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A review on present status and future prospective of hydroponics technique

N.C. Barman, M.M. Hasan, M.R. Islam and N.A. Banu*

Department of Biotechnology and Genetic Engineering, Islamic University, Kushtia-7003, Bangladesh.
* Corresponding author: nab_bt_iu@yahoo.com

Abstract

Soil based cultivation is now facing difficulties due to different man made reasons such as deforestation, industrialization and urbanization. Besides, sudden natural disasters, climate change and unlimited utilization of chemicals for agriculture purposes cause the depletion of land fertility and quality. That is why, scientists have developed a new alternative approach for cultivation system namely soil-less cultivation or hydroponics. Hydroponics is a soil-less culture technique in which plant can grow in a liquid or water solution. A large number of plants and crops or vegetables can grow by hydroponics culture. The quality of yield, taste and nutritive value of end products is generally higher than the natural soil based cultivation. This cultivation is cost efficient, disease free and eco-friendly as well as getting popularity all over the world, both the developed and the developing countries. It has a great prospect in Bangladesh along with high space research to fulfil the lack of arable land where proper cultivable land is not available. So, hydroponics would be a better technique to produce the different kinds of fruits and vegetables as well as meet the global nutrition demand with making advance future. The prospect, opportunity, success and problem of hydroponics are discussed.

Keywords: Hydroponics, soil-less culture, cost efficacy, nutrient solution, growth medium.

INTRODUCTION

Soil is the vital growing element of plants which provides nutrients, minerals, water and anchorage for plant growth. Plants grow in the soil from the very beginning of the earth. But soil based cultivation is facing some major challenges with the emergence of civilization, urbanization or industrialization which have several adverse effects. Now-a-days, conventional crop growing in soil is difficult due to soil quality change or decline of soil structure, fertility and high salinity (Raviv *et al*., 2002). Because soils contain several disease causing organisms, unsuitable texture. It needs more space with lot of labour and large volume of water for open field soil based agriculture. Besides, in many parts of the world like metropolitan areas, there have also lack of sufficient fertile arable lands due to their unfavourable geographical or topographical conditions with over population density. So soil-less cultivation might be commenced successfully and considered as alternative option for growing healthy food plants, crops or vegetables (Butler and Oebker, 2006).

Soil-less cultivation mainly refers to the technique of hydroponics. The word 'hydroponics' was used by Dr. W.F. Gericke in 1936 to describe the cultivation of edible and ornamental plants and vegetables grown in a nutrient solution of water. So, hydroponics is a technique of growing plants in soil-less condition with their roots immersed in nutrient solution (Maharana and Koul, 2011). It provides sufficient fresh vegetables and high yield of organic production. Now hydroponics has become an established branch of agronomy and various results from different countries have proved it be thoroughly practical and have advantages over conventional methods. The major merit of hydroponics is

that it potentially produces much higher yields and can be used in those places where land is not suitable or ground agriculture and gardening is not possible (Polycarpou *et al*., 2005). Moreover, it allows a better control of water, fertilizers, climate and pest factors for crops which result in increasing productivity and economic incomes. Plants grown by hydroponics have consistently well quality, quick harvest and high nutrient content.

Quality Improved By Hydroponics

Fruits and vegetables consumption highly decrease the rate of risk of many types of chronic disease in human (Giovannucci *et al*., 2002; Dorais *et al*., 2008). Several bioactive compounds or nutrients like beta-carotene, antioxidants present in the vegetables have beneficial effects for health status. So, the health promoting compounds are becoming a vital consideration for fruits and vegetable producers, growers as well as consumers. Now it is possible to improve the quality of fruits and vegetables by using green technique such as hydroponics. It is intensively used to control the environment and to avoid uncertainties in the water and nutrient status of the soil in the protected agriculture. The controlled light and temperature can also change the nutritional quality of fruits and vegetables. A statistical analysis has shown a significant difference in quality of yield between hydroponically and conventionally grown lettuces (Murphy *et al*., 2011). The taste and acidity, vitamins and carotenoids in tomatoes were better mark in soil-less culture systems (Gruda, 2009). It was found that thirty percent more yield of tomatoes in a mixture of 80% pumice + 10% perlite + 10% peat medium in comparison to the soil. Lower dry matter, chlorophyll, magnesium, iron and manganese content and a higher titratable acidity as well as total nitrogen, phosphorus, and potassium content in lettuce plants was also found in the different from soil based cultures (Mastouri *et al*., 2005). Tomatoes grown in peat were considered softer and tastier than the traditional cultivation.

Crops grown on Soil-Less or Hydroponics Culture

It is practically feasible to grow any kinds of vegetables, fruits, herb or crops using this technique. Flowers give a better bloom and colour when grown hydroponically. Hydroponics system might be automated, that is why it is well controlled and better for end product collection. Several plants including vegetables, fruits, flowers, medicinal crops can be grown using soil-less or hydroponics culture (Sardare and Shraddha, 2013).

Table 1: Crops which can be grown on soil-less culture are given below (Singh and Singh, 2012; Das *et al*., 2012; Hayden, 2006).

Type of crops	Name of the crops
Vegetables	*Brassica oleracea var. botrytis* (Cauliflower), *Cucumis sativus* (Cucumbers), *Lycopersicon esculentum* (Tomato), *Capsicum frutescens* (Chilli), *Solanum melongena* (Brinjal), *Phaseolus vulgaris* (Green bean), *Beta vulgaris* (Beet), *Psophocarpus tetragonolobus* (Winged bean), *Capsicum annum* (Bell pepper), *Brassica oleracea var. capitata* (Cabbage), *Cucumis melo* (Melons), *Allium cepa* (Onion), *Raphanus sativus* (Radish).
Leafy vegetables	*Ipomoea aquatica* (Kang Kong), *Lactuca sativa* (Lettuce).
Cereals	*Oryza sativa* (Rice), *Zea mays* (Maize)
Fruits	*Fragaria ananassa* (Strawberry)
Flower/ Ornamental crops	*Tagetes patula* (Marigold), *Rosa berberifolia* (Roses), *Dianthus caryophyllus* (Carnations), *Chrysanthemum indicum* (Chrysanthemum)
Condiments	*Petroselinum crispum* (Parsley), *Mentha spicata* (Mint), *Ocimum basilicum* (Sweet basil), *Origanum vulgare* (Oregano)
Fodder crops	*Sorghum bicolor* (Sorghum), *Medicago sativa* (Alfalfa), *Hordeum vulgare* (Barley), *Cynodon dactylon* (Bermuda grass), *Axonopus compressus* (Carpet grass).
Medicinal crops	*Aloe vera* (Indian Aloe), *Solenostemon scutellarioides* (Coleus), *Anemopsis californica* (Yerba mansa)

Cost Efficacy

Hydroponics is a very lucrative and fastest growing cultivation in agriculture sector. It is extremely clean and easy method because there is no chance of soil-borne disease, insect or pest infection to the crops (Hussain *et al*., 2014). Hence, hydroponics produce the healthiest crops with high yields in short period and operation costs become comparatively much less to soil based cultivation. In contrast, soil based culture means growing crops in the open field with irrigation and as a result it requires application of high amount of fertilizers, pesticides, and herbicides to grow the crops. So, production rate and quality of yield are comparatively lower. But hydroponics system is free from such types of pre-mentioned risks and provides high production. The commercial cultivars of roses (Das *et al*., 2012) and

various vegetables like tomatoes, lettuces, cucumbers, strawberries and so many other crops grow successfully in low cost. Overall, soil-less culture provides efficient nutrient regulation and leading to increase production with low cost.

Table 2: Hydroponics averages compared with ordinary soil yields

Name of crop	Hydroponics equivalent per acre	Agricultural average per acre
Wheat	5,000 lb.	600 lb.
Oats	3,000 lb.	850 lb.
Rice	12,000 lb.	750-900 lb.
Maize	8,000 lb.	1,500 lb.
Soya beans	1,500 lb.	600 lb.
Potatoes	70 tons	8 tons
Beet root	20,000 lb.	9.000 lb.
Cabbage	18,000 lb.	13,000 lb.
Peas	14,000 lb.	2,000 lb.
Tomatoes	180 tons	5-10 tons
Cauliflowers	30,000 lb.	10-15,000 lb.
French beans	42,000 lb. of pods for eating	
Lettuce	21,000 lb.	9,000 lb.
Lady's finger	19,000 lb.	5-8,000 lb.
Cucumber	28,000 lb.	7,000 lb.

(Source: http://en.wikipedia.org/wiki/File:Hydroponicss_vs_agricultural.jpg)

REQUIREMENTS FOR HYDROPONICS

Materials used as growth media

One of the most important factors for hydroponics technique is to choose the right medium or substrate that should be used for better yields. Different media can be used for different growing techniques. The medium or substrate which can be used for hydroponics farming is an inert material does not provide any nutrients to the plant. It only acts as base to grow the better plant roots and holds moisture (Mugundhan *et al*., 2011). Furthermore, media should be solid sufficiently to support the plant growth and water infiltration through a longer period of time. Because soft substrates might be broken down quickly and decrease the structure and particle size. This leads to poor root aeration. Hence, coarse aggregates with sharp edges should also be avoided and the medium should not hold any poisonous materials (Mattice and Brown, 2010). Growth media may be used alone or in combination with others. The most common materials may be used as growing media are coarse sand, gravel, perlite, vermiculite. There have also other specialized materials which are used for hydroponics gardening such as shredded coconut fibers, expanded clay pellets and rockwools (Berndsen and Gardener, 2014). Several crops including tomato, lettuce, cucumber, muskmelon, cauliflower, gerbera, capsicum, roses, chrysanthemum can grow on rockwool, perlite and sand media either alone or mixing of these substrate (Hassall *et al*. 2001; Bradley and Marulanda, 2001; Jiang and Yu, 2007).

Basic nutrient solution

A better quality and high yield achievement is always possible through hydroponics due to accurate management of nutrition and all the growing conditions. Nutrient solution is one of the most vital factors which influences crop quality and yield. A hydroponics system contains mainly aqueous solution of essential elements of organic or inorganic compounds. There are seventeen essential elements which are considered for proper plants growth such as carbon, oxygen, hydrogen, phosphorus, nitrogen, potassium, calcium sulphur, magnesium, iron, zinc, copper, manganese, boron, chlorine, nickel and molybdenum (Salisbury and Ross, 1994). The most vital elements used in nutrient solution are nitrogen, phosphorus, potassium, calcium, magnesium and sulphur; and they are supplemented with micronutrients. All of these essential elements have physiological role and affect directly on plant growth and yield and can influence any characters of plant if one is absent in the growth medium.

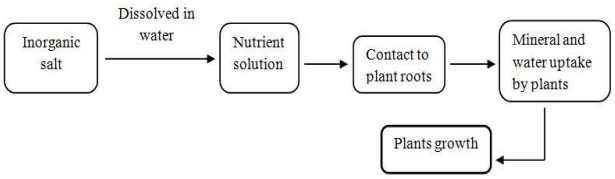

Figure 1: Flow chart of supply of nutrients to the plants by hydroponics. (Modified from this site: http://cpamoneyshop.com/make-money-online2/hydroponicss)

pH

pH is the measure of acidity or alkalinity of an aqueous solution. Changing the pH in nutrient solution constantly affect its composition, elemental speciation and bioavailability as well as also plant growth in hydroponics technique (De Rijck and Schrevens, 1998). pH values below 6.0 causing the solubility of phosphoric acid, calcium and magnesium to drop and above 7.5 causes iron, manganese, copper, zinc and boron ions to be less available to plants. Nutrient solutions must contain the ions in solution and can be absorbed by plants and that is why pH is intimately correlated with nutrient uptake and adjustment and regulation (Marschner, 1995). The optimum pH range of nutrient solution for the development of plants is 5.5-6.5 (Trejo-Téllez and Gómez-Merino, 2012) for most species but some can differ from this range.

Temperature

Temperature is the vital factor for plant growth and survival. Temperature can influence the amount of oxygen consumption of plants and uptake capacity of roots as well as has inverse relation to the dissolved oxygen. Each plant species has a minimum, optimum, and maximum temperature for their growth. Normally, cold nutrient solution decreases water uptake and increases nitrate uptake (Calatayud *et al*. 2008). In Spinach, optimum growth temperature was found at 28°C (Nxawe *et al*. 2009). Temperature has a straight and reverse relationship with dissolved oxygen from the nutrient solution as is shown in Table 3.

Table 3: Solubility of oxygen in pure water at different temperatures at 760 mm Hg of atmospheric pressure (Trejo-Téllez and Gómez-Merino, 2012).

Temperature (°C)	Oxygen solubility (mg L^{-1} of pure water)
10	11.29
15	10.08
20	9.09
25	8.26
30	7.56
35	6.95
40	6.41
45	5.93

Water (H_2O)

The water which is used for nutrient solution needs to carry out a chemical analysis. Generally water which is used for drinking and irrigation can be utilized for hydroponics. Qualities of water in hydroponics system influence the specific ion concentrations in solution (Tognoni *et al.* 1998). So, it is important to avoid harmful effect of water by heat treatment, UV radiation and membrane filtration. It would be also better to evade cheaper chemical treatments such as sodium hypochlorite, chlorine dioxide because it can introduce any other potential toxic elements in closed system (Van Os, 2010).

Light

Plants take the light and convert it into energy using a process called photosynthesis. It is important factor for indoor cultivation to supply quality of light alongside quantity. Light-emitting diodes (LEDs) allow the combination of spectra with intensity particularly adapted to plant production. The spectrum of light influences the plant productivity by direct and indirect way such as effect on leaf photosynthesis (Hogewoning *et al*., 2010; Trouwborst *et al*., 2010), plant morphogenesis and also developmental processes which promote the photosynthesis on plant and crop yield (Goins *et al*., 1997; Matsuda *et al*., 2007).

Electrical Conductivity (EC)

Total amount of ions of dissolved salt in nutrient solutions determine the growth, development and production of plants which exert a force called osmotic pressure. It is fully dependent on the measure of dissolved solutes (Landowne, 2006). Electrical conductivity is applied to estimate the osmotic pressure of the nutrient solutions which is an index of salt concentration and express the total amount of salts in a solution. EC is a good indicator of available ions in the plant root areas. The EC values for hydroponics culture range from 1.5 to 2.5 ds m^{-1}. Some plants obviously can grow in high EC values. So, appropriate management of EC in hydroponics technique can give effective tool to improve vegetable yield and quality (Gruda, 2009).

HYDROPONICS IN BANGLADESH PERSPECTIVE

A huge area of the southern and south-western regions in Bangladesh is vulnerable to high tides or submergence due to costal area. Flooding, water stagnant, soil salinity, environment change and land limitation are very common crisis in Bangladesh and creating a devastating effect among the people. As a result, life of people is affected and food insecurity rises. People of these regions depend mainly on agriculture. Hence, local people in Bangladesh have developed an alternative sustainable cultivation system for seasonal vegetables named 'floating bed cultivation or floating garden'. It is locally known as *Baira* (Shaw *et al*. 2013) and scientifically may be called as hydroponics. *Baira*, one type of hydroponics, is very old traditional practice in the native people for many years. It is mostly found in different parts of Bangladesh and includes Barisal, Gopalgani, Bagerhat and Pirojpur districts (IUCN Bangladesh, 2005). Very recently, floating cultivation (Dhap process) of Bangladesh has been recognized as a "Globally Important Agricultural Heritage System" (GIAHS) by the United Nations Food and Agriculture Organization (FAO) for its sustainability, adaptability and eco-friendly (The Daily Star, 2015). A floating bed is made with the biomass by using water-hyacinth, aquatic algae, rice straws and herbs and other water- borne creepers and plants residues. Sometimes, some sections of bamboos are required to make a floating garden. These beds are able to float on the surface of the water. The local people can cultivate and harvest crops two or three times in a year from one bed. The floating bed is usually eight meters in length, two meters in width and 0.6-1 meter in depth. It generally consists of two or three key layers. Normally most common material water

hyacinth is used as the floating base of bed (Irfanullah *et al*. 2011). The layering of the floating garden is presented in Figure 2.

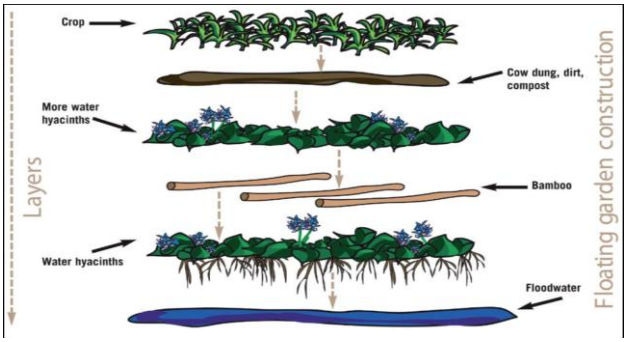

Figure 2: Materials those are used for floating agriculture. Source: (Irfanullah, 2013).

Many types of vegetables including tomato, cauliflower, radish, cucumber, red amaranth, spinach, chilli, garlic, onion can be grown on floating garden in different parts of Bangladesh. The major advantage is that there is no need to use chemical fertilizers in the floating bed cultivation and people get fresh food and nutrition from their own practice. The plants which are grown by this technique get nutrition from composted organics or water source. This traditional practice is very cost effective, eco-friendly, productive and helps to overcome dry land related problems in the flood prone areas of Bangladesh. Now this technique is extending popularly in the southern region of Bangladesh. Recently, floating gardening has become a broadly talked topic regarding climate change adaptation option and has been mentioned as "climate celebrity" (Irfanullah, 2013).

LIMITATION OF HYDROPONIC CULTURE

Although soil-less cultivation is an advantageous technique but some limitations are significant. Technical knowledge and higher initial cost is required for commercial scale cultivation and controlled environment (Sonneveld, 2000). Ensuring the proper condition for plant growth is sometimes difficult and expert management skills are necessary. It requires constant supervision and there have a chance directly or indirectly to introduce water or soil borne microorganism. If any problem arises in the culture, it might be fully lost of plant yield. Finally, it needs to supply light and energy to run the system (Van Os, 2002).

FUTURE PROSPECT

Hydroponics technique presents a "new" door of science helping more crop production for food and ornamental use. It can decrease the environmental impact of greenhouse and nurseries as well as produce improved yield quality (Putra and Yuliando, 2015). Hydroponics can supply high yield of local crops, such as leafy vegetables or flowers in the over-populated areas. If it is possible to modernize the hydroponics technique, all plants and crops can be cultivated through all over the world. Hydroponics has the ability to feed millions in areas of Africa and Asia, where water, land and crops are insufficient. Thus, hydroponics gives the ray of hope for the management of crop and food production (Maharana and Koul, 2011). Japan has started rice production by hydroponics technique to feed the people (De Kreij *et al*. 1999). Israel grows large quantities of berries, citrus fruits and bananas in the dry and arid climate (Van Os, 2002). It makes an appropriate support for biological research and to analyze interactions between multiples factors, both biotic and abiotic, influencing plant growth. To speak the truth, hydroponics technique can be a versatile knowledge in both rural or town and high-tech space stations. This can be a proficient practice for food cultivation from adverse environmental ecosystems such as deserts, mountainous regions, or arctic communities. Currently, demand of hydroponics cultivation has been increased in all the developing and developed countries (Trejo-Téllez and Gómez-Merino, 2012). So, government should make public policies and give subsidies for such production systems.

CONCLUSION

Bangladesh is a river land country. Natural disasters such as flood, drought, high tide, erosion are the most common incidents in the country. People are also using chemical fertilizers, synthetic herbicides, pesticides which deplete the quality of soil and contaminate ground water at a time. As a result, fertility of the arable lands is rapidly decreasing and a lot of people are suffering from disease and malnutrition. Therefore, hydroponics is now a promising strategy to cultivate different plants. Hydroponics is a method which can handle anyone easily. People can grow plants by hydroponics as their hobby or gardening and simultaneously they can collect the fresh vegetables. As it is possible to cultivate soil-less culture in very low spaces with low labour and short time, so hydroponics can play a great contribution for the poorer and landless people. Besides, it can improve the lifestyle of people and enhance the economic growth of a country.

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