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A review: Advantages of hydroponic techniques for production of different vegetables

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Abstract

Nowadays demand of soilless techniques is increasing all over the world because of its efficient resource regulation and better food quality production. As we know that soil agriculture is now facing a lot of problems such as abnormality, tonicity, earthquake, climate emergency, uncritical use of synthetic fertilizers and pesticides. These synthetics chemicals are decreasing soil fertility. In this review, numerous hydroponic techniques used in the soilless system i.e., wicks system, ebb and flow system, drip system, deep water culture, and Nutrient Film Technique system are explained. Out of many benefits of these different techniques most important is requirement of less growing time for crops production than traditional growing methods. In hydroponic technique diseases and pest incidence as well as weeding, spraying and watering can be eliminated. Water requirement is less and crops grow faster than traditional methods. Soilless system required 90% less water as compared to traditional farming.

Keywords: Hydroponics, nutrient film technique, lettuce, water recycle media culture

Introduction

For plants, the soil system is a very important growing medium. Because it provides nutrients, support, oxygen, H_2O, and many more for plant's successful development and proper growth [1]. At times soil give rise to significant limitations for plant growth too. Factors responsible for switching to hydroponics involve unsuitable soil reaction, presence of diseases and nematodes, poor drainage, unfavourable soil compactions, desertification due to erosion, etc. Inside a wide-open soil area crop growing is very difficult because it demands huge space, a large volume of water, and a lot of labour. It is found that a shortage of fertile cultivatable land because of their unfavourable topographical or geographical condition in some areas for eg. soil is not available for crop growing at all in metropolitan area can be a major drawback. One more serious problem is the trouble of hiring labour for conventional open filed but under hydroponics system it can be established with few workers successfully. Hydroponics is a technique of soil-less culture. The hydroponics term was obtained from two Greek word hydro and ponos “hydro” means water and “ponos” means work. This means water work [2]. Hydroponics is a technique in which plants grow without soil using some mineral nutrient solutions in water. The land plants are grown with their roots suspended in the mineral nutrient solution like gravel, mineral wood, or perlite. In soil-less conditions, in a hydroponics system, the roots are immersed in the nutrient solution [3]. For vegetable production nowadays about 3.5% of the international area cultured under tunnels and greenhouse uses soilless agriculture techniques based upon hydroponics solutions [4]. The hydroponics technique face many environment challenges and it also helps out in the management of production system for better use of natural resources and lowering the malnutrition [5]. Undoubtedly this process on the field scale signified the appearance of many benefits such as production and the use of mineral resources including water in a well organised way [6]. Honestly, in biofortification programs with oligo-elements like calcium, silicon, selenium, and iodine hydroponic solutions can be efficiently used to improve vegetable quality as reported to the market and consumer needs [7].

Scope of Hydroponics

Hydroponics system has been used strongly in some countries like Israel which has a dry and drained climate. Hydroponics is the very fastest-growing technique in the field of agriculture. It would be very useful for food production in the future. Since population is increasing day by day and fertile land is declining due to the poor management, people are shifting their focus on new technologies like Hydroponics and Aeroponics to feed the nation. Changes in climatic factors and natural misadventure like drought and floods etc are some of the reasons to switch to new technology, which undertaking food productions safely [8].

Advantages of Hydroponics

(1) Methods of hydroponic produce healthy crops with high yield and there is no possibility of any soil-borne insects and pest diseases. (2) Soilless culture (hydroponic) provides organic food and there is no use of pesticides and harmful toxins too. (3) Hydroponic needs less space in consumption to soil garden as a plant with little root can be grown very close to each other. (4) Crops grow two times faster in hydroponics which doubled the yield and from same land spaces higher production is obtained. (5) In this technique there is no wastage of water and water is reused and recycled. It only required 20th part of water as compared to conventional agriculture. (6) The less labour is required as

compared to traditional farming and many other traditional farming methods are neglected like spraying, weeding, watering and tilling [30]. (7) No effect of changing climatic conditions as crops can be grown throughout the year [7]. (8) Hydroponics is an abiotic stressless free farming technique and eco-friendly practice [8].

Techniques of hydroponics

The nutrient solution and supporting medium used here are recovered and reused. The widely used systems are wick system, dripping system, ebb- flow system and NFT system (nutrient film technique) [18]. Hydroponics commonly called as liquid hydroponics in this technique crops are cultivated in nutrients solution medium, their roots hanging in a nutrient solution. These techniques have two types of methods based on recycling and non-recycling of water.

a. closed system
b. open methods

a. closed system (circulating methods) continuous-flow solution culture

Closed systems are also called the circulating system. For nutrients, solution regulation is preferable in circulating systems that detect the result of the controlled process [20]. In this system, the main tank reservoir pumps nutrients solution through pipes to the plant's roots the plants absorb nutrients solution and the rest of the water is pumped back to the main reservoir.

b. open system (non-circulating) static solution culture

Open control systems have a quite simple structure than the closed system in the case of a large-scale system. In this system there is no recycles and reuse of water. But because of the shortage of response, such systems may be unsuitable for plants that have higher fluctuation in uptake concentration.

Wick system

In the hydroponics technique this system is a simplest method. In this system, there is no use of electricity, aerators and pump [9]. This system is made up of four components that are wick, growing medium, the reservoir for nutrients solution, and growing container. In the Wick system plants are put down in an absorptive medium like vermiculite, perlite, and coco peat, along nylon thread flowing from plant roots into a reservoir of nutrient solution [13]. Nutrient solution and liquid provided to the plants along capillary wicks activity. This type of system jobs very skilfully for minute plants like spices as well as herbs.

Ebb-Flow system

This technique works on the principle of drain and flood and it is the first hydroponic commercial technique. In this technique nutrient solution and water from reservoir flooded with the help of the water pump to grow the bed to a certain level and visits there for a period time to provides nutrients and water to the plants [13]. It is viable to grow different types of crops. But common problems in this technique of root rot, algae, and mould. So, several converted systems with a clarification unit are required [9].

Deepwater culture system

The roots of the plants are directly dangled in nutrient affluent water in deep culture along with the air be provided by a direct route to the roots with the help of air stone. The Hydroponics buckets are traditional example of a Deep water culture. The roots of plants are directly suspended in the nutrient solution in a net pot where they grow very fast in a larges mass. It is compulsory to detector the nutrients and oxygen concentration, pH, and salinity as moulds and algae will grow quickly in the reservoir. This system works effectively for wide plants like tomatoes and cucumbers that produce fruits [10].

NFT (Nutrient's film technique)

In this technique, nutrients and water propagate all over the system and enters the growth tray with the help of water pump without any control over time [10]. This is slightly sloped system in which nutrient solution flows through the roots and then get back into the main tank. Plants are kept in a channel or tube with roots hanging in a hydroponic solution. In the NFT system, leafy vegetables can be grown easily. This technique is economically most widely used for lettuce production [11]. Lettuce is a dominant vegetable grown under hydroponic conditions as the concentration of the entire nutrients can be supplied to the water. Lettuce has high demand and great urban value, making it an appropriate crop for production on large-scale. Lettuce provides minerals, vitamins, dietary fibre, and a large amount of edible biomass. It is one of the most widely grown vegetable in NFT due to its easy adaptability and high productivity, and the shortening of the cultivation cycle compared to soil cultivation. NFT as a technique provide a standardized and easily controlled environment that simplifies crop raising farming [12].

DFT (Deep flow technique)

The deep flow technique, is a hydroponic method that uses water as a medium and through ponds it provides nutrient solution to the plants. Drainage channels height is about 4-6 cm and filled with nutrient solutions that flow continuously through the roots of plants that are submerged in water. After use of nutrients and water by the plants rest of the nutrition solutions is collected back into the nutrient's basin, they are continuously pumped by a scattering pipe to the planting pond. For root flowing, solution culture systems can supply a consonant nutrients environment. If the nutrient solution flow stops for any reason rapid plant desiccation takes place because they are more responsive to the automatic control. So, continuing attention is must require in this system [18].

Root - dipping technique

In Root dipping technique, plants expanded in small containers and is filled with the small developing media. Place the container in supplementary device so that 2-3 cm of the lower part of the container is lowered in it. Some roots are placed into the arrangement while others linger palpably on the solution for air assimilation and supplementation, separately. This procedure is easy and can be created using effectively available materials. This low-technology developing technique require little upkeep. Significantly this method doesn't need costly things like water siphon, power, channels, and so forth. A resting medium must be applied to the root crops like beet, radish, etc. [14].

Floating technique

The floating technique is like a box technique but a shallow stand with a depth of 10cm can be used. Plant growing in small containers are fixed on Styrofoam board which is a lightweight board and allowed to be skimmed off the supplementary device filled in the holder, which is circulated by air [15].

Capillary action system

Planting pots with different size and shapes with gaps at the base are used in this technique. The pots are loaded with a dormant nutrient solution and seedlings are grown in inactive nutrients solution. These pots are set in a deep chamber filled with an array of supplements. The system of supplements reaches the talent medium due to its excellent activity. Air circulation is important in this method. This allows you to use old coconut dust mixed with rock or sand. This method is suitable for ornamental, flowering, and potted plants. Suitable vessels for the static system comprise of polyethylene beakers, glass jars, pots and containers lined with a black polyethylene film [15].

Media culture

Medium culture system uses a solid - medium as the roots and is named after the type of inert media such as gravel culture, sand culture, gravel, or rock wool culture [18]. Two main changes for each medium culture are: 1) sub-irrigation 2) top-irrigation. The classification is as follows:

Hanging - bag technique

Approximately 1m long molded white UV-treated thick polyethylene packaging containing sterilized coconut fiber are used. White UV- treated thick polyethylene packaging with a molding room length of approximately 1m, which contains sterilized coconut fiber. These packs are fixed at the bottom and connected to a small Polyvinyl Chloride pipe on the top which are hung vertically on the overhead help in the supplementary collection channel. Therefore, this is also called the certificate development method [16]. In this technique, planting material and seedling (seed) are build-ups in net container are crushed into the opening on the sides of the hanging bags. The replenisher device is siphoned to the top of each balance bag through a smaller-scale sprinkler joined to the top hanging bag. This miniaturized scale sprinkler is also distributed in the supplementary device in the suspended packaging. The supplements are dripped down to moisturize the coconut fiber and plants roots. The arrangements are gathered in the lower channel by the opening at the bottom of the hanging bag and move back to the replenishing device storage tank. The framework can be built in an open area or a secure structure. In the safety structure, the balance packs in the columns and between the rows must be kept apart so that satisfactory daylight falls on the sacks in the inward rows. This frame is reasonable for green vegetables, strawberries, and small flower plants. Darks-colored light-shielding tubes should be used to supplement transportation arrangements to prevent internal development.

Grow bag technique

1-1.5m long white, UV-safe, polythene packs loaded up with old disinfected coir-dust are used in this technique. These bags are approximately 18cm wide and 6cm in tallness. These bags start to finish constantly in the pillars over floor, with walking space in the middle. These packages may be placed in matching columns, depending on the development of the harvest. Make a small opening on the top of the sack, and pressurize the seedling or other planting materials in the net pot into coconut shell powder. 2 to 3 plants can be built on the upper layer. Two small cuts on both sides of the sack can be used for waste or drainage. The dark thin cylinder drives from the primary flexible line to the fertilization and polishing of each plant [17]. Before setting the sacks, the entire floor is secured with the help of UV- safe polythene. It likewise decreases occurrences of contagious sicknesses and relative stickiness in the middle of the plants.

Trench or trough technique

In trench technique, the crops are expanded in thin channels in the overground or ground troughs fabricate with blocks or solid squares. The waterproof material is used to fix the two channels and troughs to isolate the developing media from the ground. For the sake of simplicity of activity, the width of the channels or troughs can be chosen accordingly. For allowing two-column of plants high-cost troughs or channels are used. The profundity fluctuates relying upon the plants to develop and at least 30 cm might be essential. Old coconut shell fibber deposits, sand, or rocks can be used as a medium for this culture. The replenishment device and water are provided through the drip system frame, or manual application is also easy to work. A very piercing channel with a distance of 2.5 cm can be provided at the bottom of the slot or channel to deplete the excess replenishment device. Tall vines such as cucumbers and tomatoes need extra help to bear the heaviness of natural products [18].

Pot technique

The potting technique is like channel or trough cultivation, in which the medium used for cultivated is filled with soil or plastic pots. The number of holders and development media depends on the necessities of harvest development. Most of the volume is 1-10 liters. Flexible development of media supplement arrangements helps plants, etc. is like a trough or channel culture [18].

Nutrients Supply to the plants

In the soil-less system that limit the buffering capacity and rapid change capacity, it is important to monitor the system properly. Carefully manipulating nutrients solution, pH level, EC, temperature, and changing solution will leads to a favorable soil-less culture garden [31]. Two features of nutrition required are:

1. The provider of nutrients from the nutrients delivery system.
2. The plants nutrients reaction.

The critical level of nutrients has to determine for the most common crop plants.

Table 1: nutrients to the plant

Sources	Formula	Elements	Characteristics feature
Potassium nitrate	KNO_3	Nitrogen(N), potassium(K)	Very soluble salt
Ammonium nitrate	NH_4NO_3	Nitrogen(N)	Best source of nitrogen
Potassium phosphate monobasic	KH_2PO_4	Phosphorus(P), potassium(K)	Corrects phosphorus deficiency
Magnesium sulfate	$MgSO_4$	Sulphur(S), Magnesium (Mg)	Cheap, highly soluble, pure salt
Iron Chelate	Fe	Fe Cit	The best source of iron
Ammonia Sulphate	$(NH_4)2SO_4$	Nitrogen(N), Sulphur(S)	
Boric acid	H_3Bo_3	Boron(B)	The best source of boron
Calcium nitrate	$Ca (NO_3)_2$	Nitrogen(N), Calcium (Ca)	Very soluble salt
Potassium chloride	KCl	Potassium(K), Chloride (Cl)	Salt soluble

Source: (Trejo-Tellez and Gomez- Merino, 2012; Solanki *et al*., 2017) [19, 8].

The frequency and volume of the applied nutrient depend on substrate type and volume used, physio-chemical feature, development stage, crop species, container size, watering system, and prevalent environment conditions. The plants need water every day. The better time to apply the mineral solution is from 6:00 to 8:00 in the morning, although the water demand will vary greatly every day. In the plant roots solution must be applied and then try to escape wetting of the leaves to control diseases and damage. In the absences of particular condition plant will be exposed to water stress, which influences their overall yield [21]. It is suggested that the plants should be watered in a week which will help to remove extra salt remained. Without the addition of nutrients, the water will be used doubled as applied normally. To control the deposition of toxic ion and additional increase of EC in the root zone 20% to 50% of the solution must be discarded. During next watering the unwanted nutrients solutions would be drained. Last days of the week this solution can be drained out [22].

pH

The pH helps to measure the presence of necessary plant elements in nutrient solution. The pH measure of alkalinity or acidity on a scale of 1 to 14. The pH ranges vary according to plants types but the optimum range for soil-less culture is 5.8-6.5 in the nutrient solution. The plant growth will be difficult if the pH is higher than the recommended pH ranges. If the pH is lower or higher than the optimum pH ranges the toxicity symptoms will develop in particular crops due to nutrients deficiencies. To grow vegetable like lettuce, cucumber and tomatoes mineral solution was also used. Correct Electrical Conductivity and pH of nutrients solution are very important which should maintain the optimum plant performance. The electrical conductivity (EC) and pH values are different for different hydroponics *crops*. Lower the electrical conductivity will affect plants health and yields and higher electrical conductivity will inhibit the absorption of nutrients because of osmatic pressure [23]. For improving vegetable quality and yield, the appropriate electrical conductivity management in hydroponics system is an effective tool. For example, tomatoes yield under hydroponics technique increased as Electrical Conductivity increases from 0-3 Ds m-1 and decreased 3-5 Ds m-1 because of an increase in water stress [24].

Table 2: The pH values for different soilless crops

1.	Beans	6.0-6.5
2.	Broccoli	6.0-6.5
3.	Cucumber	5.8-6.0
4.	Lettuce	6.0-6.5
5.	Tomatoes	5.5-6.5

Source: (Zhang *et al*., 2016) [24].

Water conservation in hydroponics

Hydroponics saves 70 to 90 percent water as compare to soil-grown plants as water is reused and recirculated. There is another more important benefit of hydroponics that it may yield up to three times more crops than traditional gardening. Hydroponics contains 50% more nutritional values (Vitamin A, B, C, and D) than conventional crops. This method is seasonally independents and has no chance of soil-borne diseases. Hydroponics also uses 60% less fertilizer than traditional methods. In this many crops can be grown like herbs, fruits, flowers, and vegetables like tomato, lettuce etc. Waste nutrients solutions may use as an alternative resource of water for crops in the soilless system [25].

Different Crops list Grown under in Soilless system

In hydroponics culture the different crops such as flowers, fruits crops and medicinal plants may be grown. The name of different hydroponic crops is:

Cereals: Rice (*Oryza sativa*), Maize (*Zea mays*), Oats (*Avena sativa)* and wheat (*Triticum aestivum*)

Fruits: Strawberry (*Fragaria ananassa*)

Vegetables: Chilli (*Capsicum frutescens*), Tomato *(Lycopersicon esculentum)*, Brinjal (*Solanum melongena)*, Green bean (*Phaseolus vulgaris)*, Beet (*Beta vulgaris)*, Winged bean (*Psophocarpus tetragonolobus)*, Bell pepper (*Capsicum annum)*, Cabbage (*Brassica olerace*a) and Cucumbers, (*Cucumis melo).*

Leafy vegetables: Lettuce **(***Lactuca sativa)*, Kang Kong (*Ipomoea aquatica)*

C**ondiments:** Parsley (*Petroselinum crispum)*, Mint (Mentha spicata), Sweet basil (*Ocimum basilicum)* and Oregano (*Origanum vulgare*).

Flower and Ornamental Plants: Marigold (*Tagetes patula*), Roses (*Rosa berberifolia)*, Carnations (*Dianthus caryophyllus)* and Chrysanthemum (*Chrysanthemum indicum*).

Medicinal plants: Aloe (*Aloe vera)* and Coleus (*Solenostemon scutellarioides)*

Fodder crops: Sorghum *(Sorghum bicolor)*, Alphalfa (*Medicago sativa)*, Barley (*Hordeum vulgare)* and Bermuda grass (*Cynodon dactylon*) [22].

Lettuce production on hydroponics

Lettuce is good choice in hydroponic growing conditions because it thrives in the simplest setup and does not need a lot of extra attention. Lettuce can be successfully grown in the NFT technique. For yield and development of lettuce, a vertical hydroponics culture was examined through various mineral solution [26]. If the lettuce is grown in circulating hydroponics system at a distance of 40-50 plants per meter square notably there will be an increase in the crop yield [27]. In another experiment, it has been concluded that the hydroponic culture offers superior yield of lettuce crop to the tune of 3 to 4 times greater production as compared to the traditional farming [28, 31].

Hydroponics vs. conventional farming

Compared with traditional agriculture, hydroponics agriculture has many advantages. Major advantages of hydroponic is that we can grow crops on infertile and contaminated lands. Hydroponics crops have resistant to high salt water. Some other advantages are the absence of pests, weeds, animals and pathogen like fungi that are present in the growth culture. Hydroponics does not require high labour work like farming, growing, watering and fumigation [32]. Compared with traditional agriculture, hydroponics agriculture has many advantages**.** The system uses pumps or even computers to achieve automation, and labour costs will be greatly reduced. Generally, hydroponic plants use only one-tenth of water as compare to traditional agriculture, as in the traditional farming most of water passes by the root layer. The mineral solution needed for hydroponics agriculture comprises of 25% of essential element in solid fertilizers. Less space can be used to grow more plants in a hydroponics system as they do not have to compete for surrounding soil space for nutrient storage. Plants grow faster and bigger with higher yield per unit area in hydroponics as compare to normal farming. Vegetable production under soilless cultivation in India has increased in the last few years. Later on, during 1960s and 1970s, in Abu Dhabi, Arizona, Belgium, California, Demark, the Netherland, Iran, the Russian Federation, and other countries commercial hydroponics farm were developed. In 1980s, many automated and computerized hydroponic farms were established worldwide [29].

Conclusions

Different hydroponic techniques affect the growth of different vegetables yield and production. The soil system provided less amount of food to world population. The Hydroponic system is highly effective technique used in agricultural field as it requires less workers, area of land and provides high productivity of crop than traditional farming system. In this technique correct Electrical Conductivity and pH of nutrient solution is very important for maintaining optimum plant performance. In this system 90 % less water is used as compared to soil-grown plants and water is reused and recirculated**.**

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References

1. Ellis NK, Jensen MERLE, Larsen JOHN, Oebker NF. Nutriculture systems-growing plants without soil. Station bulletin-Dept. of Agricultural Economics, Purdue University, Agricultural Experiment Station, 1974.
2. Beibel JP. Hydroponics-The Science of Growing Crops Without Soil‖. Florida Department of Agric. Bull, 1960, 180.
3. Cramer GR. Sodium-calcium intractions under salinity stress. In salinity Environment plants moleculer, Lauchli A, U. Luttge: 205-227, Kluwer Academic Publishers, Dordrecht, Netherland, 2002.
4. Hickman G. International greenhouse vegetable production–Statistics. A Review of Currently Available Data on the International Production of Vegetables in Greenhouses; Cuesta roble greenhouse consultants: Mariposa, CA, USA, 2016.
5. Butler JD, Oebker NF. Hydroponics as a hobby: growing plants without soil. *Circular*, 1962, 844.
6. Rodriguez Ortega WM, Martinez V, Rivero RM, Camara Zapata JM, Mestre T, Garcia-Sanchez F. Use of a smart irrigation system to study the effects of irrigation management on the agronomic and physiological responses of tomato plants grown under different temperatures regimes. Agricultural Water Management,2017:183:158-168.
7. Schiavon M, Dall Acqua S, Mietto A, Pilon-Smits EA, Sambo P, Masi A, Malagoli M *et al*. Selenium fertilization alters the chemical composition and antioxidant constituents of tomato (Solanum lycopersicon L.). *Journal of Agricultural and Food Chemistry*,2013:61(44):10542-10554.
8. Solanki S, Gaurav N, Bhawani G. INTERNATIONAL JOURNAL OF ADVANCED RESEARCH. Int. J. Adv, Res,2017:5(11):177-182.
9. Sharma N, Acharya S, Kumar K, Singh N, Chaurasia OP. Hydroponics as an advanced technique for vegetable production: An overview. Jour. Of Soil and Water Cons,2018:17(4):364-371.
10. Domingues DS, Takahashi HW, Camara CA, Nixdorf SL. Automated system developed to control pH and concentration of nutrient solution evaluated in hydroponic lettuce production. Computers and electronics in agriculture,2012:84:53-61.
11. Anonymous. “Hydroponic”. Department of Agriculture, Ministry of agriculture, 2017, 1-45.
12. Burrage SW. Nutrient Film Technique in protected cultivation. Acta,2006:1992:323;23-38.
13. Dr George P, George N. Hydroponics (Soilless cultivation of plants) for biodiversity conservation. AInte. Jour. of Mode. Tren.in Engi. And Sci,2016:3(6):97-104.
14. Mariyappillai A, Arumugam G, Raghavendran VB. The Techniques of Hydroponic System. Acta scientific agriculture, 2020, 79-84.
15. Anonymous. “Hydroponic”. Department of Agriculture, Ministry of agriculture, 2013, 1-45.
16. Wijayabandara K. “How to plan a hydroponics garden? Board of study in plants sciences”. Sciscitator, 2014, 1-12.
17. Sengupta A, Banerjee H. Soil-less culture in modern agriculture. *World J. Sci. Technol*,2012:2(7):103-108.
18. Maharana L, Koul DN. The emergence of Hydroponics. *Yojana (June)*,2011: 55:39-40.
19. Trejo-Téllez LI, Gómez-Merino FC. Nutrient solutions for hydroponic systems. Hydroponics-a standard methodology for plant biological researches,2012:1-22.
20. Jenner G, Starkey N. Nutrient Film Technique: Practicities of cadium. Plant Soil,1980:49:333-342.
21. Kreij CD, Voogt W, Baas R. Nutrient solutions and water quality for soilless cultures. Brochure/Research

Station for Floriculture and Glasshouse Vegetables Netherland, 1999.

22. Singh S, Singh BS. Hydroponics A technique for cultivation of vegetables and medicinal plants. In Proceedings of 4th Global conference on ―Horticulture for Food, Nutrition and Livelihood Options‖ Bhubaneshwar, Odisha, India, 2012, 220.
23. Gruda N. Does soil-less culture systems influence product quality of vegetables. Journal of Applied Botany and Food Quality. 2009: 82(2): 141-147
24. Zhang P, Senge P, Dai Y. Effects of salinity stress on growth, yield, fruit quality and water use efficiency of tomato under hydroponics system. Reviews in Agricultural Science,2016:4 46-55.
25. Choi B, Lee SS, SIK OkY. Effect of Waste nutrients solution on growth of Chinese cabbages (Brassica campestris L.) in Korea. Korean Journal of Environmental Agriculture,2012:30(2):125-131.
26. Touliatos D, Dodd IC, McAinsh M.Vertical farming increase lettuce yield per unit area compared to convertional horizontal hygroponics. Food and Energy security,2016:5(3):184-191.
27. Maboko MM, Plooy CP, Bertling I. Comparative performance of tomato culivars cultivated in two hydroponic production systems. South African Journal of Plant and Soil,2011:28(2):97-102.
28. Agarwal A, Prakash O, Sahay D, Arya S, Dwivedi S K, Bala M. Performance of lettuce (Lectuca sativa) under different soil-less cultures. *Progressive Horticulture*, 2019:51(1):81-84.
29. Turner B. How Hydroponics Work. Retrieved November 18, 2008, from http://home.howstuffworks.com/hydroponics.htm,2008.
30. Jovicich E, Cantliffe DJ, Stoffella PJ. " Spanish" pepper trellis system and high plant density can increase fruit yield, fruit quality, and reduce labor in a hydroponic, passive-ventilated greenhouse. In *VI International Symposium on Protected Cultivation in Mild Winter Climate: Product and Process Innovation*, 2002:614:255-262.
31. Hussain A, Iqbal K, Aziem S, Mahato P, Negi AK. A Review on The Sciences of Growing Crops Without Soil (Soilless Culture) – A Novel Alternative for Growing Crops. Inter. Jour. OF Agri. And Crop Sci,2014:7(11):833-842.
32. Jones J. Practical guide for soilless Grower. Boca Raton, FL: St. Lucie Press, 1997.