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# Optimizing Plant Growth and Crop Productivity through Hydroponics Technique for Sustainable Agriculture: A Review

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***Authors' contributions***

*This work was carried out in collaboration among all authors. Authors VS, SS and ML carried out the total topic studies, Authors SC and PR carried out the Introduction. Authors SN, GH and AT participated in the material and methods. Authors DD and SG studies and write the result and discussion. Authors SK, SSS, NK and MNSS conceived of the study and participated in its design and coordination. All authors read and approved the final manuscript.*

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## ABSTRACT

A promising, economically viable and profitable form of cultivation is hydroponics. The findings of the present study indicate that the productivity as well as quality of different leafy vegetables and high valuable fruit crops (litchi etc) was significantly improved by adopting hydroponic techniques. The pH and EC of nutrient solution play an important role in this technique which directly affects the

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plant response. Article discusses how hydroponics can produce sustainable food while addressing issues such as climate change, lack of arable land and poor soil quality. The article highlights several hydroponic growing media and the importance of pH and dissolved solids (TDS) in a hydroponic fertilizer solution. The potential of hydroponics for Indian farmers and the need for education to facilitate their adoption is discussed at the end of the article. Presently the different substances are used to support plants, aerate them, promote maximum root growth and implement various hydroponic cultivation techniques. This paper also describes the different hydroponic techniques like nutrient film technique (NFT), deep water culture (DWC) and Ebb and flow etc and their mechanisms, applicability and advantages. Along with different hydroponics techniques the effectiveness of hydroponic growing media has also been investigated, with the best results obtained from nutrient film technique along with coconut peat as a growing media.

*Keywords: Hydroponics; artificial media; nutrient solution; nutrient film technology.*

## 1. INTRODUCTION

The term "hydroponics" derives from the Greek word "hydro" for water and "ponos" for labour. Growing plants by supplying nutrient solution near to the plant rootzone with or without the use of artificial media is known as hydroponics, sometimes known as nutriculture, soilless culture, or aquaculture. In this method, the nutritious solution is recycled in a closed loop and supply continuously near to effective plant rootzone which result more absorption of nutrient by plant and high crop yield. Computerization and connection, as well as the use of the internet of things in hydroponics, expedite and enhance the use of ion-selective electrodes in the monitoring of hydroponic nutrient solutions. The use of growing media prevents chances of soil borne diseases in hydroponics cultivation. Mostly in hydroponics, artificial media such as sand, gravel, vermiculite, rockwool, perlite, peatmoss, or sawdust are used to absorb nutrient from solution (when it will be in circulation) and supply it to the plant root when the circulation of nutrient solution stop in hydroponic structures. Field soils are typically unsuitable for growing plants in containers because they lack the necessary aeration, drainage, and water-holding capacity, and because they need to be pasteurised or fumigated to keep weeds and diseases away. In hydroponics cultivation, different growing media such as sand, perlite, gravel, cocopeat, or sawdust serve as mechanical alternatives for soil [1]. For healthy plant growth, the soil supplies nutrients, water, and other elements. The existence of soil is necessary for all significant beneficial processes, including the fixation of nitrogen, provision of moisture, and the growth of entire plants. While in urban areas, land is one of the limiting issues for any form of agriculture production, plants need a big space and an open field to develop. Plant scientists created hydroponics to overcome this constraint [2]. Different hydroponic systems are basically developed with the same goal, which is to provide water and nutrients to plants. Hydroponic systems have many variations, which makes it difficult for beginner farmers and ordinary people to determine the right hydroponic system following the commodity planted. The availability of water and nutrients that are maintained continuously helps reduce the negative impact of water and nutrient stress on plant growth. Plants that experience water shortages during the growing period can inhibit growth and reduce crop yields.

An excellent hydroponic system can supply water and nutrients, must also be able to supply oxygen to the rooting zone. This approach is the most effective for addressing climate change issues and aids in the production of crops and vegetables that are completely healthy to eat. Leafy vegetables, tomatoes, cucumbers, peppers, strawberries, and other specialty and commercial crops can be planted [3]. Hydroponic systems are not widely used by Indian farmers since they require certain abilities to operate. The key issue is the poor literacy rate among farmers and the unawareness regarding response of different crops under hydroponics techniques. Now days the population is continuously increasing at very fast rate and consequently agriculture land is now converting in urban land. The major challenge is to fulfill the food demand for growing population with limited resources like water, nutrient and land area. Therefore, it is an urgent need to optimize the plant growth and productivity of crop by using some modern cultivation technique i.e hydroponics. It will play


**Fig. 1. Nutrient film technique**

an important role for sustainable agriculture. The present study will spread knowledge regarding hydroponics techniques among the scientific persons and farmers.

## 2. MATERIALS AND METHODS

Due to hydroponic's regulated climatic conditions and lack of the need for pesticides and other unnecessary chemicals to be put on the plants, hence it is the most pure technique of growing crops [4]. In order to achieve effective growth in its pure state, nutrients that complement soil properties are required. The production technique of hydroponics uses fertilizer solutions instead of soil to grow plants. Most hydroponically grown plants are grown in controlled conditions, typically in greenhouses [5] (Table 1).

Contrary to conventional farming growing plants on artificial or natural substrates so that nutrients from a prepared nutrition solution can be drawn by the roots with ease. The implementation of various hydroponic farming techniques varies depending on the type of plant, regional climate, and financial constraints, among other things. The majority of systems include an aerator and a tank for the nutritional solution [6]. A plant uses the roots that are suspended in a nutrient stock in a hydroponic cropping system to absorb nutrients. The nutrient solution replaces soil fertility by supplying chemical elements that are good for plant growth and general plant health [7].

**Growing Media:** Growing media are substances other than soils found naturally that are used to grow plants. Peat, compost, tree bark, coconut (*Cocos nucifera* L.) coir, and chicken feathers are examples of organic materials. Inorganic materials include clay, perlite, vermiculite, mineral wool, [8,9] and mixtures like peat and perlite, coir and clay, and peat and compost [10]. Vegetables have also been grown in greenhouses using mineral soil or sand.

**Nutrient Medium:** In a general hydroponic cropping system, the growing plant takes all the required nutrients through its roots which are suspended in the standing or flowing nutrient solution. The nutrient solution provides the growing plant the required elements that are essential and beneficial for the overall plant health. The plant's physiological functions (such as photosynthesis, respiration, photorespiration, transpiration, growth, development, photoperiodism, and vernalisation) and biogeochemical cycles (such as carbon, oxygen, nitrogen, sulphur, and phosphorus cycles) are strongly interrelated with macronutrients and micronutrients concentration. Each nutrient has a distinct function in the general growth of the plant, which can only be accomplished effectively if the nutrient concentration is optimal [5].

A good management of electrical conductivity (EC) and pH is required to optimize the uptake of total nutrients and offer high productivity and better quality of produce in case of leafy green vegetable production in a hydroponic system.

**Table 1. Material required for hydroponic cultivation**

| Growing Media | | Nutrient Solution | Sources of Nutrient |
|---|---|---|---|
| 1. | Coco-coir | Nitrogen | N:P:K |
| 2. | Rockwool | Phosphorus | N:P:K |
| 3. | Vermiculite | Potassium | Potassium hydroxide (KOH) |
| 4. | Perlite | Calcium | Calcium nitrate Ca(No3)2 |
| 5. | Sand | Magnesium | Magnesium Sulphate MgSo4 |
| 6. | Rice hulls | B, Cu, Zn, Mg | Micronutrient |

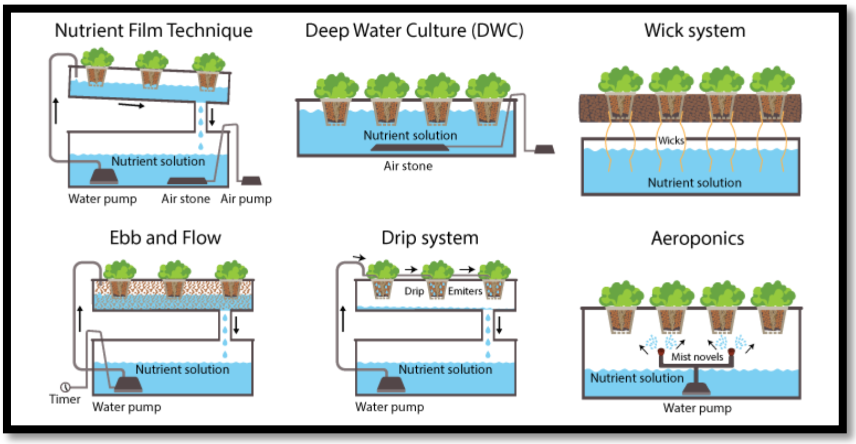


**Fig. 2. View of different types of hydroponic systems/techniques**

The pH of nutrient solution is generally managed between 5.5 and 6.5, but when the pH is lowered to a more acidic range (i.e., <5), many problematic water borne diseases are extensively attenuated. The response of plants to a changed pH is species specific and has a wide effect on the number of hydronium ions and a disturbance in cation availability. When the pH is reduced, there is an increment in hydronium ions and the cation availability is reduced [11].

Inputs are required for growing plant in Hydroponics (Table 1).

**Hydroponics Structure:** There are several types of hydroponic systems, such as Nutrient Film Technique (NFT), Deep Water Culture, Wick System, Ebb and Flow/Flood and Drain System, Drip System, Aeroponics, and others.

| Media components | Ratio |
|---|---|
| Peat + Perlite | 2 : 1 |
| Peat + Perlite + Vermiculite | 2:1:1 / 3:1:1 |
| Peat + sand | 2 : 1 |
| Peat + Bark + Sand | 2:1:1 |
| Coco coir + Perlite | 2 : 1 |

**Fig. 3. Common growing media mixture**

## 3. RESULTS AND DISCUSSION

**Responses of Different Crops under Hydroponics Cultivation:** The following section deals with response of different crops against different types of growing media materials under different types of hydroponics structures.

Chhetri et al. [1] they conducted an experiment and came to the conclusion that the different types of growing media material have a significant impact on plant shoot production of lettuce and pakchoy crops. The plant shoot output at the time of harvest was 9.2 g and root yield was 2.62 g. The maximum yield of the shoot and root was obtained when they using cocopeat as a growth medium, the lowest yield was obtained while using perlite. Compared to lettuce, pakchoy had a lower output. Plant shoot height was highly affected by the growing media at 12 DAP, 18 DAP, 24 DAP and 30 DAP. The plant shoot height of lettuce was highest during harvest when sponge was used as growing media. The study also demonstrated that a change in growth material has a significant impact on root length. The length of the root was 4.3 cm at 6 DAP to 10.44 cm during harvest whereas at 12 DAP there were no roots seen in the pot. Moreover, it was also seen that the pots having cocopeat showed comparatively longer roots than perlite in Pakchoy.

Ikeda et al. [12] they observed that in hydroponics system the plants share equal amount of nutrients which promote crop productivity as well as quality but on other hand, the diseases which are water born can spread very fast which gives more risk for crop failure.

G. Fascella et al. [13] they have conducted a research trial for rose plants, and discovered that the substrate (different types/combination of nutrient solution or growing media) affected plant quality and production. Compared to plants cultivated in inert media, which generated around 13.6 stems per plant, while plants put in the organic combination produced about 17.7 stems per plant. Even though the stems' lengths varied, they were around 58 cm and 65 cm, respectively, in inert media and in organic media respectively. Average water consumption for plants in perlite was 0.78 L/ plant/ day and mixture was 0.62 L/ plant/day with a variation across substrates like for perlite and coir it was 0.18 L/ plant/ day and 0.11 L/plant/ day in summer and winter. The concentration of minerals which are available in the various growing medias are different, in fact the organic mixture showed higher concentration in nutrients mainly cations (Ca, Mg, and K) and also some anions like (P, $NO_3^-$).

Jacob Zazkowski et al. [5] conducted a trial regarding growing lettuce under different types of hydroponics system. They have proven that a deep water culture type's hydroponic system (with a size 102 × 50.8 × 66 cm) can give larger harvest length than other dimension of same type of hydroponic structure.

Samuel E. Wortman et al. [14] the several experiments have been carried out to standardize the combination of growing media components (such as coco peat, perlite and others) for growing strawberry crop under hydroponic cultivation. They have noticed the increase in crop yield of strawberry when the plants were planted in perlite mixed with coco coir and vermiculite and treated with synthetic fertilizers.

Daniel P. Gillespie et al. [11] they suggested that when the pH of the nutritional solution was lowered, the spinach plant's growth was significantly inhibited. Elements like N, P, K, Mg, Cu, S, Mn, Zn, and Fe were least abundant in the plant's leaves when grown at pH 4.0, and when grown at pH 4, the spinach showed impaired growth, most likely as a result of harm caused by hydrogen ions. Shoot and root growth were normal in spinach grown at pH 4.5, 5.0, and 5.5, proving that pH's indirect impacts on growth were not the reason for pH 4.5 and 5.0's lower growth. When compared to control plants (EC 1.4 dS/ m1) substantially boosted plant growth under low pH 4.5 but it did not entirely recover the shoot fresh and dry weight. In order to grow spinach without experiencing substantial reductions in the growth of shoot in low pH, much more research on specific nutrient concentration must be carried out in order to understand the kinetics of nutrient intake under low pH. This could be an important low-cost method for disease control.

Kellie J. Walters et al. [15] they observed that the interactions between the EC and DLI of the nutritional solution had no effect on basil growth, morphology, or tissue nutrient concentrations. Basil growth was unaffected by EC, and tissue concentrations were frequently at or above stated sufficiency levels. Nevertheless, with rising DLI, all basil species saw an acceleration in growth. Compared to basil produced under low DLI conditions, high DLI basil has more nutrients. Nonetheless, all nutrient solutions provided acceptable tissue nutrient concentrations for all basil species under both low and high DLIs since the ECs for each solution were maintained throughout the experiment, as is typically done in the commercial scenario. Thus, it is not necessary to alter the EC of the nutrient solution for basil production in hydroponic systems using solely DLI. On-site testing, which growers are advised to conduct, should be used to identify the ideal nutrient solution concentrations for the cultivars and species that flourish in their greenhouse environment and under their production processes.

Lichun Wang et al. [16] by their study they concluded that the PH of the nutrient solution controlled the growth and nutritional value of hydroponically grown vegetables. When $H_2SO_4$ or $H_3PO_4$ were used to regulate the solution pH to the optimal range of 5.5 and 6.6, water spinach's hydroponic growth was significantly hampered. The inorganic acid $HNO_3$'s pH adjustment made it simpler for water spinach to grow, but it also led to a significant accumulation of $NO_3$ in the plant shoots. Combining 1M $HNO_3$, $H_3PO_4$, and $H_2SO_4$ at a ratio of 3:1:1 (v/v/v) produced the optimal pH adjustment for improving hydroponic plant development and nutrient quality. The combined acids provided a nutrient environment that was fairly balanced and allowed the pH of the hydroponic nutrient solution to be maintained in the desired range.

The pH in hydroponic cultivation should be managed, more study is required.

Oludare O. Agboola et al. [17] by the findings of their study, they demonstrated, despite the fact that all development metrics (plant height, number of leaves, leaf length and width, number of fruits) were delayed while sawdust may be utilized as an alternate growth medium when planting tomatoes. This might be as a result of a lack of soil microorganisms, which would have allowed the medium to break down and become more nutrient-rich than soil-based media. The aforementioned mechanism caused tomatoes planted in soil medium to grow faster and start producing fruit earlier than tomatoes planted in sawdust. The study's growth indicators frequently increase as the number of weeks after planting increases.

Dinkar J. Gaikwad et al. [18] in the experiment done by them, there were number of features, including as survival rate, leaf length, width, and area, have been impacted by different hydroponic systems and non-soil growing medium (cm2). The proportion of seedlings that survived was highest in saw dust (96.67%) and cocopeat (94.00%), whereas sterilized absorbent cotton (84.67) had the lowest percentage. Effectiveness was substantially superior between the raised trays method (90.22%) and the A-frame Hydroponics system (93.33%). The hydroponics system's link with the growing medium was shown to be significant. A similar pattern may be seen in values for leaf length. The longest leaves (30.46) belonged to sawdust, whereas the smallest leaves belonged to sterilized cotton absorbents (22.86). Several hydroponics systems have shown a large variation in the values of leaf length. Hydroponics systems' interactions with the growing material were found to be insignificant.

[19] in the experiment conducted by them when several lettuce varieties were grown on various growth media, variety showed a highly significant association between root wet weight, total wet weight, total oven dry weight, and root volume. The use of growth material had a considerable effect on the leaf area, crown oven dry weight, and root oven dry weight of lettuce cultivars 30 days after planting. Use of the growing medium and choice of lettuce type did not significantly alter any of the parameters of the plant, including its length, number of leaves at ages 9, 16, and 23 days, shoot wet weight, leaf area, economic fresh weight, or leaf root ratio. Many characteristics were noted, including the root's wet weight (20.93 g), the overall wet weight (211.83 g), the total weight of the oven (9.93 g), and the root volume, usage of husk charcoal growth material in combination with the cultivars of frizzy lettuce (M2V1) (55.00 Ccm3) might have a substantial influence.

Onggo, [20] they did the experiment and came to know that the growth medium has an impact on the nutritional supply that lettuce needs. The amount of nutrients consumed will depend on how well the growth media can bind nutrient solutions. Growth medium provides nourishment for plant growth and development as well as a place for plants to grow. A study was done to investigate the effects of husk charcoal hydroponic substrate waste to husk-charcoal substrate waste, as well as the effects of their interaction with compost applied at three different rates for substrate amendment. The findings showed that seedlings grown on a substrate made of waste husk and charcoal had greater seedling and crown weights [21].

Nurul Aini [21] the EC of the nutrients needed to grow romaine lettuce must range from 0.9 to 1.8 ds m-1 and the consortia for the AMF and PGPR+AMF. By using hydroponic substrate growth systems, the minimum fresh weight is reached after an extra 14 days even if the fertilizer content is lowered by 50%. (EC 1.8 to 0.9 ds m-1). Nutrient concentration level combined with inoculation of AMF and consortium PGPR+AMF significantly improves romaine lettuce productivity via an indirect mechanism involving changes in leaf anatomical traits by increasing leaf thickness and leaf area, as well as increasing root colonization and macronutrient uptake. Reduce the bacterial population in the rhizophore, on the other hand.

Tomato growth in the NFT system was enhanced with appropriate nutrient solution recycling, as well as improved productivity and mineral composition, but when the nutrient solution recycling time was prolonged, yield decreased.

### 3.1 Challenges

- Difficulty to maintain optimum values of EC, pH and TDS of nutrient solution with respect to operating time for significant plant growth.
- Lack of information among user for IoT framework-enabled automated system
- Water flow and level monitoring
- Water nutrient measurement

- Temperature and humidity monitoring
- Plant growth and water recycling.

### 3.2 Future Prospective

In fastest expanding area of agriculture, the hydroponics can take over food production of world in the near future. People will move to new places when the population increases and the amount of arable land decreases because of bad management of land. To provide more pathways for the production of crops, people will turn to creating new inventive techniques like Hydroponics and Aeroponics in metro cities and remote places. Due to the scarcity of land caused by population expansion in some countries, such nations have turned to hydroponic rice growing to feed their people while preserving significant land mass. Without using soil, rice is harvested in underground vaults. Since the environment is fully managed, four harvest cycles rather than the typical one may be carried out annually. Construction of hydroponics systems involves initial financial outlays that are still prohibitive, but like any technology, expenses will progressively reduce, making this choice far more feasible. Hydroponics has the ability to feed millions of people in areas of Africa and Asia where both water and crops are scarce. As a result of NASA's lofty aims for hydroponics research, which will benefit both long-term colonisation of Mars or the Moon and continued space exploration, hydroponics is seen by NASA as the "farming of the future." Using hydroponics in outer space has two benefits: Along with a biological component known as a bioregenerative life support system, it has the ability to produce a broader variety of food. Simply said, this implies that when plants expand, they will absorb musty air and carbon dioxide while also supplying fresh oxygen as a natural part of the growth process. For both space stations and other planets to be habitable for a long time, this is essential.

## 4. CONCLUSION

Hydroponics is a soil less method of growing crops using a nutrient solution that has several advantages, including efficient resource management, higher yields, and the ability to grow crops in urban areas or where soil is unsuitable for traditional agriculture. Hydroponic systems employ various types of growing media. The pH and nutrient concentration of the nutrient solution are critical factors in successful cultivation. Although hydroponics has limitations, including high setup and maintenance costs and potential waterborne disease transmission, it has the potential to play an essential role in future sustainable agriculture, particularly in urban areas. To ensure successful cultivation, it is critical to carefully consider the advantages and limitations of each specific system and manage it with appropriate care. On the basis of findings it can say that, the hydroponic cultivation can successfully used to enhance crop productivity as well as to improve the quality of harvested product. In order to fulfill the food demand of growing population, hydroponic cultivation can be a biggest tool in future for making sustainable agriculture. To promote this technique at field level the training and awareness programmes could be conducted for farmers. The present study will spread knowledge regarding hydroponics techniques among the scientific persons and farmers.

## RESEARCH CONTENT

It is a review paper so there are no such data by our side we have collected data from other research paper.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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