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Design and evaluation of low cost rectangular framed hydroponic system in leafy vegetables

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Abstract
The primary goal of this research is to develop a hydroponic system from locally available materials that can be widely used by city dwellers. Total area occupied by the system is 2.78 square meter. Fenugreek crop is grown in both hydroponic and conventional systems and essential crop parameters like crop height, root length and colour are observed at regular intervals of two days after transplantation. Crop growth and average root length are slightly higher in a hydroponic system than in a conventional system. The crop in a hydroponic system is pale yellowish-green in colour, indicating a lack of micronutrients. BC ratio and Payback Period of structure was found as 2.1 and 3.0 respectively.

Keywords: Hydroponic system, conventional, EC, pH

Introduction
Soil is primarily used as a plant-growing medium. For successful plant growth it provides nutrients, air, water etc. The accelerated industrialization and urbanization, the open field/soil-based agriculture is posing significant challenges, the most significant of which is a decrease in land availability per capita (Supraja et al 2020) [5]. With an increase in fertilizer application, soil fertility status has reached a saturation point, and crop productivity is decreasing from harvest to harvest. Growth of plant is restricted due to the presence of unsuitable soil reactions, disease-causing micro-organisms, soil compaction, poor drainage, erosion, and other factors. Furthermore, open-field agriculture necessitates a large amount of space, a lot of labour, and a large volume of water (Sardare and Admane 2013) [4]. Soil salinization is also one of the most serious sources of yield loss in modern agriculture (Signore et al 2008) [7].
The hydroponics system was considered for mitigating the aforementioned issues. Gericke coined the term hydroponics in the year 1936, and it was derived from two Greek words, hydros and ponos, which have mean water and labour respectively. It is a method of growing plants in nutrient solution with or without the use of a mechanical support medium such as sand, vermiculite, gravel, rock wool, peat moss, perlite, coir, or sawdust (Jensen 1997) [2]. Plants are grown in soilless culture without the use of soil. Growing plants in solution culture is easier than growing plants in soil culture because there is no need for soil, there are no soil-borne diseases or pests, and irrigation is less frequent. The roots are visible, and the root zone environment is simple to monitor and control. The basic idea behind hydroponics is to expose the plant's roots to the nutrient solution. It is becoming increasingly important to re-circulate and re-use nutrient solutions in order to reduce environmental and economic costs (Bugbee 2003) [6]. While also assessing the importance of oxygen for plant growth. Because the system is mobile, easy to harvest, and does not cause pesticide damage, it enables stable to high running yields, diseases, and pests that are easier to eradicate than in soil. The primary benefit of hydroponics is that it requires less water than soil and can be used in areas where in-ground agriculture or gardening is not feasible (Krishan et al 2020) [3].

Material and Methods
Description of Study Area
The experiment was carried out in a controlled environment of a naturally ventilated poly-house at the College of Agricultural Engineering in Madakasira, Andhra Pradesh, during the academic year 2020-21. Madakasira belongs to Rayalaseema region is at latitude 27.20° N and longitude 77.49° E and an Altitude of 676 meters above the mean sea level.

Experimental site and design of structure

The current research is being conducted for the "Design and Development of Rectangular-Framed Hydroponic System" during the project work at College of Agricultural Engineering, Madakasira. Angle iron is used to construct the system which includes L-angular-20 kg, circular rods-3 kg, and square pipes-10 kg. PVC pipes 2 No. of 90 mm diameter of length 6.0 m are cut into 8 pieces of length 1.5 m and holes are drilled on the pipes with a spacing of 15.5 cm. To provide proper sunlight and to prevent overlapping of plants alternate pipes i.e., 1, 3, 5, 7 were provided with 10 holes where as 2, 4, 6 and 8 pipes were provided with 09 holes. These are kept on the frame with help of U-Clamps with a spacing of 15.5 cm and these pipes are linked by LLDPE pipes to circulate the nutrient water from one to the other. Submersible pump of 0.0241 Hp (18 watt) capacity was used to pump water from water tank with the help of flexible pipe of 2 cm diameter. To prevent the drainage of nutrient solution and water from PVC pipes, end caps were fixed on both the ends of pipe. Local drums are placed at bottom of structure and are used to hold and supply water & nutrient solutions. One plant requires 500 ml of water and there are 76 plants and water required for all plants was approximately 40 litres. To circulate enough water without trapping air, two drums with a total capacity of 80 litres were provided. Water is supplied to the system via a flexible pipe and the submersible pump. T-joint, used to connect two flexible pipes so that to divide head of submersible pump equally to prevent over flow. Control valves are installed at the ends of two flexible pipes used as inlets to regulate the flow of nutrient solution and water from drums to the PVC pipes.

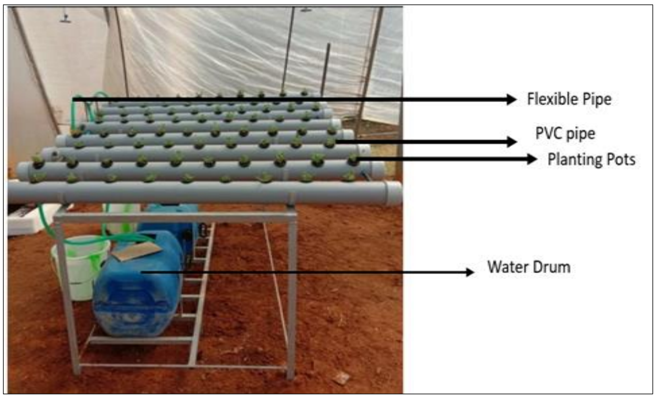

Fig 1: Rectangular framed hydroponic structure

Planting pots with media such as cocoa-peat, pebbles, sponge, and so on were used to provide stability to the plants. To prevent and protect against corrosion, the structure is painted with silver paint. The system takes up a total of 2.78 square metres. Under the poly-house, a hydroponic system using the nutrient film technique is established is as shown in the Fig. 1. Benefit cost ratio calculated by using cash inflows by cash outflows where as payback period estimated by total cash outflows and cash inflows per year.

Crop growth, maintenance and harvesting

Fenugreek seedlings are grown in trays before being transplanted into planting pots. The pots were properly inserted in the drilled holes of the pipes. Coco-peat is commonly used to provide plant stability because of its ability to store and release nutrients in plants over long periods of time. An EC metre was used to determine the salt concentration of the nutrient solution. EC for leafy vegetables should be 1600 ppm. If the value is less than 1600 ppm, nutrient solution should be added; otherwise, water should be added to maintain the required EC. pH for leafy vegetables should be maintained between 5.5-6.5 pH. Crop parameters like root length, crop height, colour are observed at regular interval of 2 days. 1st harvesting was done after fifteen days of transplantation 2nd, 3rd, 4th, 5th and 6th harvestings are done every 12 days interval.

Working of system

Nutrient solution and water are circulated from water drums to the PVC channels with the help of flexible pipe. The head of the submersible pump was divided using a T-joint to prevent water over flow. The inlet was provided into 1st and 5th pipes. Nutrient solution and water pass through each planting pot and then it enters from (1st-2nd), (2nd-3rd), (3rd-4th) and from 5th pipe water flow as follows (5th-6th), (6th-7th), (7th-8th). Water is returned to the vessels via the 4th and 8th pipes. Water and nutrient solution were thus re-circulated in this manner.

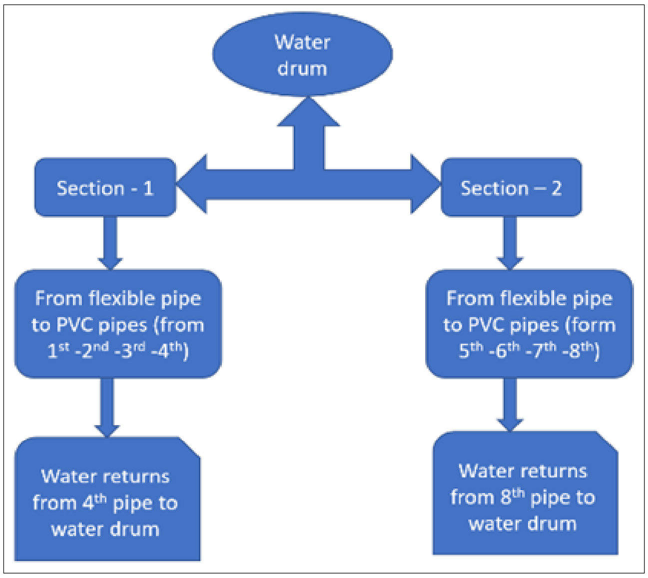

Fig 2: Water Circulation

Results

Economics of low cost Hydroponic system

The cost of the materials used to build the structure is calculated to determine the hydroponic's system economy. The total cost of the Rectangular-Framed Hydroponic structure fabrication is Rs. 6000.0. (Approximately).

Table 1: Detailed Cost estimation of Rectangular-Framed Hydroponics system of size 2.78 square meters is as shown below

Item	Quantity	Cost (Rs/-)
Metal (L-Angular, Square)	40 kgs @ 1 kg 60/-	2400.00
Submersible pump (18 watts)	1 No.	410.00
Drums (100 litres capacity)	2 Nos. @ 1 No 150/-	300.00
PVC Pipe (90 mm)	6 meters @ 2 Nos.	1400.00
End caps (90 mm)	16 caps @45/-	720.00
Planting pots of (5×5) cm	76 Nos. @ 4/-	304.00
Silver Paint	250 ml	416.00
Total Structure cost		Rs:6000.00
Seeds of fenugreek	10 grams	20.00
Coco-peat	2kg @ 25/- per kg	50.00
Nutrient solution		
a) $KNPO_3$	500 ml	70.00
b) N, P, K	500 ml	70.00
Miscellaneous (Maintenance and Electricity cost)		250.00
Cost of cultivation		460.00
Gross returns from fenugreek(6 harvestings in 3 months)	Rs: 160/-(per harvest)	960.00
Net returns(in 3 months)		500.00
B.C. Ratio		2.1
Payback period		3.0

Calculation of Benefit-cost ratio and payback period
Crop sales per harvest is 160/- and total revenue obtained to be 960/- per 3 months. BC ratio calculated as a result of gross return and cost of cultivation. Payback period was obtained by considering the net returns per annum and total structure cost.

Crop parameters
Crop parameters like height, root length and colour were observed at regular intervals of 2 days after transplantation in hydroponic system and conventional system. Plants are chosen at random from both the hydroponic and conventional systems for data collection. Thus, there are three plants (average of three replications) of each growing system from which data was collected and recorded. Height of crop, and root growth of plants are shown below in bar diagram Fig.3 & Fig.4.Due to a lack of micronutrients, the crop appears to be pale yellowish green in colour.

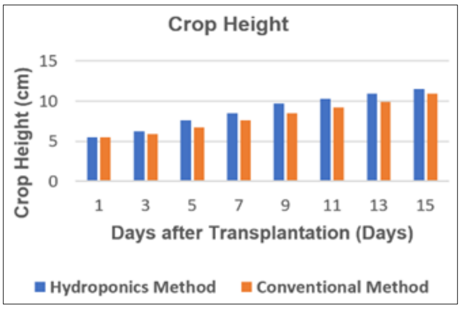

Fig 3: Root Growth

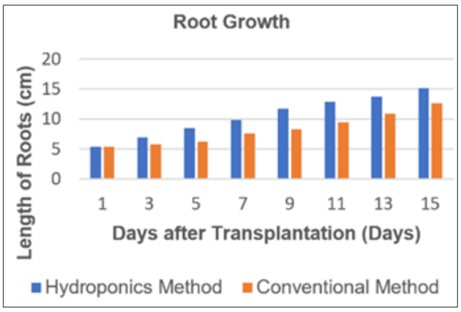

Fig 4: Crop Height

Conclusions
From this research, it is concluded that we can grow different types of leafy vegetables at a time because the nutrient solution is same for all leafy vegetables. It is difficult to carry the frame one place to another place, because it is done by welding, instead of welding, if it is fabricated with drilled angle iron along with bolts and nuts becomes more convenient to transfer from one place to other. The crop's colour is pale yellowish green due to a lack of micronutrients and insufficient oxygen availability; this issue can be solved by adding enough micronutrients or by adding perforations to PVC pipe.

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