



A novel cost effective design of the hydroponic system for kitchen gardens

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Abstract

Hydroponic systems have been used as one of the standard methods for commercial production for several crops, including lettuce and tomato. Numerous hydroponic systems have been designed to study plant responses to stresses. In this study, a non-circulating hydroponic protocol that can be easily implemented in kitchen gardens for cultivation of greens and other vegetables utilizing the concept of soil-less culture. This protocol describes the non-circulating hydroponic system set up in detail and the preparation of plant material for successful establishment. Most of the materials described in this protocol can be obtained outside scientific supply companies, making the set up for hydroponic experiments less expensive and convenient. The use of a hydroponic growth system is most advantageous in situations where the nutrient media need to be well controlled and when intact roots need to be harvested for downstream applications. The growth parameters of hydroponically grown plants were compared with the control grown plants without nutrients.

Keywords: hydroponics, vegetative growth, plant nutrition, minerals, *Mentha arvensis* L

Introduction

The hydroponics is characterized by current improvement in plant culture and this technique involves growing plants without soil in a nutrient solution. Soil is purely possessor of the nutrients, where plant roots traditionally lives and also pedestal support for plant structures. This hydroponics technique without soil; which is present in soil we can add in nutrient solution, it contains nutrients, minerals, elements. This technique in growing fresh vegetables used for commercial purposes for more than 30 years. Through elimination of soil it is ensured that soil borne diseases and weeds are eliminated and other issues related to pH, water holding capacity are also eliminated. Water contains dissolved fertilizers at suitable concentrations, in 1860 Knop and Sachs first standardized nutrient solutions technique adapted to outdoor culture, indoor culture (Hoogeland and Arnon, 1950; Wood, 2017) [7, 19]. In the United Kingdom, the Nutrient Film Technique (NFT), was introduced by Cooper (1996) [3] initially, the main hydroponic system adopted by growers on a large scale.

This technique is specially designed for elevated value crops such as fresh vegetables, fruits and flowers, compare to soil growing plants, hydroponic plants consumes 10-30 times less water, less space, and devoid of hazards. In addition, green house hydroponic crops grow throughout the year irrespective of seasons also freshly available, this kind of cash crops offered better prices in local markets because of culture quality and are also devoid of chemical influences. In this technology in green house environment (controlled) cultivation of best quality produce with a minimum of water, space and without fertilizer is achieved (Kratky, 2002) [7]. Due to express urbanization, industrialization, melting icebergs, the decline in land availability for cultivation, forces cultivars to prefer this alternate method of cultivation. Further, decrease in the annual production of cash crops, poor soil fertility due to continuous cultivation, common drought conditions and unpredictability of weather

patterns, rise in temperature, pollution of river, poor water management, and decline in ground water level etc., forced hydroponics method of cultivation indispensable.

All over the world more than 40,000 acres hydroponic crops are grown, in US 1000 acres alone. Hydroponics is a demanding from fulfill consumer's with a profitable business, Europe and US commercial hydroponics severely risen through productivity, in tomatoes 35-40 lbs per plant as compared to 20 lbs few years back, and an intensive volume could be grown in small space i.e. 4-5 thousand pounds of tomatoes every week in an area of 12000 sq ft.. Hydroponics has proved to be an excellent alternative to soil sterilization, particularly in observation of the information that the use of chemical soil sterility; methyl bromide, soon will be forbidden in many countries, due to their lofty toxicity and their unfavorable effects on the atmosphere (Thyagarajan *et al.*, 2009).

Mentha arvensis L. (wild mint), its widely grown in Asia, Europe and North America, popular flavoring and aromatic herbal plant comes under Lamiaceae family, it contains menthol rich essential oil. Mint leaves used as traditional remedy for cough, indigestion, allergy gastric troubles, and joint pains (Verma *et al.*, 2010) [17], Biological effects; antiinflammatory, antiulcer, hypnotic, antioxidants, sedative, hepatoprotective, antifertility and antibacterial activities (Shah *et al.*, 2009) [13], mint menthol contains chemicals are broadly used in drinks, foods, creams, medicines and cigarettes worldwide (Arjun *et al.*, 2017) [1]. Important plant so for that selected for hydroponic technique. This technique in plants can be improved than in crops cultivated in the soil, outstanding to the limited volume of substrate per plant and its standard, homogeneous constitution, which is well known to the grower (Savvas, 2001) [12], thereby increasing the potential length of cultivation time, which is an effective means of increasing the total yield in greenhouses.

Materials and Methods

The design of a non-circulating hydroponic system made in such a way that it is cost effective and transportable. Setting

up of non-circulating hydroponic system required the following materials as in described below, which were obtained from the local hardware shop.

Table 1: Materials required for setting up of non-circulating hydroponic system

S. No	Items	Specifications	Quality
1	PVC pipe (Star Brand)	4"X1 m	3 Nos
2	End cap	4"	6 Nos
3	Wooden pallet	1 m	2 Nos
4	GI clamp	4 m	6 Nos
5	SS screws	1/2 m	12 Nos
6	PVC solution	100 ml	1 Nos
7	Rubber grommet	16 mm	3 Nos
8	Shut PVC valve	½"	3 Nos
9	PVC pots	4"	16 Nos

The 4" PVC pipes of 1 m length were taken and holes of 5" dia were cut to make the PVC pots to fit firmly in the pipes. The PVC pots had holes at the bottom to facilitate rooting system of the plant to pass through and touch the solution in the PVC pipe. The end caps were fitted at both ends of the pipe with PVC fastening compound to prevent leakage of solution from the system. Holes 16 mm dia were made at bottom of one end of all the pipes and rubber grommet was inserted to facilitate leak proof drainage provision for the system. When in place, the rubber grommets provide excellent joinery between the shut valve and the PVC pipe (Fig. 1). The pipes were fitted on wooden planks with "U" clamps and metal screws and placed on brick columns for support at four corners. The entire setup was made immobile and care was taken to prevent any disturbance to the system.



Fig 1: Design of a non circulating hydroponic system

An inert material is added in the pots of growing plants in hydroponics for support. Though various inert materials such as coal peat, rice husk, vermiculite, pumice, gravel, clay pellet sand light expanded clay aggregates are used as media in the hydroponic system, in this experiment for construction of the system, clay aggregates were preferred over other media owing to the ease of handling and easy availability. The clay aggregates were purchased from The Garden Shop, Vadapalani, Chennai, and were thoroughly washed and soaked in water for 48 h and the inert nature of the medium is verified before usage. This medium supports the growing roots and the plant in the system and prevents the plant from tripping. The pots were filled up to ½ levels with clay aggregates and it was ensured that clay aggregates provided support to the growing root system (Fig. 2).

The PVC pipes of the system were filled with hydroponic solution, case may be up to ½ level. The plastic pots were placed in the PVC pipes so provisioned to accommodate the pots. RO water was used as control. All the organic solutions were free of contaminations, for all the dilutions RO water was used. The common field mint plant, *Mentha arvensis* L. is used in this study. Pre-treated seeds of mint are purchased from *Nursery Live*. Nursery beds were prepared for sowing the seeds. Flat bed type of nursery beds are preferred for the study. The field was worked well to break the clods in the soil. Weeds, stones and other wastes were removed manually. Height of the raised bed was made to 10-15 cm with a width of 50 cm and length of 5 mts each

for conveniences of maintenance, watering etc. Sufficient gaps were made between each row of the nursery beds. The nursery beds were prepared by mixing the field soil with two parts red soil, one part sand, one part cow dung manure, one part coco peat and farm yard manure compost. Before preparing the bed, the soil was drenched with 4 % formaldehyde to kill the pathogenic spores and nematodes in the soil.



Fig 2: Clay aggregate

The seedlings were raised in nursery beds using the seeds. The seedling beds were moderately watered everyday with gardening water can. Nursery grown seedling were used which were 6 d old. Elite seedlings were selected and transplanted in the hydroponic system for further

experiments. Seedlings were chosen in such a way that they were devoid of any physiological and pathological diseases. Each pot was planted with four seedling and the same

number of seedling per pot was ensured throughout the experiment (Fig. 3).



Fig 3: Seeding of *M. arvensis* planted in the non-circulating system

Nutrient solutions for hydroponic system

Hydroponic solution

Hydroponic nutrient solution (City Greens Company) of known composition is bought from the local seller. The solution contains two different bottles and once mixed, solution used immediately. Hydroponic solution used the concentration of 15 mL/l.

Table 2: Composition of hydroponic nutrient solution.

Composition	Source	Percentage
Nitrogen (N)	Ammonium (NH ₄)- Nitrate(NO ₃ -)	0.025
Phosphorus (P)	Mono-hydrogen Phosphate, Di-hydrogen Phosphate, Phosphate	0.005
Potassium (K)	Chloride(KI)	0.03
Magnesium (Mg)	Sulfate(MgSO ₄ .7H ₂ O)	0.007
Calcium (Ca)	Nitrate [Ca(NO ₃) ₂ .4H ₂ O]	0.014
Sulphur (S)	Sulfate (SO ₄ ²⁻)	0.012
Iron (Fe)	Ferrous Ion (Fe ²⁺), Ferric Ion(Fe ³⁺)	0.0005
Manganese (Mg)	Manganese Chloride, Manganese Sulfate	0.0001
Zinc (Z)	Zinc Sulfate	0.00006
Copper(Cu)	Copper sulfate	0.00002
Boron (B)	Boric acid, Borate	0.00005
Molybdenum (Mo)	Molybdenum trioxide	0.000008
Chlorine (Cl)	Chloride	0.0075

The experimental parameters were recorded periodically and all the data were made in triplicates (n=3). Photographs were taken periodically, results recorded and all the data were analyzed for standard deviation (SD).

Result and Discussion

Hydroponics, by definition, is a method of growing plants in water based nutrient loaded solution. Hydroponics systems do not use soil; instead the plant root system is support using any of the motionless medium such as Rockwool, perlite, peat moss, clay pellets, or vermiculite (Hoagland and Arnon, 1950) [5]. The basic at the rear hydroponics is to permit plant roots to come in direct contact with the nutrient solution, while also having access to O₂, which is necessary

for proper plant growth and developments (Santos, 2013). In the present study the non-circulating hydroponic system was designed in such a way that it meets all the requirements of a typical hydroponic system but setting aside concept of nutrient circulation thus replacing the cumbersome circulatory system with simple drain off valves (Kratky, 2009) [8]. The results show that the hydroponic nutrient solution is most preferred by *M. arvensis* in the non-circulating hydroponic system over other organic nutrient solutions supplied to the root system of the plant. All the parameters of vegetative growth considered in the study show remarkable results for hydroponic nutrient culture. The chlorophyll content of the leaves was observed to be more that of control and the same is clear from the visibly dark green colour of the leaves of the plants grown in hydroponic solution. The root system which was developed extensively up to 37 – 40 cm in length in a period of 20 d is considered that the plant establishes itself well in the non-circulating hydroponic system supplied with hydroponic nutrient solution (Table. 2).

Effect of RO water (control) on the vegetative growth of *M. arvensis*

For all the experiments, RO water supplied system was kept as control to compare the vegetative growth of the plant in system devoid of any nutrients. Even the control showed growth for the sustenance of the plant. The results are given in Table 3; Fig. 4.



Fig 4: Growth of *M. arvensis* seedling an control (12th d)

Owing to the insignificant vegetative growth of *M. arvensis* noticeably due to lack of production of chlorophyll, it is pertinent to alter or substitute the organic nutrient solutions with required mineral nutrients Mg and Fe for better chlorophyll production. Hydroponic nutrient solution showed remarkable results due to the presence of all the

minerals in desired quantity (Samangooei *et al.*, 2016) [11]. There are plenty of advantages to growing hydroponically over soil-based gardening. Among them include the ability to grow more plants in a smaller space, fewer pests to worry about and no weeding. Another advantage is that many plants grow faster when raised hydroponically (Fig. 5).



a. Supports more vegetative growth and formation of chlorophyll pigments on 6th d.
 b. Supports more vegetative growth and formation of chlorophyll pigments on 12th d.

Fig 5: Replanting of control grown plants of *M. arvensis* in hydroponic nutrient solution

Table 3: Effect of hydroponic nutrient solution on the vegetative growth of *M. arvensis* on non-circulating hydroponic system.

Days of growth	Stem length in cm	Leaf size (length in cm)	Leaf size (width in cm)	Inter node in cm	Root length	Number of leaves	Chlorophyll content of the leaves
6	13	4.1	2.5	0.4	(1cm)	13	Very high
10	15	4.5	2.5	0.5	8 (1cm)	16	Very high
15	19	5	3	0.5	9 (1cm)	18	Very high
20	20	5.5	3.1	0.5	10 (1cm)	20	Very high

Table 4: Effect of RO water (Control) on the vegetative growth of *M. arvensis* on non-circulating hydroponic system.

Days of growth	Stem length in cm	Leaf size (length in cm)	Leaf size (width in cm)	Inter node in cm	Root length	Number of leaves	Chlorophyll content of the leaves
6	26	3.5	2.4	1	8 (1 cm)	18	Low
10	20.5	2.5	1.7	0.3	6 (1cm)	15	Low
15	14.5	2.5	1.8	0.4	8 (1 cm)	17	Low
20	13	2.8	1.8	0.3	7 (1cm)	16	Low

Brar *et al.*, (2014) [2] in menthol mint, Kumar and Sood (2011) [10] in pepper mint, Farooqi *et al.*, (1990) [4], Jayanthi *et al.*, (2013) Solanki and Shaktawat (1999) [15] and Jain *et al.*, (2003) [6] Singh *et al.*, (2008) [4] reported similar results in other leafy plant with reference to growth parameters considered in this experiment. Different cultivars of menthol mint irrespective of planting dates recorded significantly

different growth parameters at harvest. In fact, some plants are ready for harvest 30 to 50 percent faster than they would be if they were grown in the soil. That means in some cases you could double your harvest from a similar number of plants over the time it takes to grow in a traditional garden (Kratky *et al.*, 2000) [9].



a. Hydroponic nutrient solution root system development on 15th d (control)
 b. Hydroponic nutrient solution root system development on 15th d (treated)

Fig 6: Extensive development of roots system of *M. arvensis*

That number could be even higher when you consider that you lose fewer plants to pests and diseases when planting hydroponically. In the present study *M. arvensis* showed faster growth and proved a good harvest in a short time proving that the system designed is preferable for home gardens and also for the farmers who grow vegetables and other leafy greens (Fig. 6). If hydroponic garden was set up on the same space as a traditional garden, the harvest output would be more since hydro plants use up less space than soil-grown plants. High nutrient liquid supply ensures high productivity and no nutrient deficiency or droughts or weed menace, improvement in vegetative growth of the plant when compared to the plants grown in soil. Further study is required to manipulate the nutrient contents of the organic nutrient solutions used in the present study by supplementing them with other organic matter with rich mineral nutrient which will support vegetative growth equivalent to that of hydroponic nutrient solution will pave way for organic hydroponic farming.

Conclusion

A novel design of the cost effective, non-circulating hydroponic system was made to target the small farmers and establishment of kitchen garden. The system was easily portable and can be fixed at desired place with ease, a suitable system for growing leafy greens, Lettuce, other herbs and vegetables. Circulating hydroponic system is replaced thus reducing the cumbersome process of circulation of nutrient solution across the system which requires electric pumps, long conduit systems, electricity, large quantity of nutrient solution supply through the system, continuous monitoring and labour thus reducing the cost of establishing the hydroponic system for the leafy plants to several folds and making the system cost effective. The static model is provisioned with a drain system also for easy removal of depleted nutrients with convenience. Light

expanded clay aggregates could be used as medium in non circulating hydroponic system. *M. arvensis* prefers hydroponic nutrient solution supplied by root system. The development of root system in the hydroponic solution was very remarkable.

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