficient Technology for Sustainable Agriculture

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## I N F O

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## A B S T R A C T

Defence Institute of Bio-Energy Research (DIBER), a constituent laboratory of DRDO has started work on soil less cultivation as early as 1980s and successfully standardized and customized technology of hydroponics cultivation of various crops. This customized hydroponics technology ensures year round vegetable cultivation with higher yield. In comparison to conventional agriculture, upto 50% water gets conserved in this system, and there is absolutely no use of pesticide and weedicides, thus ensuring no residual toxicity. Furthermore, multiple crops viz., spinach, coriander, tomato, cucumber, brinjal, parsley, pakchoy, broccoli, strawberry, bitter gourd, sponge gourd, etc. can be grown in a single nutrient solution. The entire system is low cost, low maintenance and environment friendly.Various vegetables along with strawberry and grasses have been grown successfully in hydroponics from Auli to Anatartica. Nutrient composition suitable for wide range of vegetables has also been developed by the institute. This paper studies the technology of hydroponics in detail along with the efforts made at DIBER which includes the standardization of this technology. It is envisaged that experience gained in successful cultivation of various crops in hydroponics using single nutrient solution at various altitudes through research stations of this institute like Haldwani (foot hill), Pithoragarh (5000' msl), Auli (9000' msl) will help in customization of this technology considering the shrinking land and water resources.

**Keywords:** Hydroponics, Defence Institute of Bio-Energy Research (DIBER), Water Efficient Technology

## Introduction

The earth's population has increased rapidly and is likely to reach 9-10 billion by the year 2040. The major challenges facing the world in the coming decades are to feed and provide shelter to the ever increasing population and maintaining the available natural resources and environment. The challenge to agriculture in the next few decades is to achieve maximum production of food without further irreversible depletion or destruction of our natural resources. Himalayan states of India have key role in biodiversity conservation, but these states are also going through important problem of decreasing share of agricultural livelihood and rapidly increasing problem of migration from border villages.

According to a report published in 2016, based on the Census of 2011, out of 16793 villages of Uttarakhand, about 1053 villages have no inhabitants and another 405 have a population of less than 10. Among these depopulated villages, 14 villages lied within the range of 5 km of aerial distance from the international border. This is a grim situation of migration from border villages adding to the worries of Indian Security agencies. Among the various factors reported for migration few notable are search for better livelihood and less productivity from agriculture due to changing weather and problem of wild animals. Hence, measures are required to increase the livelihood opportunities in these border areas to curb the problem of migration through intervention of modern technologies. Among these technologies, soil-less cultivation (hydroponics) have shown potential for profitable agriculture in varying environments from mountainous region to Antarctica as researched by DIBER (DRDO) during past several decades. Hydroponics is a technique of growing plants in nutrient solution without using soil. It is a simple yet effective technology. The present day hydroponics systems are more customized for user requirement and are available of the shelf. DIBER has successfully customized hydroponics for varying altitudes like Haldwani (foot hill), Pithoragarh (5000' asl) and Auli (9000' asl). A successful demonstration of this technology has been done during Antarctica expeditions of the 90s.

## Advantages

The hydroponic system has been used primarily for growing vegetables, cut flower saplings, potted foliage plants as well as grasses with several advantages such as:

- A soil-less system with 70-80 percent less requirement of water
- Judicious utilization and optimization of nutrients for growing multiple crops in single nutrient solution,
- More production per unit area with additional possibility of vertical farming leading to space conservation
- Protection from pest or diseases being devoid of soil and under controlled condition
- Organic agriculture can be achieved
- Spaces available at roof tops and indoor can be productively utilized
- Fresh farm produce can be in the vicinity of user (reducing transportation cost)
- Cultivation possible in remote and harsh areas where soil cultivation is not possible

The key advantages, which hydroponics technology can offer in the livelihood opportunity development in the border villages of Uttarakhand are protection from wild animals. Most of the time due to topographical challenges it is not possible to codon the farm area with fencing and thus make it vulnerable to attack by stray and grazing animals vis-à-vis wild animals. Secondly, possibility of vertical farming allows farming in a compact area with substantial water saving due to reuse and recycling and hence dependency on rain can be minimized for farming. Third advantage of round the year production possibility make it more promising for these border areas where natural calamities and inclement weather keeps the area land locked and not condusive for open field agriculture.

Hence, hydroponics is one among few technologies which has the potential to transform agriculture scenario in border areas and offers ample opportunities for livelihood development provided small capital investment and technical skill could be provided to the villagers and entrepreneurs.

**Figure 1.Tomato crop grown successfully under hydroponics at DIBER, Haldwani**
(Source: DIBER, Uttarakhand)

## Development of Hydroponics at DIBER

Historically hydroponics culture of crops has been known to world for almost 3 centuries but in India this technology came with British colonization and popularly termed as 'Bengal System of Hydroponics' during 1946. Hydroponics is a Greek word. In Greek the word hydro means water and ponos means labour. This method uses mineral nutrient solutions for growing plants and no soil is used. Under the same conditions, the plants grown by the hydroponic method tend to grow faster than plants grown in the soil.

With the increasing concerns of residual toxicity in fresh foods and their ill effects on health vis-à-vis acceptance of organically grown food as safe alternatives, growing medium quality has taken the paramount importance. Hydroponics is one such growing medium which eliminates such worries as the medium is devoid of any such residual toxicity effect of pesticides and hazardous chemicals and pollutants which otherwise are available is crops grown in soil where polluted water is either used for irrigation or soil gets contaminated due to long term use of pesticides. These hazardous chemicals finally get translocated to plant

system and get accumulated in the edible parts.

The successful attempts of standardization of hydroponics technology for Central Himalayan region started during 1980s at Defence Institute of Bio-Energy Research (the then Defence Agricultural Research Laboratory). Initial efforts were made to explore feasibility of cultivation of vegetable crops, herbs and strawberry under hydroponics at various altitudes and agro-climatic conditions. This institute has successfully demonstrated hydroponics technology during 9th, 10th and 11th Antarctic expedition during 90s.

The recent efforts of institute have been in standardizing and customizing hydroponics and vertical farming units with specific requirement and also developing single nutrient solution to grow more number of vegetable crops successfully. The institute has successfully demonstrated the cultivation of eight crops viz., tomato, lettuce, broccoli, knol-khol, capsicum, celery, lahi, palak, under customized hydroponics system using single nutrient solution. A patent has also been submitted for filing by the institute during 2018.

## Requirements of Hydroponics

**Light:-** It is essential for plants grown hydroponically as well as for those grown in soil. Hydroponically grown outdoor plants rely on solar radiation whereas, artificial illumination is provided for the indoor plants. In the past, balance has been achieved by using a combination of fluorescent tubes and ordinary sodium lamps, so that both the blue and red ends of the spectrum were present respectively. Now a days, LED light emitters may be preferred. Photosynthetically active radiation (400-700 nm) is essential is artificial lighting. Generally areas with good sunlight do not require artificial lighting for out door cultivation.

**Temperature:-** Favourable temperature is required for both the artificially cultured and soil grown plants.The stem growth and fruit setting of tomato is affected by the night temperature. Usually a temperature range of 15–32°C and 18–27°C is considered favourable for optimum production of cucumber and tomato, capsicum respectively. Though the leafy European vegetables and tolerate up to 7°C of temperature, still temperature range of 15–18°C is considered as optimal for them.

**Water:-** Water is another requirement for plant growth that must be satisfied in hydroponics as well as in soil. Quality of water used is hydroponics is of parameters importance as most of the nutrients availability is linked with pH. Polluted water or hard water is generally not recommended for hydroponics as dissolved impurities interfere with the nutrient availability. Rainwater has been found the most preferred and suitable option for hydroponics.

**Aeration for the roots:-** In order to absorb water and nutrients, the roots require a certain amount of oxygen. Water logged soil which is devoid of air space is of no use for the growth of plants. Provision should be made for aeration either by circulating or bubbling air into the solution. The solubility ofoxygen in water is low (0.004%) and further decreases with increase in temperature.

**Figure 2.Aeration of the roots**

**Anchorage**:- For plants growing in soil, sand or gravel culture anchorage is not a problem. However, when plants are grown in water culture, it is necessary to provide some means of support for the seedlings (like clay balls filled in the plastic mesh cups) and later the plants above the nutrient solution (stacking threads or wires) to allow plats to grow vertically.

**Figure 3.Vertical 'A' frame hydroponics unit supporting multiple crops at DIBER, Haldwani**

## Components for Establishing Hydroponic System

The hydroponics has several basic components.

- Shallow fiberglass trays/ plastic trays (8 cm. deep) in which plants are grown (1m x 0.5m size or any other suitable size) for NFT, circular or square pipe for modern hydroponics unit
- Storage tank for nutrient solution or a collection tank (capacity may vary from few liters to few 100 liters, depending upon the size of unit)
- Water pump (to circulate the nutrient solution from the storage tank to the trays through polyethylene tubes).

- A sequential timer to control the operation of pump.
- An aerator connected to reservoir through polyethylene tube, to aerate the nutrient solution to maintain the oxygen level in the nutrient solution.

The proper slope must be maintained in trays for free flow of nutrient solution to avoid stagnation of water in trays. Oxygen deficiencies have resulted in root damage in some types of hydroponic system unless air was bubbled constantly into the nutrient solution.The trays and tank containing nutrients must be covered from top either with a thermocol or black polyethylene sheet.This provides some support to the young plants and keeps the roots of the plant and nutrient solution in the dark.Since the nutrient media favours the growth of algae, it may foul the pump, pipes and also consume the nutrients.Therefore, the best way is to avoid growth of algae, is to prevent exposure of the nutrient solution to lightby covering with an opaque material such as thermocol sheet, black polyethylene sheet to restrict the growth of algae. It will also prevent the media from getting contaminated by dirt and other foreign media.

**Reservoir**:- Generally a plastic container having 50 to 500 litre water capacity is adequate. However, it will depend on size of hydroponic system that has to be set up for growing the plants. It is better to insulate the reservoir so that it does not get sun rays directly and the solution does not get heated as the warm solution holds less oxygen. This also restricts the growth of algae in the solution.

**Pump**:- It is good to use a pump that has few metallic parts as they tend to corrode and are toxic to plants. However, brass or stainless steel may be considered as they cause no damage to the plants. Small AC mono block pump would be adequate for this procedure.It is also recommended that a timer controller be used to control the operation of pump. It becomes advantageous to intermittently turn the pump ON and OFF.If the oxygen supply is not proper in the nutrient solution, the root system that has grown into a dense mat at the bottom will restrict the supply of oxygen to the roots. Therefore, it is recommended that the pump be turned ON for 10–15 seconds and then be turned OFF for 1–2 minutes. This ensures lesser wear and tear of pump and saves power. In this way the solution can drain from the tray exposing the roots, to the air. At the same time the roots should remain moist and never allowed to become dry.

**Application Using Photo-Voltaic Panel**:- Solar photovoltaic panels can be used to make the independent hydroponic system so that it can be easily used in remote areas. The panel generates DC electricity, which can be used to drive pump, timer and ventilating fans in the greenhouse. For low power applications photovoltaic panels provide ideal solution with least sophistication. In this case, the requirement will be i) Photo- voltaic panel to generate DC power, ii) Voltage controller, iii) Timer, iv) DC water pump and v) DC air pump. This system can be used even in places where good solar radiation is available like remote army posts or terraces.

**Nutrients:-** In hydroponics system, nutrients are supplied through an aqueous solution, which contains inorganic ions including some organic compounds like iron chelates to allow plants to complete their life cycle without physiological disbalance. Seventeen elements are considered essential for plants. These are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, copper, zinc, manganese, molybdenum, boron, chlorine and nickel.

The recommended pH for hydroponic culture is between 5.5 to 5.8. Plants growth has been optimum between pH 5.5 and 7 in general, provided nutrients supply in maintained. The problem high and low pH causes reduction in nutrient availability to plants and thereby reduced nutrient uptake, creating artificial nutrient deficiency. The availability of Mn, Cu, Zn and Fe reduces at higher pH. Whereas, lower pH lead to small decrease in availability of P, K, Ca, Mg. In general, buffering capacity of hydroponic systems is poor and therefore pH monitoring and correction is necessary.

## Cost of Various Hydroponics Unit

Cost of hydroponics unit depend upon the local availability of materials, size of the unit to accommodate plants, requirement of automation, quality of water, etc. customization hydroponics unit generally being used in commercial farms are fully automatic.

**Figure 4.Rs. 10000–12000 per 100 sq. ft.**

**Figure 5.Rs. 15000–18000 per 100 sq. ft.**

**Figure 6.Rs. 30000–35000 per 100 sq. ft.**

**Figure 7.Rs. 4000–6000 per 100 sq. ft.**

**Figure 8.Rs. 1500–2000 per 100 sq. ft.**

## Impact of Technology in Border villages of Uttarakhand

Border villages in Uttarakhand are facing dual challenge of lesser options of livelihood opportunities and decreasing profit from conventional agriculture due to wild animals interference & climate change. Hydroponics technology offers options to overcome these challenges. DIBER has been instrumental in disseminating customized version of low cost hydroponics in these border areas of Uttarakhand. Villagers of Pithoragrah district, block Munakot have adopted the technology and set an example for the others to follow. Vegetables grown by these farmers under hydroponics are fetching premium price in Indian mega marts.


**Figure 9.Packed cherry tomato grown by Hydroponic technology ready for selling**


**Figure 10.Packed lettuce grown by Hydroponic technology ready for selling**

Although hydroponics is a simple technology but it involves challenges in terms of maintaining nutrient balance of growing media, buffering capacity of the system and substituting nutrient deficiencies in growing media. Therefore, support of computerized programming automation and artificial intelligent system are required to monitor the system requirement and communicate the requirement in real time for correction. The main challenge in taking this technology to masses is requirement of skill and knowledge of system regulation. Although Artificial Intelligence (AI) has supported the automation of hydroponics unit but the technology is complicated and costly. To make this technology, a technology of every household more customization with user friendly is required with inclusion of hybrid power system like use of solar power or auxiliary power to make it practically acceptable in off-grid areas.

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