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Low-Cost Hydroponic Techniques for home and kitchen gardens

M. Kamakshi Kanchana (Asst. Professor)
B. Design (I.D), Jawaharlal Nehru Architecture and Fine Arts University
Hyderabad, India

Abstract: Hydroponics is a technique to grow plants and food without soil using water and nutrients to sustain plant growth. Hydroponics uses less water to produce the same quantity of food when compared with traditional soil-based farming. Water culture and growing plants is a technique discovered four hundred years ago and hydroponics is an extension and evolution of this principle. Space scientists have done extensive research to grow plants in space for future space exploration and human settlements in space and on other planets. There is an increased interest in hydroponics as a contending concept for the next green revolution to grow food with limited resources and space. Hydroponic farms are being built as a proof of concept. In desert areas, countries are encouraging hydroponic farms to achieve local food security to reduce dependence on food imports. Hydroponics is a viable option to grow food in cities using limited space. Rapid urbanization has pushed farms far away from cities. Food miles- the average distance that food has to travel to reach from farms to consumers makes it expensive. Fuel used for the transportation of food from growing areas to consumption centers is contributing to global warming and climate change. Hydroponics is a promising technology to build vertical farms and grow food in urban areas reducing the food miles. This paper presents the current techniques adopted by commercially successful farms and proposes low-cost techniques to adopt the technology to grow plants at home and in kitchen gardens. The designs proposed in this paper are based on locally available materials in India. Prototypes are built and plants are grown using water and nutrients and results are reported. Detailed drawings are given to build hydroponic containers with low-cost material available in the market so that a small home garden, kitchen garden, or balcony garden is built without soil.

Keywords: Food miles, Food security, Hydroponics, Kitchen garden, Vertical farming

1.0 Introduction

Growing plants in just water medium without is a documented four hundred years old technique. Francis Bacon mentioned this in a book titled Sylva Sylvarum published in 1627 (Bacon and Rawley 1670).

Hydroponics uses less water to grow food when compared to soil-based plants ("Hydroponics" 2022). Around 200 liters of water is needed to produce one-kilogram tomatoes whereas hydroponics requires just 70 liters of water. Hydroponics is definitely a contending technique to grow food under scarce resource situations.

Dubai has the world's largest vertical farm (Davos 2022). Annually 900 tonnes of leafy greens are produced in a 30,000 square-meter vertical arm. Artificial light, a controlled indoor environment, and hydroponics is an integral part to achieve production. The current trend of urbanization is leading to densely populated cities. It is estimated that by 2050, 70% of the human population will be living in urban locations. Conventional intensive farming techniques are not sustainable (Boylan 2020). Vertical farms and the production of food closer to the cities where people live is the solution to the problem. Large-scale vertical farms are needed to produce food addressing sustainability issues. Providing water for the irrigation of crops is a challenge. Droughts and drying rivers are posing a threat to sustainable crop yield. Excessive usage of chemical fertilizers and pesticides has resulted in serious environmental concerns. Hydroponics uses less resources and promises to address sustainability concerns (Boylan 2020).

Food miles are an important concept in the food production and supply chain ecosystem. In India, fresh vegetables travel anywhere between 40 kilometers to 2000k kilometers to reach from farm to dining table. Transportation costs are the major component in the pricing of food items.

Apart from the economics, food miles contribute to increase usage of fuel and lead to global warming. Sustainability considerations make it important to reduce food miles. Producing food closer to consumption centers is prudent and ecologically friendly (Paulrajan 2010).

Home gardens and kitchen gardens in cities will supplement food production and go a long way in reducing the food miles. Traditional soil- based home gardens require good potting soil and water. Furthermore, watering plants is a daily ritual. People who frequently travel avoid growing plants at home because of watering constraints. Hydroponics is a promising technique and water and nutrient replenishment is not required daily.

Commercially available hydroponic systems are expensive and are targeted to address large rooftop systems. This paper proposes a design for small home gardens with inexpensive material which is locally available.

Detailed illustratins are provided. Prototypes are built based on the design and plants are grown as a proof of concept and results are reported.

2.0 Essential components of Hydroponic system

Any hydroponic system design will consist of the following components:

- Components for germination
- Net pots or Mesh pots for growth and support of plants
- Growing substrate
- Containers-Bato Bucket (Dutch bucket) to hold water, nutrients, and plant root system ("What is Bato Bucket (Dutch Bucket)? - Definition from Maximum Yield" 2021)
- Water
- Fertilizer

2.1 Components for germination

Germination of seeds and obtaining healthy sprouts is essential to growing plants using hydroponics. Sponge, rock wool, and paper can be used for germination and sprouting. The following images show germination using a sponge and paper napkin.

Figure 1: Germination of Basil Seeds on paper napkin and sponge

2.2 Net pots or Mesh pots

Net pots or mesh pots are needed to anchor the plants. Plastic moulded net pots are commercially available in the market and are available in varying sizes- 2" to 6" diameter (Marco 2022). Regular plastic containers can also be used to convert them into mesh pots by making cuts for aeration and spreading the root system.

(a) (b)

Figure 2: (a) Illustration of Net Pot for hydroponics, (b) Commercially available Net Pots sold by various manufacturers (Tmtamye Brand, n.d.)

2.3 Growing substrate

Soilless method of growing substrate is an essential component of any hydroponic system. Light Weight-expanded clay aggregate (LECA) is an excellent substrate for growing plants using hydroponics techniques. It is made of small one-inch diameter clay pebbles and heating them in a kiln at 1200 degrees Celsius. It can be procured from the market or can be made if you have a potter's kiln in your garden. The author has extracted clay from garden soil and produced good-quality clay pebbles ("Expanded clay aggregate" 2022).

Figure 3: Clay made from garden soil

Clay from garden soil was extracted using the technique explained in the article ("How to Make Clay From Dirt: Steps for Producing Natural Clay - 2022" 2022)

2.4 Containers to hold water, nutrients, and root system

Net pots are placed over closed containers. Containers hold water, nutrients, and roots of the plant. Bato or Dutch buckets are extensively used in commercial farms. However, any plastic container, plastic bucket, or paint can be easily converted to support plant growth

2.5 Water and fertilizer

Normal tap water can be used for hydroponic systems. However, it is essential to maintain the correct pH value by using the concentrations of fertilizer per liter of water as recommended by the fertilizer manufacturer. Hydroponic plants require thirteen essential nutrients as tabulated in the following table:

MACRO NUTRIENTS	MICRO NUTRIENTS
Nitrogen	Iron
Phosphorous	Manganese
Potassium	Copper
Calcium	Boron
Magnesium	Zinc
Sulfur	Molybdenum
	Chlorine

Ready-made liquid fertilizers are available in the market. However, they are very expensive. It is possible to buy normal fertilizers from the market and create your own recipe (Wortrich 2022).

3.0 Design of Low-cost Hydroponic Components

This paper proposes the following low-cost hydroponic component designs. Design is based on inexpensive material that is readily available in Indian markets.

- Bucket System
- Basket System
- Recycled Mineral water bottle system

- PVC plumbing pipe system

3.1 Bucket System

Commonly available plastic bucket with a lid is used in this system. A suitable hole is drilled on the lid to push the net pot. The bottom portion of the bucket will act like the holding unit for water, nutrients, and roots.

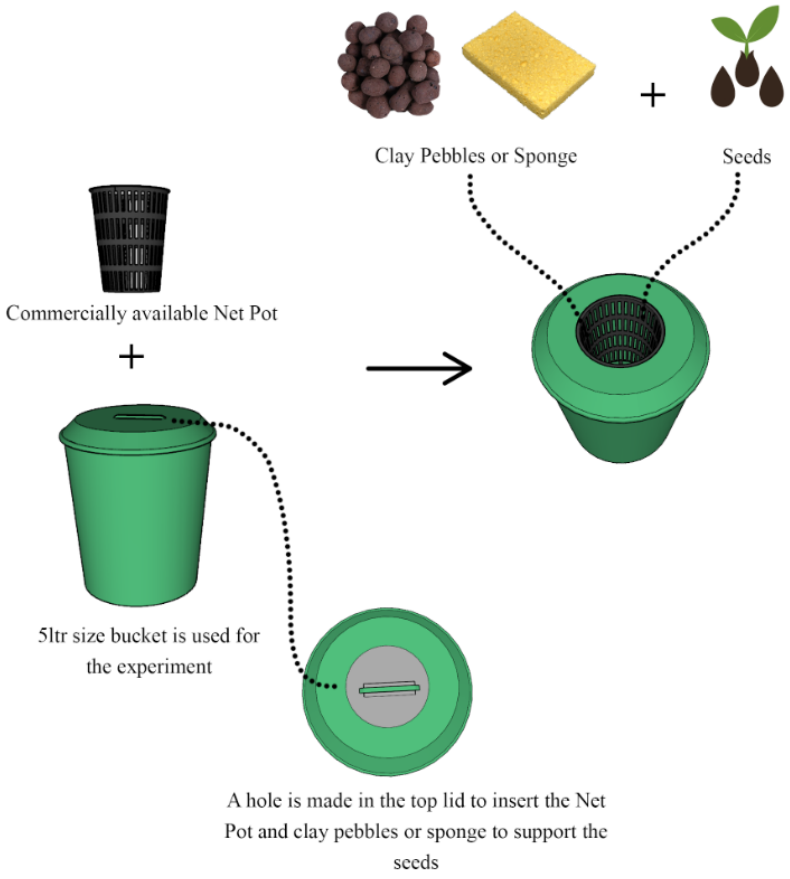

Figure 4: Illustration Showing the Bucket System

3.2 Basket System

Plastic trays are readily available in the market. Design involves using two plastic trays stacked over each other. The bottom portion of the top tray is cut and replaced with a stainless-steel mesh and glues using epoxy-based resin. The top tray acts like a net pot and the bottom tray will act like a container. On the top tray, either paper or cloth is used as a substrate for germinating the seeds. The basket system is suitable to grow green leafy vegetables.

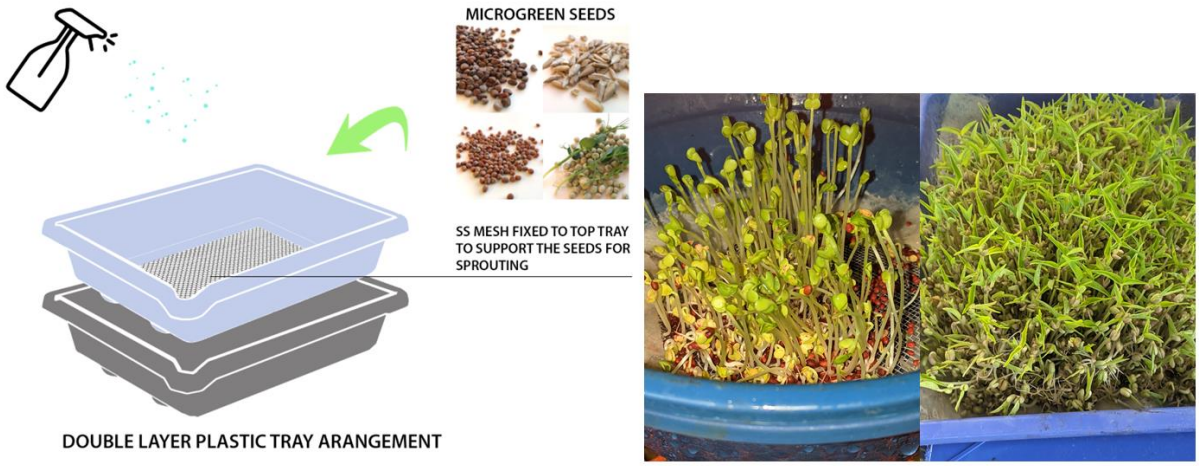

Figure 5: Illustration and Experimental results of the Tray systems

3.3 Recycled Mineral water bottle system

Millions of mineral water plastic bottles are discarded every day creating environmental issues. These bottles can be converted into Hydroponic containers to grow ornamental plants and food. The lid and neck are cut to accommodate a small net pot. The bottom portion of the bottle will act like a container.

Figure 6: Hydroponic farming using recycled mineral water bottles

3.4 PVC Plumbing System

Design of this system involves using standard 2-inch diameter PVC plumbing pipes and two end caps. Suitable holes are made on the top side of the pipe to insert net pots. The ends of the pipe are sealed using end caps and sealant. The pipe will act like a container. This system is suitable to grow small plants and leafy vegetables.

4.0 Experimental Results

The prototypes were built based on the designs included in this paper. Tomatoes, leafy vegetables, onions, and garlic were grown as proof of concept. Commercially available liquid fertilizer was used and also for a few plants standard NPK fertilizer was used and mixed in water with excellent results. Images of plants grown are given below:

5.0 Conclusion

Hydroponics is a promising technology to usher in the next green revolution. Production of food with limited resources and urban locations where the bulk of consumers live is an important goal for all town planners. Reduction of food miles by producing food closer to cities will serve the sustainability concern. Food security during natural calamities and pandemic situations can be achieved by building small farms and kitchen gardens. The low-cost designs proposed in this paper will a long way to encourage households to adopt hydroponic techniques.

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