International Journal of Agronomy and Agricultural Research (IJAAR)
ISSN: 2223-7054 (Print) 2225-3610 (Online)
http://www.innspub.net
Vol. 10, No. 3, p. 37-47, 2017

RESEARCH PAPER OPEN ACCESS

An easy and reproducible field to table technology for the production of hydroponics lettuce in Bangladesh

Abdullah Mohammad Shohael[1*], Ananya Azad Hrisha[1], Tanvir Ahamed[1], Sayeda Mahfuja Khatun[2]

[1]*Department of Biotechnology and Genetic Engineering, Jahangirnagar University, Savar, Dhaka, Bangladesh*

[2]*Jahangirnagar University School and College, Savar, Dhaka, Bangladesh*

Article published on March 30, 2017

Key words: Hydroponics, Nutrient medium, Plastic bowl, Soilless culture, Vegetables.

Abstract

Lettuce (*Lactuca sativa* L.) is a green crunchy leafy conventionally soil grown vegetable consumed worldwide as food or food component. Soil grown lettuce is exposed to inorganic fertilizers, pesticides and possesses risk of pollution or contamination. Hydroponics is a soilless culture system that is used for growing lettuce alternatively. As there is no soils are used so lettuce plants become free from soil borne pathogen and nematodes and labor for tilling, cultivating, fumigating, watering, and other traditional practices is not required in this system. A balanced nutrient solution was applied in the fresh water for the production in hydroponics system. In our non-circulating hydroponics system the lettuce plants were supported on a Styrofoam board floating on the nutrient mix in an easily available plastic bowl. Compared to the production of lettuce in hydroponics is found better than produced in the soil. Maximum fresh weight per plant was obtained 155.0gm in hydroponics system followed by 148.0gm grown in the soil at the same age. Shape, taste and size of hydroponically grown lettuces were found excellent in compared to the soil grown. After 32-35 days of culture fully grown lettuce bowls were transferred to the dining table under low light for regular consumption and it was survived another 7-10 days without changing its color, shape and taste. Thus we developed an easy to grow and environment friendly field to table technology that will be very beneficial and economic for growing lettuce anywhere in Bangladesh.

* **Corresponding Author:** Abdullah Mohammad Shohael ✉ amshohael@juniv.edu

Introduction

Hydroponics is a technique of cultivation where no soil is required so it is known as soilless culture. In this cultivation method plant roots are suspended in either a static, continuously aerated nutrient solution or a continuous flow or mist of nutrient solution. Hydroponics is a method of growing plants that takes advantage of providing all of the nutrients, in their inorganic form, in a liquid solution with or without solid media (Nguyen *et al.*, 2016). Hydroponics system is very popular and demanding system that requires skills, financial supports and production knowledge of specific crops.

A hydroponics system provides the necessary nutrients directly to the crop roots as a solution with the supplied water. Hydroponic is a system where specific plants are grown in appropriate nutrient solution without soil. Hydroponics is now used in almost every country in the world (Resh, 2012).

In addition to higher yields and water efficiency a hydroponic systems sustain continuous production throughout the year (Brechner and Both, 2014) and quality of the products are remain excellent in this system. Hydroponics systems are very versatile and can range from very small scale (in door) to commercial enterprises (Barbosa *et al*., 2015). Now a day's various commercial crops are growing using hydroponics including tomatoes, cucumbers, peppers, eggplants, strawberries etc.

The leafy vegetables, lettuce can grow hydroponically and perform best using the different hydroponic techniques (Tognoni and Pardossi, 1998). Hydroponics is a valuable culture method to grow fresh vegetables in countries having a large population with limited arable land like Bangladesh.

The main advantages of hydroponics culture over soil culture are more efficient nutrient regulation, availability in low arable land with dense population, efficient use of water and fertilizers ease of low cost of medium and higher density planting leading to the increased yields (Resh, 2012).

Lettuce (*Lactuca sativa* L.) is a popular leafy vegetable belongs to the asteraceae family. It is one of the most consumable and frequently grown vegetables in the cool season. Generally lettuce is consumed as a fresh vegetable in salads sometimes in cooked formed (Rubatzky and Yamaguchi, 1997; Lebeda *et al.*, 2007). It is especially important as a commercial crop in Asia, North and Central America, and Europe. China, United States, Spain, Italy, India and Japan are the world's largest lettuce producers (Lebeda *et al.*, 2007; Mou, 2008). Lettuce is a good source of vitamin A, potassium, as well as several other vitamins and nutrients (Barry, 1996).

It also contains a good amount of protein and carbohydrates (Tindall, 1983). However, contaminated lettuce is often a source of bacterial, viral and parasitic outbreaks to humans, including *Escherichia coli* and *Salmonella* when not carefully produced (Davis and Kendall, 2015). Safe lettuce can contribute to a healthful diet because of not having cholesterol as constituent and has very low amount of calorie and sodium. It also contains beta-carotene, calcium, folate, fiber, and phytonutrients. Those phytonutrients are very beneficiary for human health.

The concern of food safety is addressed through better control of the environment and microclimate around the crop so as not to introduce unwanted pests, pesticides, and microorganisms (Kobayashi *et al.*, 2013).

In Bangladesh many constrains for growing a specific vegetables in a suitable weather period. Conventional lettuce productions are hampered by huge water supply, soil borne pathogens, expensive supply chain maintenance for marketing and high price of lettuce seeds.

To overcome those constrain an easy, reproducible, lost cost and reliable cultivation system is required. Non-circulating hydroponic system in available plastic bowls will be a solution to lettuce production anywhere in Bangladesh. Maximum yields are possible, making the system economically feasible in

high-density and expensive land areas.

The objective of our study is to develop a method of growing lettuce easily and low cost in a hydroponics system. In this article we described about an easy and reproducible field to table technology for the easy production of lettuce in home and garden. We used very simple available plastic bowl in our experimental set-up.

There was no pump or other electrical components were used in our system. Fully grown lettuce bowls were transferred to the dining table and were freshly harvested during consumption for another 7-10 days.

Materials and methods

Basic requirements of hydroponics

Naturally soils maintain the temperature and aeration needed for root growth of a plant. Hydroponic systems require the same requirements for good growth as field-grown plants.

Plants needs support for stand and accumulate the nutrients. In hydroponic system nutrients are available in the solution but they need extra support for standing.

Beside the support in hydroponic system plants need enough light, appropriate temperature, water, oxygen supply and balanced nutrients.

Lettuce variety and seed germination

Japanese lettuce variety Green Wave (Takii and Co., Ltd. Kyoto Japan) was selected for this experiment. Freshly available seeds were collected from the local seed shop and seeds were germinated in to the disposable plastic Petridis on the moist tissue paper under low light before transplanting in to the hydroponic bowl.

Plastic bowl selection

Five, Ten and Twenty liter capacity dark plastic deep bowls were selected for this experiment (Fig. 1). At the top of the bowl a plastic liner helps to hold Styrofoam sheet. Each bowl costs about 20-80 BDT and bowl head diameter was 25, 30 and 35cm respectively. Those bowls were capable of producing 6-12 bunches of lettuce in every 5-6 weeks.

Bowl cover for plant support

One inch thick Styrofoam board was used to cover the bowl and support the plants. The board was cut in unique size to fit the bowl. Four to twelve 1”X1” squire holes were made by sharp knife for different bowl. Covered bowls was filled with 4 to 18 liters of nutrient solution per six to twelve plants prior to planting (Fig. 2).

Preparation of foam block

Foam sheet was collected from local market and was cut into small pieces (1”X1”) for the equal size of Styrofoam hole for the support of lettuce seedling. Small holes were made through them so that they can hold seedlings on them and root can pass through (Fig. 1).

Nutrition medium

A 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 also present (Steiner, 1968).

The medium composition and stock solutions are listed in the Table 1. Certain amount of stocks were added to water and mixed to make the nutrient solution. Then those were filled into the bowl prior to planting. And bowls were allowed to grow under direct sunlight.

Seedling transplantation in the hydroponic bowl

Finally 1”X1” foam pieces were taken and germinated Lettuce seedlings (about 2-3 cm long) were entered (two seedlings per pore) into their pore and then transplanted into the holes of the Styrofoam then cover the bowl (Fig. 2).

Placement for growth

Ready plastic bowls finally kept under the direct sunlight in a suitable place. For small scale home

gardening bowls were kept different places for their growth performance. At the roof top, balcony, veranda and small karnish was selected to place the bowls (Fig. 3).

Lettuce grown in the soil

Experimental plots for the lettuce production were made at the departmental periphery. Soil was prepared with sufficient amount of cow dung and organic fertilizer. Seeds were sown directly to the experimental plots and watered every day.

Harvest and storage

For growth curve preparation 10-15 lettuce plants were harvested every week. Lettuce plants were selected randomly and fresh weight was measured. Finally fully grown lettuce from the field and some hydroponic bowls were harvested with intact of roots.

A good number of hydroponic bowls with plants moved to the indoor dining table to check their status under the normal light in the dining table without applying more nutrient solutions.

Statistical analysis

Lettuce plants were harvested randomly from the field and hydroponics bowl to measure the fresh weight data using a laboratory weight scale.

The experiments were repeated twice within two seasons. Data were calculated on the basis of average of fresh weight and calculated standard deviation respectively using Microsoft excel.

Results

In our experiment at first we compare the growth of lettuce in hydroponics system and grown in the soil. A balanced nutrient solution was applied in the plastic bowl mixed with sufficient amount of water before planting the lettuce seedlings. Stock solutions were prepared using all essential micro and macro nutrients (Table 1).

Table 1. Different stock solution, their types of nutrients and constituents used in this experiment.

Stocks	Type	Constituents
Stock Solution 1	Macronutrient	KNO_3
		$Ca(NO_3)_2.4H_2O$
		NH_4NO_3
Stock Solution 2	Macronutrient	$MgSO_4.7H_2O$
Stock Solution 3	Micronutrient	H_3BO_3
		$MnSO_4.4H_2O$
		$ZnSO_4.7H_2O$
		$CuSO_4$
		$Na.MoO_4.H_2O$
		KH_2PO_4
Stock Solution 4	Iron-EDTA	Fe-EDTA

Plastic bowl was covered with Styrofoam and nutrient solution was applied about ¾ of the bowl to keep enough space between bowl top and medium (Fig. 1). As in this system no circulation of nutrient was provided so air space was helpful for growing roots (Fig. 2 & 3). In the soil lettuce seeds were sown in the well manures soil and watered every day.

Table 2. Morphological changes of field grown and hydroponically grown lettuce. Hydroponic lettuce was moved from outside to the dining table under low light. Field grown lettuce was harvested and kept in the refrigerator.

Post harvest status	Shape	Size	Color	Taste
Hydroponic lettuce in the dining table after 7 days	+++	+++	+++	+++
Field grown lettuce preserved in a refrigerator after 7 days	+	-	-	+

(+++: Excellent, ++: Better, +: Good, -: Dull).

Data for fresh weight after harvesting of the randomly selected lettuce plants from the field and hydroponics bowl is presented in Fig. 4. In our study it was found that lettuce grown in hydroponics system was grown faster than grown in the soil and obtained the highest yield (Fig. 5). Maximum yield was recorded 155.0gm of fresh weight per plant in hydroponic system in compared to 148.0gm of fresh weight per plant grown in the soil after 35 days of planting.

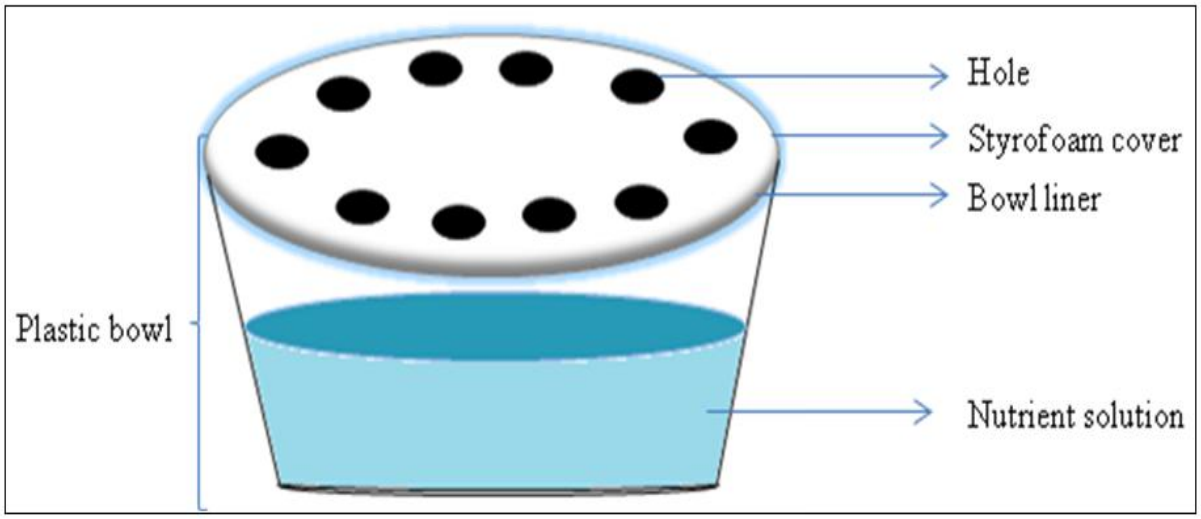

Fig. 1. Plastic bowl with Styrofoam cover.

The lettuce quality was high, had good flavor (students' choice), were free of insect pests and disease, and were produced in about a 5 weeks of period. On the other hand field grown lettuce was less attractive, had medium flavor (by students choice) and some of the infested with insects and pests. Taste and odor was crunchy and soft when it was grown hydroponically those was better than field grown.

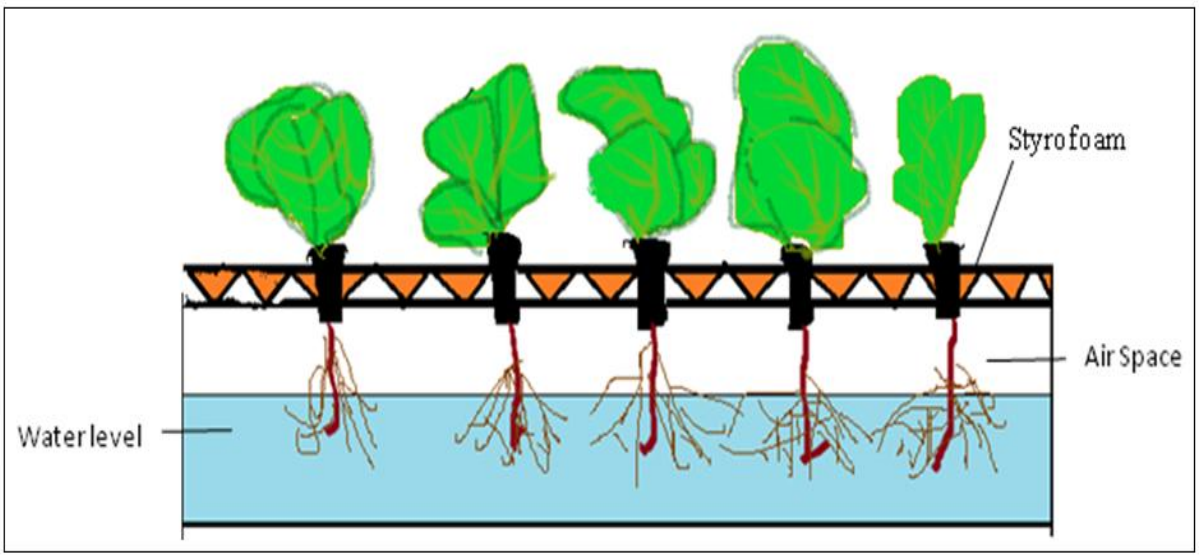

Fig. 2. Cross section of a non circulating hydroponic system.

The growth curve also showed that lettuce grown in plastic bowl with nutrient solution was faster than grown in soil (Fig. 5). Taste, flavor, and appearance showed better than field grown plants (Data not shown). In our system it is more promising that after 30-35 days of outdoor growth lettuce bowls were moved to the indoor, decorated in the dining table under normal light without applying additional

nutrients. Only simple tap water was applied to maintain the water level in the bowl. Those lettuces were survived another 7-10 days and remained fresh, crunchy and green (Fig. 6E) without changing shape, size, color and taste (Table 2). As there is no soil involved, the plants remain clean and looks nice while put in the dining table (Fig. 6E, Fig. 6F). From the indoor place it was easily harvested on demand without destroying whole plants. Colorful bowl and green lettuce made nice decorative combination in the table.

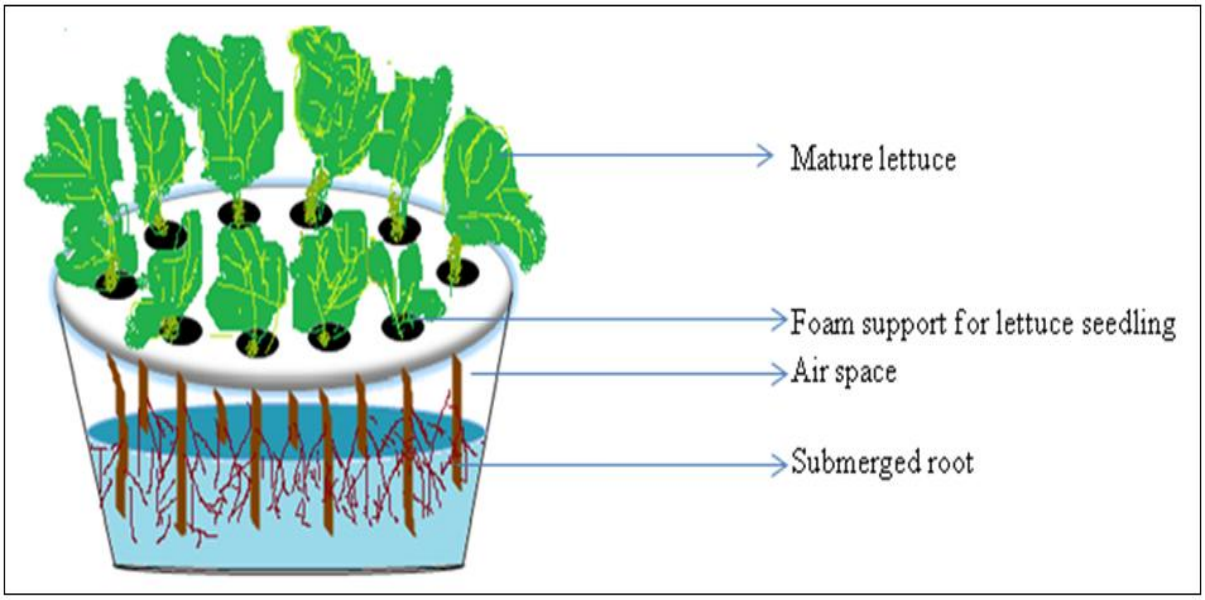

Fig. 3. Lettuce growing in a not circulating hydroponic plastic bowl.

It is suggested that our system is efficient and feasible for small scale production (Fig. 6E, Fig. 6F). Within the plastic bowl it will be an attractive alternative for marketable vegetable products in fast food shops and super shops.

Soil is the natural substrate and most available growing medium for the growth of plants. Although different soil borne disease occurred in plants due the presence of different types of soil borne pathogens, nematodes and other microorganisms.

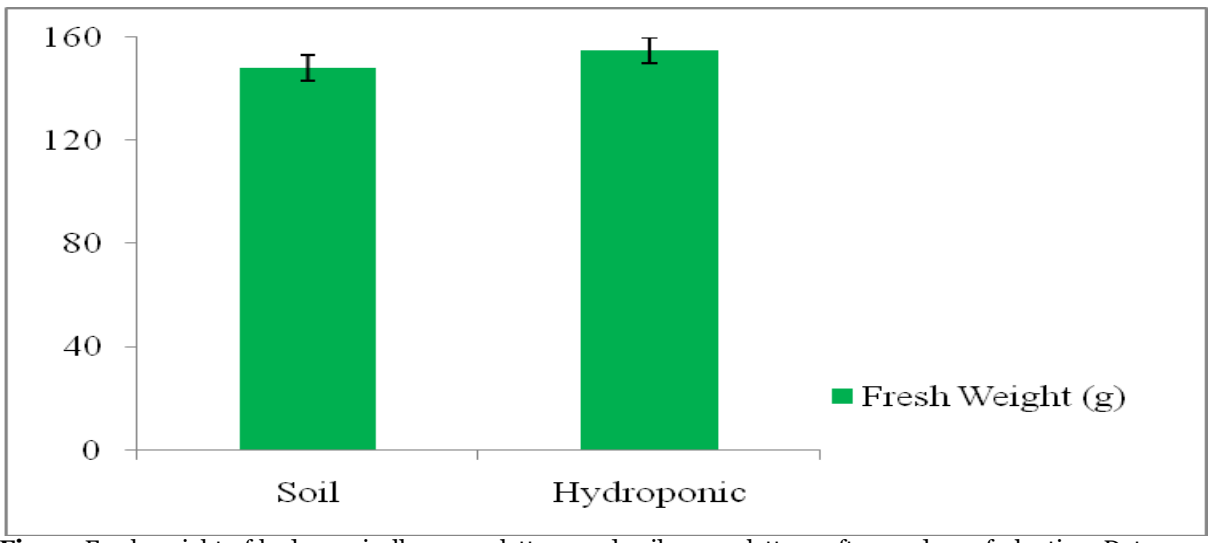

Fig. 4. Fresh weight of hydroponically grown lettuce and soil grown lettuce after 35 days of planting. Data was recorded randomly selected plants from each method.

Plant growths also inhibited by the changing of soil acidity level, soil salinity, water deficiency of excessive water, poor nutrient level and also soil characters. To avoid those constrains soil less hydroponic culture system was adopted for the cultivation of many crops under controlled environment. In soilless culture plants obtained their nutrients from the supplied solution that supplies all the necessary nutrients for plants growth and development. To support the plants in the water an artificial base (basically Styrofoam) is placed on the top (Fig. 3). The nutrient solution is act as growing media and that should include all necessary macro and micro nutrients for plant growth.

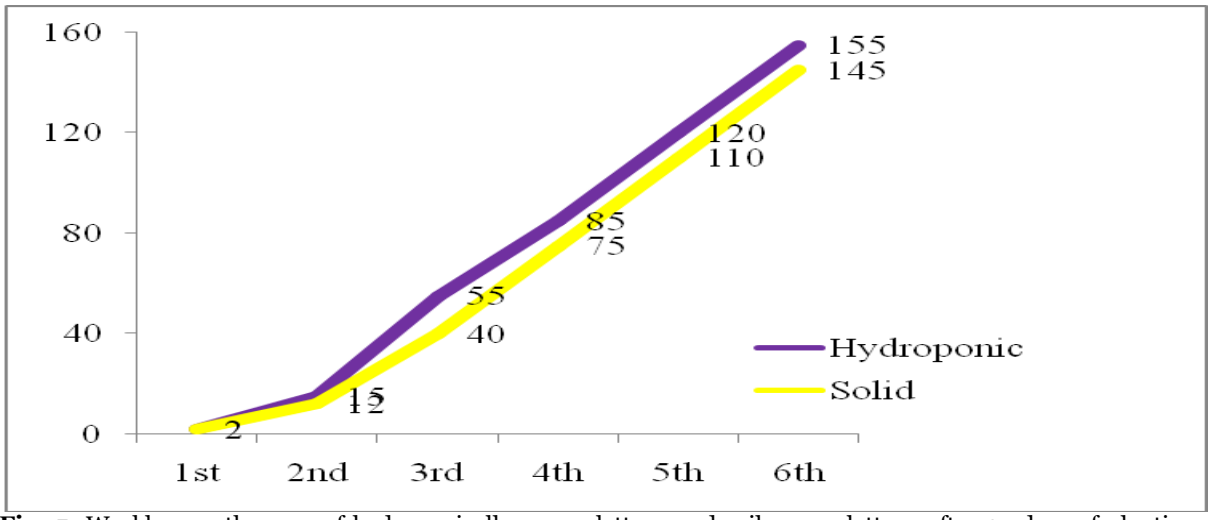

Fig. 5. Weekly growth curve of hydroponically grown lettuce and soil grown lettuce after 35 days of planting. Data was recorded randomly selected plants from each method.

Discussion

Lettuce can be grown in small scale and commercial scale in a hydroponic system in Bangladesh. The advantages of this system are, cost-effective, simple, no electric or other power supply required any extra costs for additional expense of fertilizers, pesticides, herbicides and cleaning is not required. Faster growth saves both time and money. No risk of microbial pollution. For home gardening to commercial enterprises this easy to grow technique is applicable (Kratky, 2010). In small scale production hydroponic bowl can keep under direct light in the open roof top, small balcony, varanda, kitchen yard or any other suitable place in a house where sunlight is available. For medium scale production small plastic house or in the open field pots could be placed. As it can grow indoor place of outdoor during winter no loss from natural disasters. Those advantages pose a greater scope, promising benefits, suitable opportunity and strong future marketplace in a developing country like Bangladesh. Moreover, lettuce grown hydroponically in this method are robust, crunchy and sweeter in comparison with the field grown ones and this applies the 'field to table technology' that makes this method possible at one's fingertips. Similar result was reported by Ferguson *et al.*, 2014. So, the non-circulating hydroponic method for growing lettuce in a small plastic bowl is very potential and committing for the upcoming years (Gichuhi *et al.*, 2009; Murphy *et al.*, 2011). Hydroponics or soil-less culture is a technology for growing plants in nutrient solutions that supply all nutrient elements needed for optimum plant growth with or without the use of medium such as soil, gravel, vermiculite, Rockwool, peat moss, saw dust, coir dust, coconut fiber, etc. to provide mechanical support. Hydroponics offers several advantages over soil-based systems. When removed from soil, root tissue is often mechanically sheared causing loss of tissue or damage. This is particularly true for fine root structures such as lateral roots and root hairs. Hydroponic systems that do not utilize an inert particulate media allow a less invasive separation of root and shoot tissues. In soil systems, nutrient

bioavailability changes throughout the soil matrix as nutrients bind to soil particles creating micro-environments within the soil. This heterogeneity could add an extra level of complexity in experiments needing a precise control on the external concentration of nutrients or other molecules. In contrast, the hydroponic solution is homogeneous and can be easily replaced throughout the course of the experiment (Nguyen *et al.*, 2016). Hydroponic cultures for the production of ready-to-eat salad have increased rapidly in recent years. This is a simple, convenient, and highly productive culture technique that allows farmers to obtain a clean product without soil residue (Curducci *et al.*, 2015).

Fig. 6. Hydroponically grown lettuce at different week's interval of planting. A) Germinated lettuce plants ready for planting in hydroponic pot B) Plants after 1 week C) Plants after 2 weeks D) Plants after 4 weeks E) Plants after 5 weeks F) Lettuce plants in the dining table.

There are many advantages of growing vegetables in aqueous media for its nutritional values. For the success of hydroponic system is the supply of proper nutrient solution for plant growth (Hedio Ikeda, 2000). Different nutritional values, such as flavonoids, ascorbic acid (vitamin C), and tocopherols (vitamin E) are influenced by nutritional status of the plant, the light environment, and other environmental stresses (Ehret *et al.*, 2013; Pauliz and Belanger, 2001; Kimura and Rodriguez-Amaya, 2003; Buchanan and Omaye, 2013). A nutrient solution for hydroponic system 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 (Steiner, 1968). An essential element has a clear physiological role and its absence prevents the complete plant life cycle (Taiz and Zeiger, 1998). The roles of essential elements in the manufactures and breakdown of various metabolites required for plant growth. Many are found in enzymes and coenzymes that regulate the rate of biochemical reactions. Others are important in energy carrying compounds and food storage (Resh, 2012).

There is no physiological difference between plants grown hydroponically and in soil. In soil both the organic and inorganic components decomposed in to inorganic elements prior the available form to the plant (Gent, 2012). These elements adhere to the soil particles in the soil solution those are absorbed by the plant root. On the other hand in hydroponics the plant roots are moistened with a nutrient solution containing the necessary elements provided in the water. The subsequent processes of mineral uptakes by the plants in both systems are the similar. The suspended bowl non-circulating hydroponic system is very time efficient and gives healthy plant as a result of easy uptake of necessary nutrients that soil. It's a very fruitful procedure and enables farming from field to table come true. Hydroponic lettuce grown through our system has beneficial as well as some unique properties over conventionally grown lettuce in soil. It has no risk of contamination or pollution or pest or microbial attack as well as is not exposed to chemicals and natural calamities being grown in controlled environment under proper monitoring. This procedure holds a very potential impact. In hydroponic system optimal conditions are applied that helps to grow plants in a better way. Due to controlled environment and artificial food higher yields are obtained than grown in the open field. In hydroponic system no soil was needed so that there are no chances of soil borne disease in growing plants. On account of the increasing demand of hydroponic production method in Bangladesh, easy and simple types of techniques are being invented and applied. In our system it is one of the simplest, easiest and cost-effective techniques. Suspended bowl is a non-circulating hydroponic growing method that makes the entire crops grow with only an initial application of nutrients and water. No electricity, pumps and wicks are needed in this method and so there is no additional costs and complexities related to aeration and circulation unlike many conventional hydroponic system.

Conclusion

In compare to the field grown lettuce the suspended plastic bowl, non-circulating hydroponic method is an effective technique and was found better in our study. Growing lettuce hydroponically enables better control of the environment including weather factors, pests and diseases, and plant nutrient management. A formulated nutrient solutions are used in our system, no excess fertilizer is wasted and no leaching of fertilizers into the ground or the groundwater system. In this system the lettuce plants were grown with only an initial application of nutrients without any circulation and application of further watering. This innovation allowed us to grown lettuce move towards dining table from the field and can keep another few days for freshly harvest. In addition to saving labor and hassle, this method also utilized space more efficiently because interior balcony, roof carnies and roof top can also be used for initial production outdoor. Initial set up costs, personal skill, scientific knowledge and purity of the chemicals may hinder the growth and production in this system should be considered before start.

Acknowledgement

The authors were gratefully acknowledged for the financial support provided by the Jahangirnagar University research grant.

References

Barbosa GL, Gadelha FDA, Kublik N, Proctor A, Reichelm L, Weissinger E, Halden RU. 2015. Comparison of land, water, and energy requirements of lettuce grown using hydroponic vs. conventional agricultural methods. International Journal of Environmental Research and Public Health **12**, 6879-6891.

Barry CB. 1996. The Handbook to Hydroponic Nutrient Solutions. Casper Publications Ptv Ltd. Narabeen, NSW, Australia.

Brechner M, Both AJ, Staff CEA. 2014. Hydroponic Lettuce Handbook. Cornell Controlled Environment Agriculture 504-509.

Buchanan DN, **Omaye ST.** 2013. Comparative study of ascorbic acid and tocopherol concentrations in hydroponic-and soil-grown lettuces. Food and Nutrition Sciences **4**, 1047.

Carducci A, Caponi E, Ciurli A, Verani M. 2015. Possible internalization of an Enterovirus in hydroponically grown lettuce. International Journal of Environmental Research and Public Health 12, 8214-8227.
http://dx.doi.org/10.3390/ijerph120708214

Davis JG, Kendall PA. 2005. Preventing E. coli from Garden to Plate. Colorado State University Cooperative Extension.

Ehret DL, Usher K, Helmer T, Block G, Steinke D, Frey B, Diarra M. 2013. Tomato fruit antioxidants in relation to salinity and greenhouse climate. Journal of Agricultural and Food Chemistry **61,** 1138-1145.

Ferguson SD, Saliga III RP, Omaye ST. 2014. Investigating the effects of hydroponic media on quality of greenhouse grown leafy greens. International Journal of Agricultural Extension **2,** 227-234.

Gent MP. 2012. Composition of hydroponic lettuce: effect of time of day, plant size, and season. Journal of the Science of Food and Agriculture **92**, 542-550.

Gichuhi PN, Mortley D, Bromfield E, Bovell Benjamin AC. 2009. Nutritional, physical, and sensory evaluation of hydroponic carrots (*Daucus carota* L.) from different nutrient delivery systems. Journal of Food Science **74,** 403-412.
http://dx.doi.org/10.1111/j.1750-3841.2009.01338.x

Hideo Ikeda. 2000. Hydroponics/ or soilless culture. Osaka Prefecture University 6-17.

Kimura M, Rodriguez-Amaya DB. 2003. Carotenoid composition of hydroponic leafy vegetables. Journal of Agricultural and Food Chemistry **51,** 2603-2607.
http://dx.doi.org/10.1021/jf020539b

Kobayashi K, Lazaro M, Amore T. 2013**.** Light-emitting diodes (LEDs) for miniature hydroponic lettuce. Optics and Photonics Journal **3(1)**,74-77.
http://dx.doi.org/10.4236/opj.2013.31012

Kratky BA, Maehira GT, Magno EJ, Orzolek MD, Lamont WJ. 2008. Growing Lettuce by a float-support non-circulating hydroponic method in Hawaii and Pennsylvania. In Proceedings of the 34th National Agricultural Plastics Congress.

Kratky BA. 2010**.** A suspended net-pot, non-circulating hydroponic method for commercial production of leafy, romaine, and semi-head lettuce. Vegetable Crops **1,** 1-19.

Lebeda A, Ryder EJ, Grube R, DoleŽalovÁ I, KŘÍstkovÁ E. 2007. Lettuce (Asteraceae; Lactuca spp.). In: SINGH R.J. (ed.), Genetic Resources, Chromosome Engineering, and Crop Improvement,

Vol. 3, Vegetable Crops, Boca Raton, CRC Press, Tailor and Francis Group: 377–472.

Mou B. 2008. Lettuce. In Vegetables I, Springer New York. 75-116.

Murphy MT, Zhang F, Nakamura YK, Omaye ST. 2011. Comparison between hydroponically and conventionally and organically grown lettuces for taste, odor, visual quality and texture: A pilot study. Food and Nutrition Sciences **2**, 124-127. http://dx.doi.org/10.4236/fns.2011.22017

Nguyen NT, McInturf SA, Mendoza-Cózatl DG. 2016. Hydroponics: A Versatile System to Study Nutrient Allocation and Plant Responses to Nutrient Availability and Exposure to Toxic Elements. Journal of Visualized Experiments **113,** 54317. http://dx.doi.org/10.3791/54317

Paulitz TC, Bélanger RR. 2001. Biological control in greenhouse systems. Annual Review of Phytopathology **39,** 103-133. http://dx.doi.org/10.1146/annurev.phyto.39.1.103

Resh HM. 2012. Hydroponic food production: a definitive guidebook for the advanced home gardener and the commercial hydroponic grower. CRC Press.7th edition.

Rubatzky VE, **Yamaguchi M.** 1997. World Vegetables: Principles. Production and Nutritive Values. Chapman and Hall, New York.

Steiner AA. 1968. Soilless culture. In The fertilization of potted crops. Proceedings of the 6th Colloquium International Potash Institute, Berne, Switzerland, 324-341.

Taiz L, **Zeiger E.** 1998. Plant Physiology. Sinauer Associates, Inc. Publishers. Sunderland, Massachusetts, USA, 1-2.

Tindall HD. 1983. Vegetables in the tropics. Macmillan Press Ltd.

Tognoni F. Pardossi A. 1998. Soilless culture for greenhouse crops in the Mediterranean countries. In workshop on methyl bromide alternatives for North African and southern European countries, Rome, 143-148.