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Vegetable Cultivation under Hydroponics in Himalayas : Challenges and Opportunities

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ABSTRACT

Defence Institute of Bio-Energy Research, Haldwani has successfully developed a hydroponics system by clubbing the soil less cultivation with rain water harvesting technology. The institute has also developed a suitable nutrient composition suitable for wide range of vegetables. Among the various varieties/hybrids grown in hydroponics, cucumber line PC 4C-8 exhibited the maximum fruit yield (448.3 q/ha). Among the various tomato hybrids, Avinash-2 exhibited highest yield (1052 q/ha) and number of fruits (154 per sq m) whereas TSS, total sugars, crude protein and minerals content were the maximum in tomato hybrid DARL-304. Interestingly, hydroponics system prolonged the harvesting period by 45 days in tomato. Plant population density of 6 plants/m^2 was found optimum with the highest fruit yield in tomato and cucumber. Tomato hybrid DARL-304 exhibited higher fruit yield (6.5 kg/plant). Hydroponics system have been found successful in Auli (9000' MSL), Joshimath with fruit yield of 2.25 kg/plant to 3.79 kg/plant in tomato. The yield was higher in rain water as comparison to river water. The article deals with the hydroponics technology in detail vis-à-vis efforts made at DIBER for standardization of hydroponics 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 the institute.

Keywords: Soil less cultivation, Hydroponics, Nutrient film technology, Nutrient solution, Controlled environment cultivation, Urban agriculture, Vegetable production

1. INTRODUCTION

The world 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. Agriculture will play a major role in achieving this goal[1]. The challenges to agriculture in the next few decades are to achieve maximum production of food without further irreversible depletion or destruction of our natural resources. The purpose of agriculture has always been to produce enough food to feed the entire human population. This will require a doubling of present crop production capacities in the next fifty years which though difficult is not impossible. However, there is an urgent need to adopt ecofriendly technologies and conserve fast depleting land and water resources. In this context, hydroponics technology can be an efficient technology for food production in extreme environmental ecosystems such as deserts, mountainous regions, or arctic communities. Various terms have been used to describe the technique for growing plants in some medium other than soil including hydroponics as soilless culture, tank farming and nutriculture.

The term Hydroponics was derived from the Greek words *hydro* means water and *ponos* means labour. It is a method of growing plants using mineral nutrient solutions, without soil[1]. In India, Hydroponics was introduced in year 1946 by an English scientist, W.J. Shalto Duglas. He established a laboratory in Kalimpong area, West Bengal and had written a book on Hydroponics, named as Hydroponics- The Bengal System. Different solutions were suggested by different scientists for growing different vegetables in hydroponics and for different seasons. These recommendations were so complicated that the farmers could not implement it to grow the vegetables in a large scale. Break through attempts were made at Defence Agricultural Research Laboratory now Defence Institute of Bio-Energy Research (DIBER), during late 80s to eliminate the complicacy of growing vegetables without soil and success was achieved by clubbing the soil less cultivation with rain water harvesting technology and developed a suitable nutrient composition[3-6]. The composition was further amended, with the result, now farmers can grow the vegetables in soil less medium by using the rain water harvested from the roof tops. Thus, the great hurdle in soil less cultivation technology was removed and commercial cultivation was made possible by using single nutrient solution for wide range of vegetables. The hydroponic system of growing plants has been used primarily for growing vegetables, cut flower saplings, potted foliage plants as well as grasses with several advantages[6]. This institute has already showcased Hydroponics technology successfully at Maitri station, Antartica[8-14] and higher hills[15-16].

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2. REQUIREMENTS OF HYDROPONICS

2.1 Light

The requirement for light is just as essential for plants grown hydroponically as for those in soil. When plants are grown hydroponically out door one may rely mostly on solar radiation, while growing plants indoor it is necessary to provide artificial illumination. 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 nm - 700 nm) is essential is artificial lighting is required. Generally areas with good sunlight do not require artificial lighting.

2.2 Temperature

A favorable temperature is just as important for plants in artificial culture as for those in soil. The night temperature profoundly affects stem growth and fruit setting of tomato. Generally temperature range of 15 °C - 32 °C for cucumber and 18 °C - 27 °C for tomato and capsicum are optimum for crop production. For leafy European vegetables temperature range of 15 °C - 18 °C is optimum although they can tolerate as low as 7 °C temperature.

2.3 Water

Water is another requirement for plant growth that must be satisfied in hydroponics as well as in soil. Some of the water absorbed is used by the plant but most of it is lost by transpiration from the leaves. A significant amount may be lost by evaporation.

2.4 Aeration for the Roots

In order to absorb water and nutrients, the roots require a certain amount of oxygen. Plants do not grow well in water logged soil devoid of air space and most plants do not grow well in water culture unless provision is made to aerate the solution by circulating it or by bubbling air into it. The solubility of O_2 in water is quite low (at 75°F about 0.004 per cent) and decreases significantly with increase in temperature.

2.5 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.

3.0 COMPONENTS FOR ESTABLISHING HYDROPONIC SYSTEM:

The hydroponics has several basic components.

i) Shallow fiberglass trays/ plastic trays (8 cm. deep) in which plants are grown (1m x 0.5m size or any other suitable size)
ii) A collection tank/ nutrient solution storage tank. Capacity may vary from few litres to few hundred litres depending on the size of unit.
iii) A water pump which will circulate the nutrient solution from the reservoir tank to the growing trays through polyethylene tubes.
iv) A sequential timer to control the operation of pump.
v) 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 growing trays and nutrient tank must be covered from the top with a thermocol sheet 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. Another important point is that the nutrient media is an excellent growing media for algae which may foul the pump, circulating pipes and consume the nutrients. The best way is to avoid growth of algae, is to prevent exposure of the nutrient solution to light. All channels of the flowing solution and the reservoir are covered with a dark opaque material such as black polyethylene to restrict the growth of algae. This will also prevent dirt or foreign matter from contaminating the nutrient solution.

3.1 Reservoir

Generally a plastic container having 100 l to 500 l 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.

3.2 Pump

A small AC monoblock pump is adequate. It is desirable to have as few metal parts as possible because metal will corrode and possibly prove toxic to plants. However, pump with brass, or stainless steel parts exposed to the nutrient solution seems to cause no damage to the plants. 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. When the root system enlarges and forms a dense mat on the bottom of the tray the movement of oxygen to the roots, even in a thin film of nutrient solution may be limiting if the oxygen content is not proper. Therefore, it is recommended that the pump be turned ON for 10 s to15 s and then be turned OFF for 1 min to 2 min. 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.

3.3 Application Using Photo-Voltaic Panel

To make the hydroponic system independent of conventional power supply or to use it in remote areas, the solar photovoltaic panels can be used. 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: Photo- voltaic panel to generate DC power, Voltage controller, Timer, DC water pump, and DC air pump. This system can be used even in places where good solar radiation is available like remote army posts or terraces.

3.4 Nutrient Solution

Nutrient solution for hydroponic systems is an aqueous solution containing mainly inorganic ions from soluble salts of essential elements for higher plants. Eventually, some organic compounds such as iron chelates may be present[17]. An essential element has a clear physiological role and its absence prevents the complete plant life cycle[18]. Currently 17 elements are considered essential for most plants, these are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, copper, zinc, manganese, molybdenum, boron, chlorine and nickel[19]. With the exception of carbon (C) and oxygen (O), which are supplied from the atmosphere, the essential elements are obtained from the growth medium. Other elements such as sodium, silicon, vanadium, selenium, cobalt, aluminum and iodine among others, are considered beneficial because some of them can stimulate the growth, or can compensate the toxic effects of other elements, or may replace essential nutrients in a less specific role.

In hydroponics, nutrients are provided to the plants by dissolving salts (fertilizers) containing the required nutrients in water[20]. It is important to note here that chemical analysis of the water, to be used for making nutrient solution, must be done so as to make the final concentration of solution. A unique feature of the active system of ion absorption by plant roots is that exhibits ion competition, antagonism and synergism. The rate of absorption is also different for different ions. The monovalent ions K^+, Cl^- and NO_3^- are more rapidly absorbed by roots than divalent Ca^{2+}, Mg^{2+} SO_4^{2-} ions. The uptake of certain ions is also enhanced in active uptake. If the nitrate (NO_3^-) ion is the major nitrogen source in the surrounding rooting environment, then there tends to be a balancing effect marked by greater intake of the cations K^+, Ca^{2+} and Mg^{2+}. Uptake of Cl^-, SO_4^{2-} and $H_2PO_4^-$ is stimulated when nitrate (NO_3^-) uptake is strongly depressed If the ammonium NH_4^+ ion is major source of nitrogen then uptake of cations K^+, Ca^{2+} and Mg^{2+} is reduced. The presence of NH_4^+ enhances NO_3^- uptake. If Cl^- ions are present in sizable concentration NO_3^- uptake is reduced. The interaction effect of these elements with each other is also important and needs specific knowledge for success of Hydroponics. Like phosphorus in excess affects availability of Fe, Mn and Zn. There is critical balance between K, Ca and Mg cation and when not in balance plant stress occurs. Ca deficiency or excess occurs as a result of an imbalance with K and Mg. similarly iron and zinc also play critical role. The root hairs will be almost absent on roots exposed to a high concentration 100 mg/l (ppm) of nitrogen NO_3^-. High phosphorus will also reduce root hairs development where as changing concentration of K, Ca, Mg will have little effect.

It was observed that once the nutrient solution is made it can last for 7 to 8 days. The solution level in the reservoir should be maintained at a constant level. This can be done by adding water if the plants are young and using very little nutrient solution. However, addition of weak (half of the original concentration) nutrient solution or alternating with water and weak solution may prove best as the plants mature. The list of composition of nutrient solution which has been developed by DIBER for the successful growth of various vegetables is given in Table 1 with detail procedure for its use discussed earlier[4]. While making composition make it sure that the : (a) The micronutrient stock solution be made separately, (b) The chelated iron solution be made separately, and (c) The Ca $(No_3)_2$, KH_2PO_4, KNO_3, Mg SO_4 be dissolved separately and added one by one.

Table 1. Nutrient composition developed at DARL for hydroponic/ soil less cultivation using rain water for crop growth

Macro nutrients	
Ca $(No_3)_2$	120 g / 100 l water
KH_2PO_4	20 g /100 l water
KNO_3	80 g /100 l water
Mg SO_4	50 g /100 l water
Micro nutrients	
Boron	0.30 ppm
Manganese	0.20 ppm
Zinc	0.203 ppm
Copper	0.022 ppm
Molybdenum	0.015 ppm
Chelated Iron	
Iron	1 ml/l water

4. ELECTRICAL CONDUCTIVITY AND PH

These are two important parameters which work as key to successful hydroponics cultivation. These parameters not only affect the availability of nutrients to the crop but also decide the salinity of the growing solution which ultimately affect the fruit quality[21] including the plant physiological parameters[22,23]. The total amount of ions of dissolved salts in the nutrient solution exerts a force called osmotic pressure, which is a dynamic property of the nutrient solutions and it is directly dependent of the amount of dissolved solutes[24]. An indirect way to estimate the osmotic pressure of the nutrient solution is the electrical conductivity (EC), an index of salt concentration that defines the total amount of salts in a solution. Hence, EC of the nutrient solution is a good indicator of the amount of available ions to the plants in the root zone[25]. The ideal EC is specific for each crop and dependent on environmental conditions[25]. However, the EC values for hydroponic systems range from 1.5 to 2.5 ds/m. Higher EC hinders nutrient uptake by increasing osmotic pressure, whereas lower EC may severely affect plant health and yield[27]. The decrease in water uptake is strongly and linearly correlated to EC[28].

The pH value determines the nutrient availability for plants, therefore its adjustment must be done daily due to the lower buffering capacity of soilless systems[29]. The changes in the pH of a nutrient solution depending on the difference in the magnitude of nutrient uptake by plants. When the anions are uptaken in higher concentrations than cations (nitrate), the plant excretes anions (OH^- or HCO_3^-), to balance the electrical charges inside, which produces increasing in the pH value. Hence, incorporation of ammonium as N source in the nutrient solution regulates the pH and therefore nutrient availability is ensured. Ammonium lowers the pH of nutrient solution even in the presence of nitrate[30]. Regulation of pH is can also be carried out by using nitric, sulphuric or phosphoric acid, either individually or combined. The recommended pH for hydroponic culture is between 5.5 to 5.8. Generally plants grow well between pH 4 and 7, if nutrients do not become limiting because the direct effects of pH on root growth are small. The problem high and low pH renders is reduced nutrient availability. Reduced availability means reduced nutrient uptake, but not necessarily nutrient deficiency. The availabilities of Mn, Cu, Zn and especially Fe are reduced at higher pH, and there is a small decrease in availability of P, K, Ca, Mg at lower pH. Hydroponic systems are poorly buffered and it is difficult to keep the pH between 4 and 7 without pH control. Phosphorous (in form of phosphates) in solution buffers pH, but if phosphorous is maintained at levels that are adequate to stabilize pH (1 mM to 10 mM), it becomes toxic to plants[31].

Table 3. Performance of cucumber cultivars grown under hydroponic system

Cultivars	Fruit yield (q/ha)	Fruit length (cm)	TSS (%)	Total mineral (%)
PC 4C-8	448.3	14.0	3.35	0.78
PC 4C-15	393.3	18.6	2.33	0.40
DARL-102 (Hy)	223.3	15.0	1.32	0.43
DARL-103 (Hy)	223.3	18.3	3.35	0.58
DC – 2	306.6	15.3	2.33	0.76
DARL-81	370.0	19.3	3.35	0.67
KTCH-89(Hy)	356.6	20.0	2.32	0.53
SE±	61.2	0.94	-	-
CD (P=05)	188.7	2.91	-	-
CD (P=01)	264.5	4.08	-	-

Table 4. Performance of tomato hybrids in commercial hydroponics system in summer season in hills

Hybrid	No. of fruit / sq m	Fruit yield (q/ha)	Quality traits	
			TSS %	Ascorbic Acid (mg/100 g)
Avinash-2	154	1052.9	3.07	15.19
Deva	102	590.0	2.35	17.27
Lahar	88	670.0	4.95	22.28
Maharshi	66	521.0	4.55	24.94
Indam-213	129	846.0	3.35	25.94
Indam 1116	82	608.0	3.35	20.63
Indam 9501	151	848.0	4.35	27.45
Apurwa	74	550.0	3.35	23.89
ARTH-16	61	315.0	3.35	75.2
Rakshika	82	454.0	4.35	24.01
DARL-305	44	440.0	4.35	29.20
CD (P=01)	6.0	431.8		
CD (P=05)	50.0	316.6		

5 PERFORMANCE OF VARIOUS CROPS IN SOIL LESS CULTIVATION

DIBER has tried and tested various crops under single nutrient system over the years. Performance of various crops viz., tomato, cucumber, summer squash, lahi, bottlegourd, beans, strawberry etc under hydroponics system have been evaluated and presented in Tables 2-5 and Figs 1-7. Various varieties/hybrids of cucumber were grown in the hydroponics and tested for their agronomic performance (Table 2). Among the various varieties/hybrids grown in hydroponics, line PC 4C-8 exhibited the maximum fruit yield (448.3 q/ha), TSS and mineral content whereas the yield was the lowest in hybrid DARL-102 and DARL-103 (223.3 q/ha). The longest fruits were observed in hybrid KTCH-89 (20.0 cm) and the smallest fruits were observed in PC4C-8 (14.0 cm). Early marketable yield of fruits and length has also varied significantly (1.0 to 2.6 kg per plant and 103.3 to 17.1 cm, respectively) among thirteen mini-cucumber cultivars grown under hydroponics by Shaw and Cantliffe[32]. Among the various tomato hybrids, Avinash-2 was the best with highest yield (1052 q/ha) and number of fruits (154 per sq m) (Table 3). Hybrid ARTH-16 exhibited the lowest yield (315.0 q/ha) whereas number of fruits per plant were the minimum in DARL-305 (44.0). Total soluble solids ranged from 2.35 to 4.95 per cent and ascorbic acid content ranged from 15.19 to 29.20 mg/100g fresh wt. In another experiment, five tomato hybrids were evaluated under hydroponics system for their biochemical quality (Table 4). Results revealed that TSS, total sugars, crude protein and minerals content were the maximum (4.67, 4.26, 0.94 and 1.52 per cent, respectively) in tomato hybrid DARL-304 whereas Vit. C content was maximum (30.12 mg/100g) in BT-20-2-1 (Table 4). Variation in marketable and total fruit yield has also been reported in tomato under hydroponics by Gent and Short[33]. In a trial on standardization of plant population for cucumber in hydroponics, population densities from 2 to 10 plants/m^2 were tried. Plant population of 6 plants/m^2 was optimum with the highest fruit yield during both the years (Table 5).

Table 2. Biochemical parameters of hydroponically tomato hybrids

Parameter (per centage)	DARL-303	DARL-304	BT 20-2-1	Larica	Ellora
Moisture	95.20	93.38	94.17	93.92	94.79
TSS	3.67	4.67	4.47	4.47	4.47
Vit 'C' mg/100g	13.14	24.35	30.12	25.91	29.00
Crude fat	0.36	0.48	0.38	0.43	0.35
Crude fibre	0.63	0.50	0.58	0.69	0.57
Crude protein	0.84	0.94	0.73	0.79	0.65
Total mineral	0.87	1.52	0.96	0.88	1.03
Total sugar	2.98	4.26	3.94	4.12	3.18

The results also revealed superiority of hydroponics system over soil culture for yield and quality traits in tomato and lahi (Fig 1). Although results have revealed that days to flowering and first fruit set was delayed under hydroponics system compared to soil culture by 5 days but interestingly hydroponics system prolonged the harvesting period by 45 days. Hydroponics system also supported better plant height which ultimately resulted into 3.0 times higher number of fruits/plant (55.0) over soil system (17.0) along with superiority in fruit yield also by 3.0 times. As far as keeping quality of lahi leaves is concerned, hydroponically grown leaves comparatively longer time (4-10 days) to spoil compared to soil grown crop (Fig 1). The single nutrient solution developed by this institute was

Table 5. Exploring suitable plant density for hydroponically grown cucumber (cv. Green long)

Plant density (plant / m^2)	No. of fruit/m^2		Fruit yield (q/ha)	
	2001	**2002**	**2001**	**2002**
2	6	13	93.32	671.10
4	17	19	204.43	811.09
6	20	25	259.99	1017.72
8	15	24	151.103	788.85
10	15	23	144.43	757.72
CD (P=05)	4.5	3.4	61.77	163.33
CD (P=01)	6.5	4.9	89.76	237.33

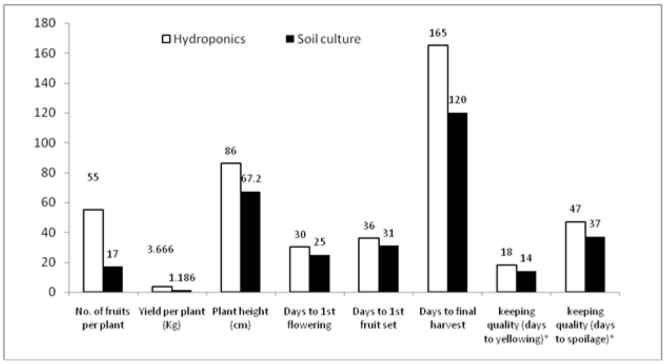

Figure 1. Comparative performance of tomato and lahi* (only parameter presented is keeping quality) grown in hydroponics system against the crop grown in soil at DIBER.

also tried to assess its suitability for various crops like tomato, cucumber, summer squash, bean, bottle gourd, and strawberry (Fig. 2). The results revealed the satisfactory performance of the single nutrient solution developed by the institute. Days to flowering and number fruits per plant were also recorded for these crops. Results presented in Fig 3 revealed the satisfactory performance of single nutrient system for growing various crops.

Experiment was also conducted to standardize plant density of tomato in hydroponics system. Plant density of 2 to 12 plants/m^2 was evaluated, and results revealed that density of 6 plants/m^2 is optimum for hydroponics system as it exhibited the highest number of fruits per unit area with fruit yield (Fig 4). Performance of various tomato hybrids and varieties under hydroponics system has been presented in Fig 5. Results revealed that hybrid DARL-303 was the earliest to set the fruit (39.0 days) with maximum number of fruits per plant (138.0). Tomato hybrid DARL-304 exhibited the maximum fruit yield (6.5 kg/plant). Tomato variety Arka Vikas took the maximum days to set the fruits. Whereas under high altitude conditions, hybrid Avinash -2 set the fruits earliest but fruit yield was the maximum (2.05 kg/plant) in C-21 (Fig 5).

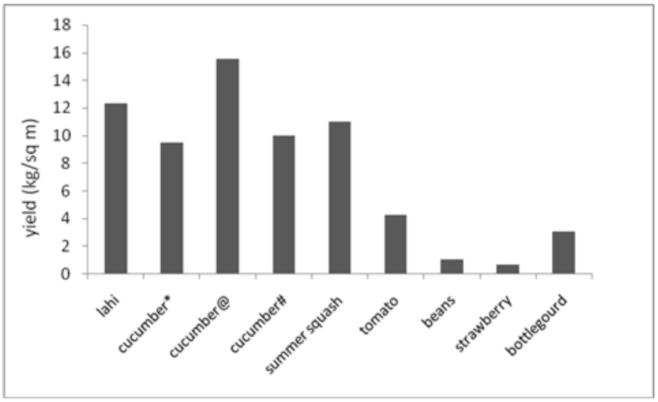

Figure 2. Performance of various crops grown in hydroponics at DIBER. Cucumber variety grown were Green Long (*), Greenlong (@) and Pusa Sanyog (#).

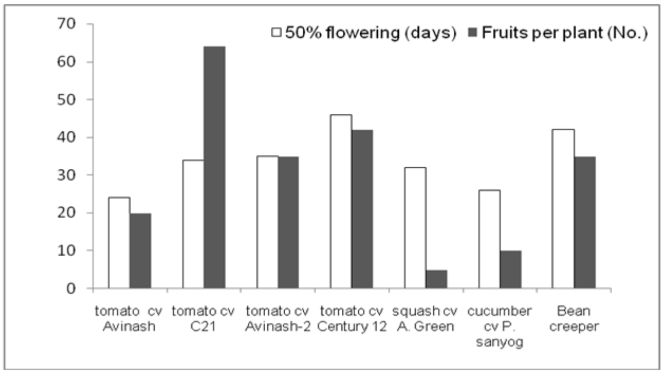

Figure 3. Effect on days to 50% flowering and number of fruits per plant in hydroponically grown tomato (Avinash, C-21, Avinash-2 & Century 12), summer squash (Australian Green), Cucumber (Pusa Sanyog) and French bean (creeper) at DIBER.

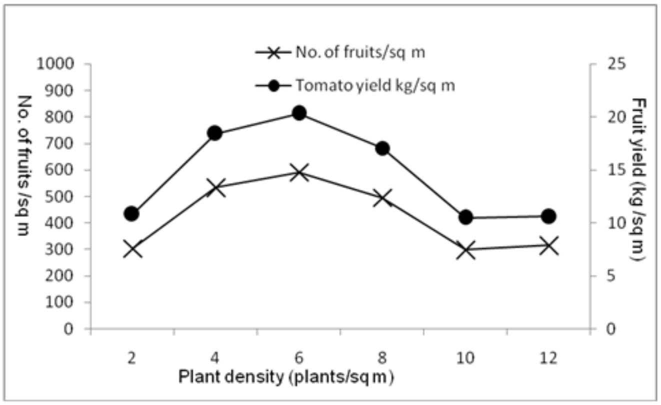

Figure 4. Effect of plant density (number of plants per sq m) on number of fruits and fruit yield in tomato in hydroponics at DIBER.

Hydroponics technology relies on the supply of nutrients through water solution, therefore quality and source of water is very important. Experiment was conducted to compare the performance of rain water against the river stream (Rayee river stream), main source of irrigation water for this area. The results revealed that rain water is better over river water for hydroponics system (Fig 6) which may be attributed to the presence of various organic and inorganic pollutants including detergents in stream water which led to fluctuating EC and pH of water and thus resulting into poor availability of nutrients[20,26,34]. Photosynthetic efficiency of five hybrids of cucumber was also evaluated under hydroponics system (Fig 7). Photosynthetic rate was the maximum in DARL-102 and the lowest in PC4C-15 whereas transpiration rate was minimum in PC4C-8 and maximum in DC-2. Hydroponics system have been found successful in Auli (9000' MSL), Joshimath also and various crops have been evaluated successfully there. Eleven tomato

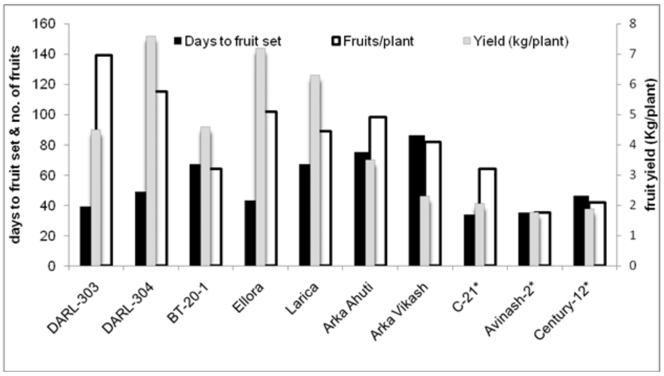

Figure 5. Performance of tomato varieties and hybrids grown in hydroponics system at DIBER. Variation in days to fruit set and number of fruits per plant (primary axis) and fruit yield (kg/plant) on secondary axis. Values presented are average of three plants with significance at P<0.05

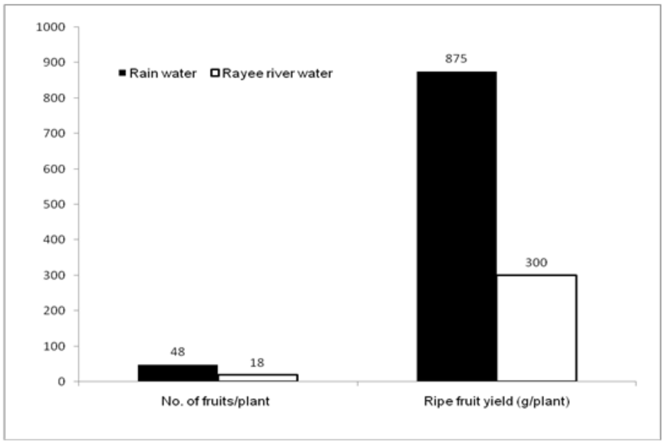

Figure 6. Effect of water source (Rain water and water from Rayee river-water is lifted for irrigation purpose from the river) on performance of hydroponically grown tomato at DIBER.

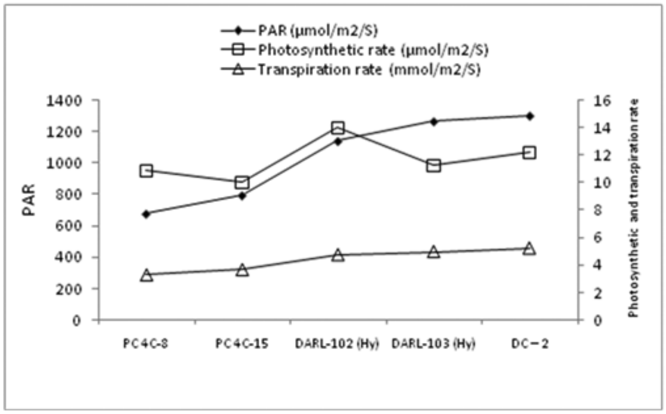

Figure 7. Variation in Photosynthetic rate, transpiration rate and PAR of cucumber cultivars grown in Hydroponics at DIBER.

Figure 8. Various crops grown in Hydroponics system at DIBER. (A) Tomato hybrid DARL-305, (B) Lahi cv ARU black, (C) Cucumber hybrid DARL- 102, (D) Bottle gourd var DARL-28, (E) Summer squash cv Australian green, (F) Strawberry.

varieties and hybrids including varieties and hybrids released by DIBER have been evaluated in Hydroponics system to screen suitable variety or hybrid for hydroponic system. Fruit yield of 2.25 kg/plant to 3.79 kg/plant have been recorded. Tomato hybrid Vaishali exhibited the maximum fruit yield.

6 CHALLENGES AND OPPORTUNITIES

The greatest challenge our agriculture production system facing worldwide are maintaining the productivity levels with changing climate and depleting soil fertility. To mitigate these adverse effects of climate and soil fertility offers the opportunity to develop a sustainable system. One more challenge which Indian sub-continent is facing the availability of safe farm produce. Although organic farming has offered the safe alternative but most of the farm produce available is contaminated with more residual toxicity which is mainly due to the indiscriminate use of pesticides. The main challenge lies in supplying safe products that are needed for a quality of life while maintaining a healthy planet. Here lies an opportunity which such technologies can offer.

The challenges ahead are to produce safe and nutritious food in a way that is sustainable and does not harm the environment. A major challenge ahead for agriculture community is to grow crops with a minimal use of safe pesticides. Hydroponic technology, aquaculture and aquaponics are intensive plant production systems that are all well placed to meet the challenges ahead. However, it will be necessary to develop production systems that are more efficient in terms of water, energy and labour use.

The quantity and quality of water available for farming and urban populations throughout the country in particular is an important issue. Management of our water resources is important to the success of agricultural and horticultural enterprises. Water conservation and recycling can play an important part in determining the most efficient ways of using this resource. Hydroponic production systems are water-efficient and offer opportunity for water recycling and conservation in terms of less water use.

Therefore, hydroponic technology offers the opportunity to develop water efficient, sustainable growing systems to supply high quality, safe products that are needed for a quality of life while maintaining a healthy planet. Some of the basic challenges faced by this technology in popularization are requirement of start-up capital, technical knowledge of the subject specially nutrient interaction and daily monitoring , no or very less prior work on standardization of crops and variety suitable for hydroponics system for Indian conditions and their availability, availability of customized hydroponics systems - although this problem has reduced with online shopping options, limitation of growing only few crops, power supply – to maintain circulation of water/ nutrient solution-specially for areas with limited or no electricity supply or remote army locations, water quality is also critical factor- requires technical intervention if water is hard or polluted, involvement of higher risk of crop loss during disease incidence. To popularize this technology, the hydroponics industry needs to develop new sustainable pest and disease control practices, without pesticides and fungicides, develop more efficient production systems with customized requirements, invest in renewable energy resources like the development of cheaper plastic solar cells and its integration with hydroponics system to avoid dependency on electricity, develop market for 'clean and green' products with greater public awareness.

Opportunities for hydroponics technologies lie in the fact that growing food within cities at the doorstep of the consumers eliminates the need for transport, therefore reducing greenhouse gas emissions and food-waste. More over multitier farming of selected vegetables specially leafy vegetables allow production of more biomass per unit area through utilization of vertical environment of greenhouse facility throughout the year. With rampant urbanization and proven records of higher profits over conventional agriculture[35,36], this technology can also offer opportunity of employment generation in cities.

7 CONCLUSION

Hydroponics is a versatile technology, appropriate for both village or backyard production systems to high-tech space stations. Hydroponic technology can be an efficient mean for food production from extreme environmental ecosystems such as deserts, mountainous regions, or arctic communities. The chemical technologies like detergents and pesticides are deteriorating the water resources which is affecting the nutrient availability to plants and ultimately the production and an innocent chemical war is on. This needs proper planning for use of chemical based technologies that goes in the hand of common people and there is great need to go for safe technologies to maintain earth ecosystem and ensure that the available water does not become carcinogenic. It was also identified that irrespective of the water resources available nearby troops can cultivate the vegetables in inaccessible areas where water resources are not available or available resources are polluted by the detergent waste and sewage waste but the rain fall is available. In highly populated areas, hydroponics can provide locally grown high-value low volume crops. Hydroponics also will be important to the future of the 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 the Moon[37]. We are hopeful 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, Pithoragarh, Auli and even Antarctica will prove a role model to disseminate the benefits of hydroponics technology on mass scale in immediate future.

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