# Hydroponic Technique: A New approach for Crop Production at Trans Himalayan High-Altitude Cold Desert Regions of India


**ABSTRACT:**

**Aims**: The trans-Himalayan high-altitude cold desert regions of India is characterized by a rugged topography at an altitude ranging from 2550 to 7742 meters above sea level. It has a vast geographical area of 72976 $km^2$ with very little cultivated area of about 13726 hectare. Hydroponic is a soilless cultivation technique which may produce fresh vegetable in areas where environmental stress (cold, heat, dessert etc.) and limited space or on non-arable land is a major constrains for agriculture production.

**Methodology:** The experiment was conducted under open natural ventilated double layer polycarbonate green house in cold desert high altitude conditions of Leh, India. The hydroponic structures were designed for crop production (viz. leafy greens, vegetables, fruits etc) in deep water culture (DWC) and nutrient film technique (NFT) hydroponic techniques and compared them with conventional soil grown system. Nutrient solution for growing vegetables was prepared and standardized.

**Results:** The result obtained has shown that crop yield was significantly higher in hydroponic system as compared to traditional system for all crops. The recorded increase in yield for various crops in hydroponic system compared to soil grown system were: arugula 221%, atriplex 248%, coriander 288%, fenugreek 208%, lettuce 293%, mint 237%, mustard 227%, spinach 294%, cucumber 533%, strawberry 280%, summer squash 229% and tomato 345% which were significantly higher. Hydroponics can be explored to grow vegetables round the year especially for leafy greens. The hydroponic systems may come out as a valuable asset to forward and remote area of trans-Himalayan region for growing fresh vegetables where cultivated land and availability of the water are the limiting factors for crop production.



**Keywords**: Cold desert, Crops yield, NFT Hydroponic, water conservation


## 1. INTRODUCTION

Modern hydroponic cultivation technology is becoming more popular in recent days due to its efficiency in resource management and is also known to produce good quality crops. On the other side fertility of landscape is depleting due to climate change, urbanization, natural disaster, excess use of chemicals and pesticides in traditional agriculture techniques. With the use of hydroponic technique one can produce more crop yield in less time than conventional agriculture practice. It eliminates the ploughing, cultural practice, pesticides application and weeding practice. Hydroponic technique has been used commercially to produce leafy as well as other vegetables with 70 to 90% less water than usual throughout the world. Australia, Canada, Netherland, England, France, Israel, and USA are the leading countries in hydroponic technology. For successful implementation of commercial hydroponic technology, it is important to develop low cost techniques which requires less labour and low cost overall setup and operational cost. It operation and maintenance should be easy to understand [7].

The Trans-Himalayan high-altitude cold desert regions situated in the north of India between 32° 15 to 36"' latitude and 75°.15 to 80.15 longitude (Fig. 1). In India UT-Ladakh and Himachal Pradesh district Lahaul and Spitiis characterized as a rugged topography at an altitude ranging from 2550 to 7742 meters above sea level. It has a vast geographical area of 72976 $km^2$ and agriculture cultivated area is 13726 hectare. Despite the vast geographical area, 60% of the households has less than one hectare cultivable land. Single-cropping is dominant in that region and double-cropping is possible only in a limited area that is below an altitude of approximately 3500 meters [1],[2]. Agriculture is entirely based on irrigation. Glaciers are the main source of water for irrigation and the rivers that own in the region remain underutilized for agricultural practices but can be utilized for hydroponics based crop production. High-altitude cold desert Trans-Himalaya regions show a very wide variation in texture as it includes sandy, loamy, silty loam, etc. Crops production vary in different soil types and local farmers are less aware of this [3]. Nutrition index of this region reveals that organic carbon and available macro & micro nutrient fall under low to medium class. In view of the above, in order to improve in crop productivity and soil health in the region, it can be concluded that the intensive soil management practices are required than it return require extensive finance investment, hard labour work and extreme energy expenditure etc. [4]. Production of natural resources such as crops remain limited due to water scarcity, limited availability of aerable land and extreme climatic conditions in this region. There is glut of farm produce in August and September, while fresh fruits and vegetables are less or not available during the extreme winter months of the year. Domestic food production is unable to meet the demand for the increasing population in this area. Himalaya regions gets approximately 73% of its food grain from outsourcing. The total crop cultivated area of Trans-Himalaya is only 0.2% of its total geographical area. Due to inaccessibility and use of tribal farming systems, latest technology interventions have not been able to reach the farming community [5]. In the present experiments, deep water culture (DWC) and nutrient film technique (NFT) system of hydroponic techniques have been introduced in high altitude cold desert Leh region for production of leafy greens (viz. spinach, lettuce, mint, coriander, atriplex, arugula, fenugreek, mustard), vegetables like tomato, summer squash and cucumber and strawberry in modified hydroponic nutrient solution standardized for each crops. This study will focus on water conservation and benefits of different hydroponic structures over traditional soil grown system for production of various vegetables and fruit.

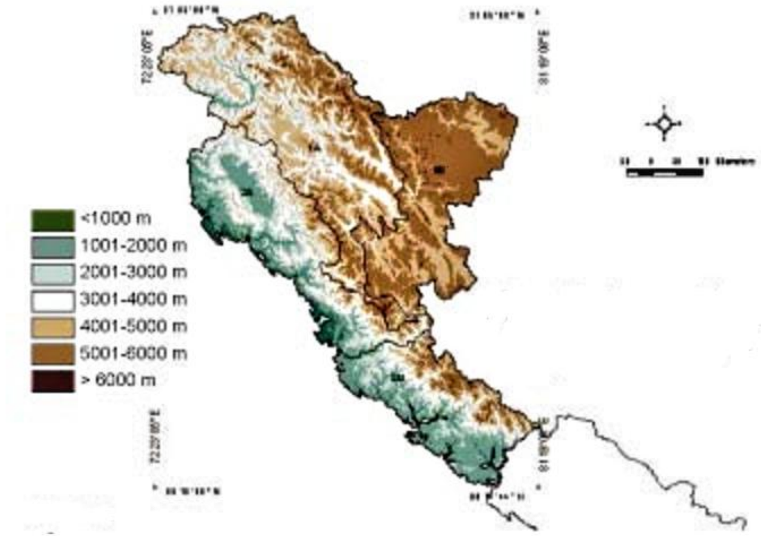



**Fig.1. Trans-Himalayan high-altitude cold desert regions of India. Source-[6]**

## 2. MATERIALS AND METHODS

**2.1 Experimental Site:** Various experiments were conducted at Vegetable Research Unit, Defence Institute of High Altitude Research (DIHAR), DRDO, Leh-Ladakh (latitude, longitude, 34°08'23"N, 77°34'21"E. and Altitude 3333 meter) during years 2017 to 2021. The average day length of that specific site was approximately 9-14 h; temperature ranges from 5 to 34$^{o}$C and relative humidity was 30 to 85% during experimental trial in green house. The experimental site was fairly uniform and levelled and was conducted in an open window double layer polycarbonate greenhouse. The two types of hydroponics system viz. deep water culture (DWC) and nutrient film technique (NFT) were used in the present experiment.

**2.1.2 Nutrient film technique (NFT) circulating method:** In NFT systems, constant film of water and nutrients were provided along the water channel. Some part of roots was dip into the water/ nutrients and some lied above the water line. Dimension of vertical circulated system were L×W×H (160×90×150cm) with 60 net pot & reservoir of 60L capacity (Image 1). The Nutrient film technique was supplied with continuous electricity for 18 hrs

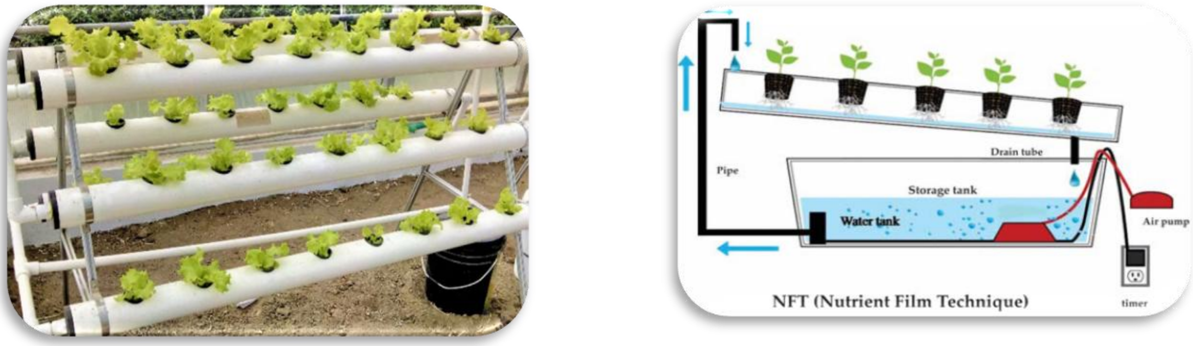



**Image 1: NFT (Nutrient Film technique)**

**2.1.3 Deep water culture (DWC) non-circulating method:** In this system, roots of the plant were totally immersed in nutrient solution. Root dipping technique was used to grow leafy and fruits crops in box & bucket system with reservoir capacity of 10L. Non-circulating method does not require electricity (Image 2).


**Image 2: Deep water culture**

**2.2 Preparation of Nutrient Solution-** Plant absorbs nutrients used in their inorganic and ionic forms when dissolved in nutrient solution. Nutrient solution is composed different chemical combinations of17 essential elements that plants require for their growth. Modified Hoagland nutrient solution (DIHAR-I and DIHAR-II) was prepared (Table 1), standardized and multiple experiments were conducted for hydroponic cultivation of leafy greens and other vegetables. To prepare nutrient solution for leafy vegetable (lettuce, spinach, coriander, mustard, fenugreek, arugula and atriplex) 2ml of each DIHAR-I and DIHAR-II nutrient solution were mixed with 1 liter of tube well water and for fruits crops (Tomato, Cucumber and Summer Squash) 2.5 ml of nutrient solution was mixed with 1 liter of tube well water up to flowering stage whereas 5.0 ml of nutrient solution was mixed with 1 liter of tube well water for fruiting stage. The pH and EC values of the hydroponics nutrient solution were measured routinely using a pH and EC meter (Hach, USA). The pH range of hydroponics solution varies between 6.0-6.5 for optimum growth of plant. The NaOH and HCl were added to obtain the pH of nutrient solution optimum range [8].

**Table 1. Modified Hoagland Nutrient Solution composition**

| Component | Stock Solution (g/L) |
|---|---|
| **DIHAR-I** | |
| $Ca(NO_3)_2*4H_2O$ | 202 |
| Iron EDDHA (Iron Chelate) | 5.6 |
| **DIHAR-II** | |
| $KH_2PO_4$ | 136 |
| $KNO_3$ | 133 |
| $MgSO_4*7H_2O$ | 58.1 |
| $H_3BO_3$ | 2.89 |

| | |
|---|---|
| $ZnSO_4*7H_2O$ | 0.22 |
| $MnCl_2*4H_2O$ | 0.20 |
| $CuSO_4*5H_2O$ | 0.08 |
| $NaMoO_4*2H_2O$ | 0.12 |

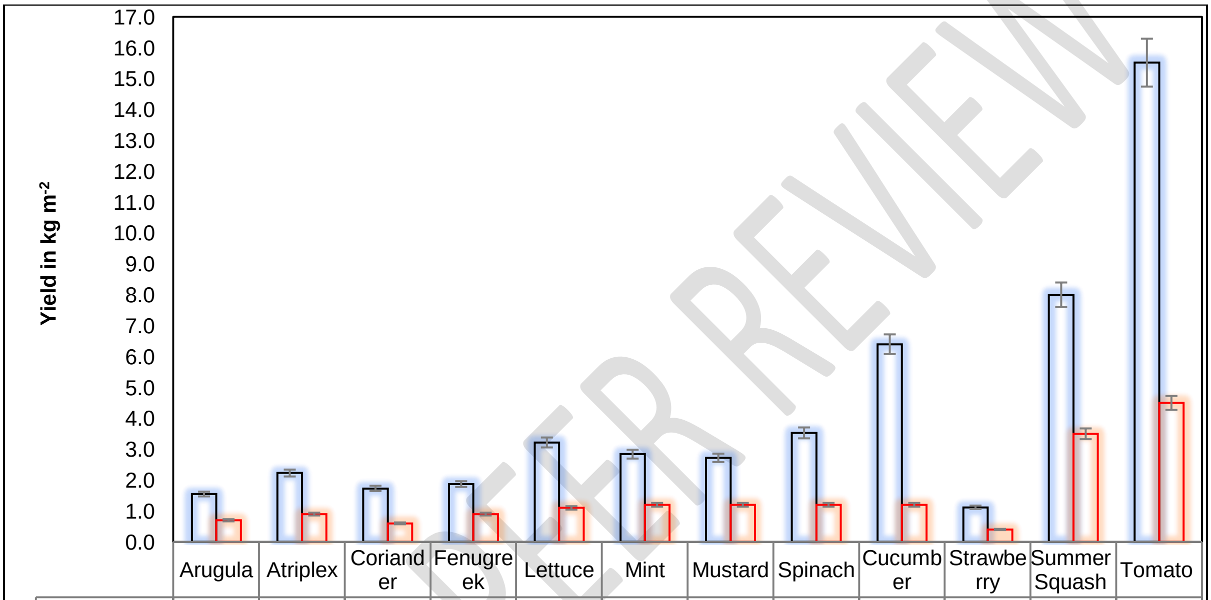
**2.3 Crop management**- The seeds of vegetable like lettuce, spinach, coriander, mustard, fenugreek, arugula, tomato, cucumber, summer squash and atriplex were sown in a mixture of cocopeat, vermiculite and perlite (5:2:1) media in pro-trays. Seeds were sown at proper depth and its optimum moisture level was maintained from seed germination to seedling transplant stage. The seedlings were transplanted in hydroponic units during two-three leaf stage and tip cutting procedure was used in some plants like mint. The seedlings were placed into net pots in growing channels of hydroponic systems. The net pots were filled with clay balls to support seedlings. The nutrient solutions were added in every 10-12 days interval in hydroponic systems. Crops were harvested after it attain marketable size.

**2.4 Crop Sampling**-Nine randomly selected plants were taken from each experimental site. These were tagged and yield production was recorded at the time of harvesting. The traditional crops cultivation data was recorded form previous researches [9]. Standard statistical methods were adopted to analyze experimental data with SPSS 22 (SPSS Corporation, Chicago, Illinois, USA) and MS excel 2019 [10].

## 3. RESULTS AND DISCUSSION

**3.1 Yield Potential of Leafy and Fruits crops**: The data recorded for the study of plant average yield attributing character of various crops grown in hydroponic and traditional crops cultivation is presented in Fig.2. It was observed that crops yield was significantly higher in hydroponic systems as compared to traditional system for all crops. Average production of leafy vegetable in hydroponic system for various crops were: arugula 1.6±0.08 $kgm^{-2}$, atriplex, 2.2±0.08 kg $m^{-2}$, coriander 1.7±0.78 kg $m^{-2}$, fenugreek 1.9±0.09 kg $m^{-2}$, lettuce 3.2±0.08 kg $m^{-2}$, mint 2.8±0.08 kg $m^{-2}$, mustard 2.7±0.08 kg, $m^{-2}$ and spinach 3.5±0.08$m^{-2}$. Similarly, fruits crops yield obtained were: Cucumber 6.4±1.01 kg,$m^{-2}$ Strawberry 1.1±0.09 $kgm^{-2}$, Summer Squash 8.0±1.05$kgm^{-2}$ and Tomato15.5±1.16 $kgm^{-2}$. Productions of crops depend on supply of water, nutrient and air. The plants grown in hydroponics systems were supplied with sufficient nutrition and favorable environment conditions were setup to increase the crops yield potential [11]. Hydroponics system was found to be successful for fruit crop production with river water. It is envisaged that single nutrient solution can be used at various altitudes for successful cultivation of various crops in hydroponic techniques [12]. In plant, light and nutrient solution are the most effective factors improving yield and quality of vegetable [13], [14]. Hydroponics technique may also contribute to the future of space program. NASA has extensive hydroponics research plans in place, which will benefit current space exploration, as well as future, long-term colonization of Mars or Moon [15].
The increase in crops yield recorded were: arugula 221%, atriplex 248%, coriander 288%, fenugreek 208%, lettuce 293%, mint 237%, mustard 227%, spinach 294%, cucumber 533%, strawberry 280%, summer squash 229%, tomato 345% higher yield in hydroponics system compared to traditional system (Fig. 3). From the overall results, it was observed that, about 70-80% of water was saved using hydroponics technology. Pictorial representation of various crops grown in hydroponic systems are depicted in Fig 4. Hydroponic can increase crops yield upto 150%-188.3%[16]. When hydroponically and soil-grown lettuce were compared, it was observed that there was significantly higher yield on both dry (15.32%) and wet-basis (41.20%). This represents the first comprehensive growth demonstrating that leafy vegetable grown hydroponically is not the same quality as that grown in soil [17]. The developed modified nutrient solution was used successfully for a wide range of vegetable production and from other experiments it has shown that hydroponics system can produce 2 to 3 times more yield than soil that was of high nutritional value [18]. The hydroponic systems are cost-effective and complement sustainable leafy green production. Hydroponically produced vegetables/ crops are much safer and healthier than conventional alternatives. Hydroponic agriculture can yield high quality crops with proper nutrient solutions, optimum temperature range, and other environmental conditions [19]. The main advantage of soilless hydroponic systems is conservation of water and less or no use of agrichemicals which are dangerous to the human health if consumed [20]. Hydroponically-grown produced are better in pigment and texture than soil-grown system [21]. Changing climatic conditions and erratic weather behavior over the years has fueled the existing

problems of land and water scarcity that is continuing to exact a toll on agriculture. Hydroponic cultivation can act as an alternate planting system to greenhouse soil-based cultivation. Early harvesting of hydroponically grown vegetables was also achieved in the present experiments. In NFT system, leafy greens (viz. lettuce and spinach) was harvested in 35-40 days after transplanting, whereas in soil grown system harvesting was done in 50 days. Researchers also reported that hydroponic system can reduce the duration of the crop production by 25-35 days. It reflects higher values of quality parameters like chlorophyll, total soluble solids, protein, and crude fiber content under hydroponic system. Hydroponic system nutrient film technique (NFT) saved around 70% water than soil grown crop produce. According to economic analysis indicators, both hydroponic techniques performed better than the soil-based systems, having benefit-cost ratio is greater than two. It is one of the most promising system to adopt under protected agriculture owing to its simplicity, ease of operation, higher yield, economic feasibility, and nutritionally superior produce [22].




| | Arugula | Atriplex | Coriander | Fenugreek | Lettuce | Mint | Mustard | Spinach | Cucumber | Strawberry | Summer Squash | Tomato |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hydroponic | 1.6 | 2.2 | 1.7 | 1.9 | 3.2 | 2.8 | 2.7 | 3.5 | 6.4 | 1.1 | 8.0 | 15.5 |
| Traditional | 0.7 | 0.9 | 0.6 | 0.9 | 1.1 | 1.2 | 1.2 | 1.2 | 1.2 | 0.4 | 3.5 | 4.5 |

**Fig.2. Yield of vegetables grown under soil less hydroponic system and conventional farming**

It is possible to grow short duration crops especially leafy vegetables throughout the year in very limited spaces with low labour and chemical-free crops are harvested sequentially from hydroponic system. Hydroponically produced vegetables provide more nutritional value than traditional grown crops. It can be act as a great support as a health, economy and fragile environment to this trans-Himalayan high-altitude cold desert regions of India. Based on the overall experiments on hydroponic system, Table 2 represents suitability chart of various vegetables and fruit grown under hydroponic systems at trans-Himalayan high altitude cold desert regions of India.

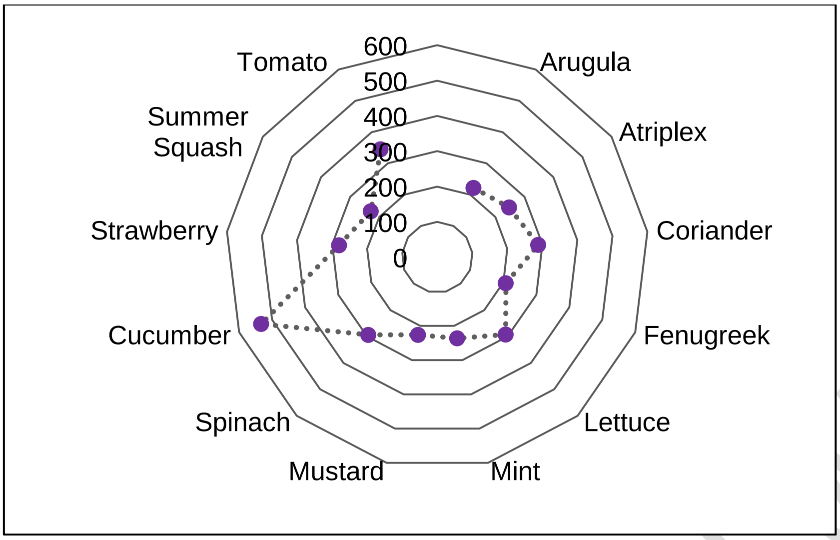



**Fig.3. Percentage yield enhancement of vegetables grown under soil less hydroponic system compared with conventional farming**

**Table 2. Suitability chart of various plants grown under hydroponic systems at trans-Himalayan high altitude cold desert regions of India**

| Sr. no. | Crops Name | varieties | Type of crops | Recommendation | Remake |
|---|---|---|---|---|---|
| 1 | Arugula | *Garden Tangy* | Condiments | YES | Suitable |
| 2 | Atriplex | *A. hortensis L* | Leafy vegetables | YES | Suitable |
| 3 | Coriander | *ACr-2* | Condiments | YES | Suitable |
| 4 | Fenugreek | *Co.1 & 2* | Condiments | YES | Suitable |
| 5 | Lettuce | *Grand rapid,NS 1454* | Leafy vegetables | YES | Suitable |
| 6 | Mint | *DIHAR Mint-1* | Condiments | YES | Suitable |
| 7 | Mustard | *KBS-3* | Leafy vegetables | YES | Suitable |
| 8 | Spinach | *Delta, All green* | Leafy vegetables | YES | Suitable |
| 9 | Cucumber | *BSS-646 & 647* | Vegetables | NO | Research Requirement |
| 10 | Strawberry | *Sweet Charlie* | Fruits | NO | Research Requirement |
| 11 | Summer Squash | *Australian green* | Vegetables | NO | Research Requirement |
| 12 | Tomato | *Roma. Tolstoi,Cherry tomato* | Vegetables | YES | Suitable |

## 4. CONCLUSIONS

Hydroponics technology is a major solution to increase crop yield and quality of crops with limited agricultural land. It also works efficiently if there is any water or energy shortage in the area. Vertical hydroponics promises to be the technology of near future in India where people in urban areas can also grow their own crops with limited space. This study can conclude that hydroponic leafy vegetable and tomato production can act as a sustainable alternative to conventional soil-based crops production for water scarce cold desert regions. To grow crops like cucumber, strawberry and summer squash in hydroponics, further research is required so as to figure out the suitable nutrient and optimum conditions to improve the production. We can set up hydroponic crop production system in polycarbonate green houses, local green houses and underground room conditions throughout the year when the land is unfertile. The temperature can be maintained manually by operating ventilators that are south-facing with west frame. Supplementary lighting and heating can be provided depending on location. In this way, hydroponics can be used to produce vegetables or fruits with less resources and self-sufficient food system worldwide. More research is needed to identify soilless growing media options such as reusable nutrient solution. It is necessary to identify ways to improve overall hydroponic system sustainability within a circular economy.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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Fig. 4 Hydroponic crops production ***A.*** Atriplex, ***B.*** Coriander, ***C.*** Spinach, ***D.*** Mint, ***E.*** Lettuce, ***F.*** Fenugreek, ***G.*** Arugula, ***H.*** Mustard, ***I.*** Cucumber, ***J.*** Summer Squash, ***K.*** Strawberry and ***L.*** Tomato at trans-Himalayan high altitude cold desert Leh-Ladakh of India