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Hydroponic systems for cultivation of horticultural crops: A review

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Abstract
Hydroponics system is used for the cultivation of horticultural crops in controlled condition with or without the use of any substrate for the good quality production. In this paper hydroponic systems developed by the research workers for cultivation of horticultural crops have been reviewed and summarized. Attempt has been made to review low cost hydroponic systems and can be easily adopted by the urban as well as rural people. There are many techniques which are used in the hydroponics systems like A-frame, U-shaped, Vertical Tower, Horizontal System with the direct circulation of water with nutrient where as in some techniques water is not directly re-circulated but used once like in case of Trough or Grow Bag techniques. On the basis of circulation of water also there are some techniques like flood and drain method, Nutrient Film Technique and Deep Flow Technique which are used in hydroponic systems. Study revealed that system developed and reported are required to be modified further for their adoption for cultivation of horticultural crops.

Keywords: Grow bag, hydroponics, NFT, trough

Introduction
Hydroponics is a technology for growing plants in nutrient solutions (water containing fertilizers) with or without the use of an artificial medium (sand, gravel, vermiculite, rockwool, perlite, peatmoss, coir, or saw dust) to provide mechanical support (Jensen, 1997). Nutrients are mixed in the water and fulfills nutrient requirement of the crop. Among different soilless growing media available, coco peat is cheapest and easily available. Joseph and Muthuchamy (2014) [8] suggested that there is a need for low cost, readily available, simple, attractive technologies which can utilize space and water efficiently to increase the productivity in agriculture. Simplified hydroponics is one such option which does not require costly facilities, high running cost and intensive care. In India, hydroponics was introduced by a english scientist, who established a laboratory in Kalimpong area, West Bengal. He written a book on Hydroponics, named as Hydroponics the Bengal System (Douglas, 1951) [4]. Later on during 1960s and 1970s, commercial hydroponics farms were developed in Abu Dhabi, Arizona, Belgium, California, Denmark, German, Holland, Iran, Italy, Japan, Russian Federation and other countries. During 1980s, many automated and computerized hydroponics farms were established around the world (Hussain *et al.*, 2014) [7]. There are many different methods which can be used to grow crops hydroponically. It ranges from the cultivation of horticultural crops in pipe systems in which water is circulated inside the pipe system with nutrient solution. Classification of hydroponics cultivation depends upon type of structure, nutrient delivery system to the plant and drainage. On the basis of it different hydroponics systems are used in the cultivation of horticultural crops. Troughs and grow bags are another method of cultivation which also comes under hydroponic system with use of some substrate and application of water and nutrients externally for the growth of horticultural crops covering vegetables, flowers as well as some fruit crops. The enhancement of product quality, particularly in vegetable crops can be achieved through the complete control of nutrition in hydroponics (Savvas, 2003) [13]. It is highly productive with less labour and time, conserves water and land and protects the environment. This also overcomes problems like soil borne diseases, salinity, poor structure and improper drainage (Arathi, 2016) [1]. Soil less culture can be defined as "any method of growing plants without the use of soil as a rooting medium, in which the inorganic nutrients absorbed by the roots are supplied with the irrigation water". The fertilizers required to supply essentially containing nutrients for the maximum production of a crop to be supplied are dissolved in the appropriate concentration in the irrigation water and the resultant solution is referred to as "nutrient solution" (Savvas *et al.*, 2013) [13].

Hydroponics Systems: Hydroponics system is an emerging technique in the field of horticulture. This technique can be used in combination with protected environment for the cultivation of various horticultural crops where land is not suitable for the cultivation. Nowadays roof top and terrace gardening is gaining popularity in urban areas for various reasons and hydroponic system can be a good opportunity for the production of vegetables, flowers and some fruits in kitchen garden and roof top cultivation techniques. There are many types of hydroponics systems are being used in India and abroad for the cultivation of horticultural crops, details of few hydroponic systems developed based on different aspects are considered in this paper.

1. Based on structure and material

a. **A-Frame hydroponic system:** A study was carried out at Centre of Excellence on Protected Cultivation and Precision Farming (CoE-PCPF), IGKV, Raipur (C.G.) during the year 2017-18 for fabrication and performance evaluation of A-frame hydroponic system under protected structures (Fig.1) (Krishan *et al.*, 2020) [10]. The experiment was laid out with three treatments T_1 (A-frame PVC pipe), T_2 (A-frame UPVC pipe), T_3 (A-frame CPVC pipe), of hydroponic system for the cultivation of leafy garlic. Hydroponic system in this study has been fabricated with the help of locally available material which reduced cost of construction substantially. Details of A-frame hydroponic system is given in Table 1. Effects of material on the growth of plants, EC and pH level of nutrient solution have been studied and it was found that material has a very little or no effect on the growth as well as EC and pH aspects of nutrient solution at least in the first year of cultivation which might be changed in later years. Appearance wise good and moderately costlier UPVC pipes can be a better option for the design and construction of commercial hydroponic systems.

b. **U-Shaped hydroponic system:** In this system pipes are arranged in a manner which forms U shape thus the name of the structure has been given as U-shaped hydroponic system (Krishan *et al.*, 2020a) [11]. The U-shaped hydroponic system in shown in Fig.2. An experiment was carried out on it at IGKV, Raipur in the year 2017-18. The experiment was laid out with three treatments T_1 (U-Shaped PVC pipe), T_2 (U-Shaped UPVC pipe), T_3 (U-Shaped CPVC pipe), of hydroponic system for the cultivation of lettuce crop. It was concluded that UPVC pipes can be a better option for the design and construction of commercial hydroponic system. Details about the U-shaped hydroponic system are given in Table 2.

c. **Vertical hydroponic tower:** Heredia, (2014) [6] conducted an experiment on design construction, and evaluation of a vertical hydroponic tower in California. It was similar to A-frame hydroponic system but in this case flat pipes instead of circular pipes have been used. Vertical hydroponic tower is to increase the productivity per acre of land. Two hydroponic systems drip and nutrient film technique were used for the cycle of nutrient rich water then return back to the reservoir (Fig.3). Five different plant varieties were evaluated on the basis of elevation, system type and crop type to determine the most productive. They recommended for future growing cycles is to use the same wood frame but to modify the troughs by adding an additional hole between the existing holes to increase the amount of plants grown.

Fig 1: A-Frame Hydroponic System

Fig 2: U-Shaped Hydroponic System

Fig 3: NFT and Drip Trough

Table 1: Details of A-Frame hydroponic system (Krishan *et al.*, 2018)

S. No.	Particulars	Specification
1.	Length of system	152.40 cm
2.	Height of system	182.88 cm
3.	Width of system	91.44 cm
4.	Slant height of system	198.12 cm
5.	Length of pipe	152.40 cm
6.	Distance between hole	26.67 cm
7.	Distance between pipe	30.48 cm
8.	Tank capacity	100 lt.
9.	Dia of hole	64 mm

Table 2: Details of U-Shaped hydroponic system (Krishan *et al.*, 2018) [9]

S. No.	Particulars	Specification
1.	Length of system	152.40 cm
2.	Height of system	152.40 cm
3.	Distance between three angle rod	76.20 cm
4.	Distance between hole	26.67 cm
5.	Length of pipe	154.40 cm
6.	Tank capacity	30 lt
7.	Dia of hole	64 mm
8.	Distance between pipe	30.48 cm

d. Horizontal hydroponic system (HHS): In this system pipes are arranged only in horizontal manner on a stand. Touliatos *et al.*, 2016 experimented with vertical and horizontal hydroponic system and according to them the HHS comprised of five cylindrical PVC pipes (45.5 cm high and 3.6 cm radius), filled with 130 g ±0.5 g of perlite (LBS
Horticulture Ltd, Lancashire, UK) and placed in parallel at 20 cm apart center to center. Each pipe held four plants placed in 4.4 cm square holes, in rows. Each HHS contained 20 lettuce plants in total as shown in Fig. 4.

e. Trough system with substrate: In this system plastic troughs are used in place of pvc pipes in which substrate like cocopeat, perlite, vermiculite are filled and seedlings are transplanted and grow fully on this media only. Water and nutrients are generally supplied through drip irrigation system as per the nature and growth of crop. These troughs are durable and easy to transport from one place to other. It comes in rolled form which can be laid down on the field after spreading and cut at a particular length as per requirement. Specifications and other details of plastic troughs are given in Table 3. It is used in many places inside protected structure for the cultivation of different horticultural crops like Tomato, Capsicum and Cucumber. Experiment being carried out at IGKV, Raipur on trough cultivation is shown in Fig. 5.

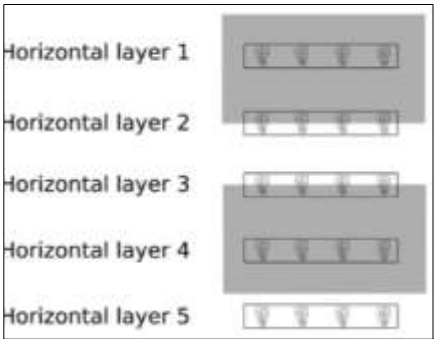

Fig 4: Overhead view of HSS

Fig 5: Trough System with substrate

Table 3: Specifications and other details of plastic trough

S. No.	Particulars	Details
1.	Material of trough	Polypropylene
2.	Colour	Black
3.	Shape	Rectangular
4.	Thickness of sheet	700-1000 micron
5.	Available widths	50-180 cm as per crop needs
6.	Quality	UV stabilized
7.	Width of bottom trough in rolled form	36 cm
8.	Width of bottom trough after placing on land	23 cm
9.	Width of upper trough in rolled form	60 cm
10.	Width of upper trough after placing on land	20 cm
11.	Depth of upper trough	20 cm
12.	Volume of 1metre long trough	0.04 m^3

f. Grow bags with substrate: In this type of cultivation practices small grow bags usually white in outside and black inside (nowadays green outside also available) is used with substrate like cocopeat and perlite. These grow bags are easily available in market with different sizes and capacity. It can be used on lands which is not suitable for cultivation by placing these grow bags after some leveling of the land. These grow bags can also be used in urban areas for the roof top gardening. Bauerle, 1984 suggested that there is a new system in future which shows considerable merit-growing crops in a peat vermiculite mix placed in plastic bags, which are then oriented into rows in the greenhouse. This particular bag culture system has been investigated and tested over four growing seasons in greenhouses at the Ohio Agricultural Research and Development Center (OARDC), Wooster, Ohio, USA. The bag culture system of greenhouse vegetable production has proven highly successful and offers a number of advantages over conventional planting in soil ground beds i.e. control of plant growth is more precise. Faster crop turnaround is possible. There is better utilization of energy where bag culture is used. The system offers optimum use of fertilizers and reduction in fertilizer usage. There is no recirculation of spent nutrient water in the bag culture system. Thus disease introduction by water is virtually eliminated. Cultivation of vegetable in grow bags in IGKV, Raipur is shown in Fig.6.

Fig 6: Grow Bags with Substrate

2. Based on nutrient flow

a. Flood and drain hydroponic system: Patwardhan, 2016 carried out a study on design of flood and drain vertical hydroponic system for cultivating Chinese leafy vegetable Pak-choi at Nashik, India. The sowing of 112 seeds of Pak-choi was done in perforated net pots containing media of coco-pit (8% *N : P : K* treated) and vermiculite in 1:1 proportion. Irrigation was applied to the crop by deep flow technique through beds. They observed Yield of Pak-choi crop in hydroponic system was twice than the yield obtained from field conditions and the Flood and Drain Vertical (FDV) hydroponic system designed gave 66% more cropping area than the open field. Flood and drain hydroponic system is similar to the Ebb and flow system consists of water-tight growing bed and tank of nutrient solution. The nutrient solution present in the tank is pumped for fixed interval of time into the growing bed for a short duration (5 -10 min). The tank of nutrient solution is placed below the growing bed so that nutrient solution can easily re-circulate in the system. (Krishan *et al.*, 2018) [9].

b. Nutrient film technique (NFT): It is a hydroponics system, where the plant roots are directly exposed to the thin film of (thickness 0.5mm) nutrient solution flowing through the channel. The growing media absorbs the nutrient solution though the porous root system of the plant. (Hasan *et al.*, 2018) [5]. Burrage, 1993 [3] stated that the flexibility of the NFT system has enabled it to be adapted to a wide range of crops. There have been many improvements in the system over the years but it has been characterized by producing a high quality and quantity of the particular crop.

c. Deep flow technique (DFT)/ pipe system: In this technique, 2-3 cm deep nutrient solution flows through PVC pipes to which plastic net pots with plants are fitted. The plastic pots contain planting materials and their bottoms touch the nutrient solution that flows in the pipes (Hussain *et al.*, 2014) [7]. Pump, tanks, valves, timers and other accessories including nutrient monitoring system are placed over the floor of the protected structure. PVC pipes are arranged in single horizontal plain or in multiple zig-zag vertical plain (Hasan *et al.*, 2018) [5].

Other than these there are methods which are also used in hydroponics system like root dipping technique, floating technique and aeroponics techniques etc.

Conclusions

On the basis of review on hydroponic system developed considering different mentioned in this paper it can be concluded that A-frame, U-shaped, vertical tower and horizontal hydroponic systems are suitable for small area, however trough and grow bags hydroponic systems are suitable for large area. This can also be concluded that all the nutrient flow techniques are suitable for uniform flow of nutrients in the plant root to achieve higher production. Some more studies are required to be reviewed and modifications should be done, if needed for reducing the cost to enhance their better adoptability among the rural and urban farmers.

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