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Design and Fabrication of Hydroponic System for Leafy Vegetables

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Abstract — In today's date urban farming is one of the key solutions to global food insecurity, however due to land scarcity inside urban areas, implementation of these solution is challenging. To address this urban hydroponic farming is introduced since hydroponics is an effective way of conserving both water and space. However, hydroponics itself is complicated because there are various factors that can affect the growth of plants. This study shows the design, fabrication and testing of hydroponic tower prototype for growing various crop using cocopeat as a growing media. Also, analysis on various parameters such as plant length, leaf size, ambient temperature, relative humidity, pH level and electrical conductivity can be done. Plant growth and environmental condition showed that hydroponic tower was a success in terms of growing 'Fenugreek' (Methi) using cocopeat media.

Keywords — *Urban Farming; Hydroponic; Tower Prototype; Cocopeat.*

1. Introduction

Hydroponics is also called as "controlled environment agriculture" (CEA) since raising plants hydroponically requires control of environmental factors such as light intensity and duration, temperature, humidity, pH of the media and mineral nutrients (Valentin *et al.,* 2017). One of the new progressive ways of the plant productivity increases in the development of a new branch of biological industry i.e. biotechnology of soilless cultivation of plants in a completely or a partially controlled environment this will allowed to discover all potential opportunities of plants and to make a good use of the lands abandoned by traditional agriculture. Soilless cultivation is now developing fairly fast in many countries of the world (Japan, Netherland, France, Italy, and Sweden) where in addition to research centers, are big hydroponic farms.

Growing crops in hydroponics under protected cultivation can be considered the most complex production system available today. In terms of farming systems, Ruthenberg (1980) classified hydroponic cultivation as a "high input – high output- high risk" system. In fact, the available techniques to date required considerable specialisation with sophisticated management and know-how as well as high financial inputs to realise expected production potential, otherwise the crop failures can be disastrous. Before going for a large-scale hydroponics system, the growers should be much more critical in regard to site selection, structures, the growing system, pest control and markets (Pandey *et al*., 2009).

Today, hydroponics is an established branch of agronomical science. Progress has been rapid and results obtained in various countries have proved it to be thoroughly practical and to have very definite advantages over conventional methods of agriculture/horticulture. Hydroponics is the fastest growing sector of agriculture, and it could very well dominate food production in the future. As population increases and arable land declines due to poor land management, people will turn to new technologies like hydroponics and aeroponics to create additional channels of crop production. To get a glimpse of the future of hydroponics, we need only to examine some of the early adopters of this science. In Tokyo, land is extremely valuable due to the surging population.

In aggregate hydroponics system, a solid, inert medium provides support for the plants. As in liquid systems, the nutrient solution is delivered directly to the plant roots. Aggregate systems may similar be either open or close depending on whether, once delivered, surplus amounts of the solution are recovered and reuse.

2. Materials and Methods

2.1 Construction of Hydroponic Unit

2.1.1 Fabrication of Tower

The frame serves as the structural support that will hold the PVC pipes and other devices such as drip laterals in place. In choosing the right material for the frame various factors considered are cost, durability and availability. The indoor tower had a total dimension of 1.30 m × 1.33 m × 1.03 m and was made from galvanized steel pipes.

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Fig.1: Fabrication of Tower

2.1.2 Growing Channels

Considering the minimum area required for holding of root biomass of the plant, a PVC pipes of 90 mm diameter and 1.2 m in length was used as a growing channel. There are total 8 PVC pipes mounted on the frame. Each PVC pipe was provided with some slope to drain the excess water.

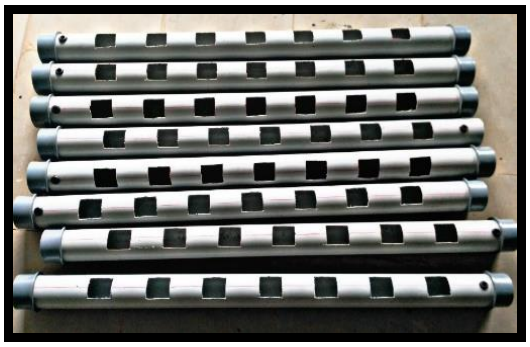

Fig.2: Growing Channels

2.1.3 Drilling of Holes

Square shaped holes were drilled on the PVC pipe using hack saw. Total of 7 holes were drilled on each pipe of length 1.2 m.

Fig.3: Drilling of holes

2.1.4 Assembling

The drilled PVC pipes were placed horizontally on the frame. Online drip lateral of 16 mm diameter was placed along each PVC pipe. Small microtubes was fitted to each lateral to supply water from lateral to the roots of plants. Total of 12 m lateral was required for whole structure.

Fig.4: Assembling of Hydroponic system

2.1.5 Water Supply System

The water tank of 75 litre was provided above the structure to irrigate the crop through lateral pipes. Drip laterals were connected to the water tank by using grommet and take off.

Fig.5: Water tank

Fig.6: Irrigation accessories

2.2 Crop

The crops are planted into the pipes with the mixture of cocopeat and vermicompost. The mixture filled in pipe about two third of pipe diameter. 15 to 20 seeds are sown in one square shaped holes. Fenugreek (*Trigonella Foenumgraceum*) is an annual plant in the family Fabaceae, consisting of three small obovate to oblong leaflets. It is cultivated worldwide as a semiarid crop. Its leaves and seeds are usually consumed as an ingredient of many Southern and Central Asian dishes. Fenugreek is used as a

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herb (dried or fresh leaves), spice (seeds), and vegetable (fresh leaves, sprouts, and microgreens). Sotolon is the chemical responsible for the distinctive maple syrup smell of fenugreek.

Table 1. Crop Details

Crop variety	Average height (cm)	Germination Period	Cost per 1 kg	Harvesting period	Germination rate
Fenugreek (*Trigonella Foenumgraceum*)	40-80 cm	3-5 days	150 Rs.	30 days	91.80%

Table 2. Devices and Instruments

S.No	Devices and Instruments	Vegetative Parameters
1	Weighing Balance	Number of emergences
2	pH-meter	Plant height
3	EC- meter	Number of leaves
4	Measuring scale	

Table 3. Material

S. No.	Material	S. No.	Material
1	Water tank	6	Cocopeat
2	PVC pipe	7	Vermicompost
3	Metal stand	8	pH indicator
4	Seeds	9	Electrical conductivity meter
5	Dry & wet bulb Thermometer	10	Irrigation material

Table 4. Specifications of the given hydroponic system

S. No.	Specification	Measurement
1	Total length of model	1.33 m
2	Total height of model	1.30 m
3	Total width of model	1.03 m
4	No. of PVC pipes used	8 nos.
5	Diameter of PVC pipe	90 mm
6	Diameter of lateral	16 mm
7	Capacity of water tank	75 litres
8	No. of holes on each pipe	7 holes
9	Total length of lateral	12 m

2.3 Methods

Step 1 : Assemble the Hydroponic System

The complete structure was assembled by placing the PVC pipe on the tower framed stand and connecting the water tank to the lateral. The tank was placed at some height above the structure. The lateral for irrigation were provided along the PVC pipe. The lateral consists of small microtubes which provide the water from lateral to pipe.

Step 2: Washing of growing media

The selected growing media i.e. cocopeat was washed properly before filling it in the PVC pipes.

Step 3: Calculation of Electrical Conductivity and pH of the media

Using Digital EC and pH meter electrical conductivity and pH of the media was measured

Step 4: Preparation of media

Dried cocopeat and vermicompost were mixed in the ratio of 25:5. Then the prepared growing media was filled into the PVC pipes completely throughout the pipes.

Step 5: Sowing of seeds

Total of 15-20 seeds were sown into the growing media through each hole. The seeds were sown manually and in a random pattern. The seeds were then properly covered with growing media.

Step 6: Monitor plant growth

The plant growth was monitor daily. The growth was concluded on various vegetative parameters such as plant height, number of leaves and number of emergence.

Step 7: Inspect for pests and Diseases

Close eye was kept on any signs of pest and diseases that may attack the plant during its growth. One disease plant can swiftly infect all other ones since they are so close to each other. Sick plants were remove immediately. Also measure were taken to prevent attack of pests and diseases.

3. Results and Discussions

Measurements of vegetative parameters were frequently carried out to track the performance of fenugreek in the coco peat media in the hydroponic unit throughout the experiment. The results are obtained are stated as under.

Table 5. EC and pH of growing media

No. of wash	Coco peat	
	EC	pH
Initial	0.771 $mScm^{-1}$	7.00
After wash (final)	0.094 $mScm^{-1}$	6.77

- Media whose electrical conductivity and pH need to be measured was taken into container.
- EC and pH of the corresponding mixture was noted.
- Again, water wash added to a mixture.
- Same procedure was repeated until a constant EC and pH was achieved.
- Then the media were kept for drying by spreading over paper.

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Table 6. Temperature and Humidity Readings

Date	Timing	Temperature (℃)			Humidity (%)
		Maximum	Dry bulb	Wet bulb	
05/10/2019	10.00 AM	33	33	27	63
	02.00 PM	33	33	27	63
06/10/2019	10.00 AM	32	32	28	74
	02.00 PM	34	34	29	69
07/10/2019	10.00 AM	33	33	27	63
	02.00 PM	32	32	28	74
08/10/2019	10.00 AM	31	31	27	74
	02.00 PM	33	33	28	69
09/10/2019	10.00 AM	28	28	26	86
	02.00 PM	33	33	28	69
10/10/2019	10.00 AM	30	30	26	73
	02.00 PM	35	35	29	64
11/10/2019	10.00 AM	33	33	28	69
	02.00 PM	34	34	29	69
12/10/2019	10.00 AM	32	32	28	74
	02.00 PM	33	33	28	69
13/10/2019	10.00 AM	32	32	28	74
	02.00 PM	35	35	30	69
14/10/2019	10.00 AM	33	33	28	69
	02.00 PM	34	34	29	69
15/10/2019	10.00 AM	30	30	26	73
	02.00 PM	34	34	29	69
16/10/2019	10.00 AM	32	32	28	74
	02.00 PM	33	33	28	69
17/10/2019	10.00 AM	33	33	28	69
	02.00 PM	35	35	30	67
18/10/2019	10.00 AM	32	32	28	74
	02.00 PM	38	38	33	71
19/10/2019	10.00 AM	31	31	27	74
	02.00 PM	34	34	29	69
20/10/2019	10.00 AM	28	28	26	86
	02.00 PM	30	30	28	86

3.1 Height, Emergence and Number of leaves count

In each hole 20 seeds of fenugreek were sown. The height, emergence and number of leaves were noticed 5 days after sowing. The result of height, emergence and number of leaves are given in following tables.

Table 7. Height, Emergence and Number of leaves count after 05 days

CHANNEL A							
PARAMETERS	A_1	A_2	A_3	A_4	A_5	A_6	A_7
HEIGHT(cm)	7.2	7.4	7.6	8.5	7.5	8.0	7.8
EMERGENCE	20	17	20	18	18	19	20
NO. OF LEAVES	2	2	2	2	2	2	2
CHANNEL B							
PARAMETERS	B_1	B_2	B_3	B_4	B_5	B_6	B_7
HEIGHT(cm)	7.4	7.5	7.8	7.2	8.1	7.3	7.6
EMERGENCE	20	20	20	19	20	20	20
NO. OF LEAVES	2	2	2	2	2	2	2
CHANNEL C							
PARAMETERS	C_1	C_2	C_3	C_4	C_5	C_6	C_7
HEIGHT(cm)	7.8	7.6	7.5	7.2	7.6	7.3	7.4
EMERGENCE	20	20	16	20	20	20	19
NO. OF LEAVES	2	2	2	2	2	2	2
CHANNEL D							
PARAMETERS	D_1	D_2	D_3	D_4	D_5	D_6	D_7
HEIGHT(cm)	8.4	7.7	8.1	7.7	7.8	8.0	7.7
EMERGENCE	20	17	17	18	17	14	20
NO. OF LEAVES	2	2	2	2	2	2	2
CHANNEL E							
PARAMETERS	E_1	E_2	E_3	E_4	E_5	E_6	E_7
HEIGHT(cm)	6.5	7.5	7.3	7.4	7.7	7.2	7.5
EMERGENCE	20	18	16	17	20	20	11
NO. OF LEAVES	2	2	2	2	2	2	2
CHANNEL F							
PARAMETERS	F_1	F_2	F_3	F_4	F_5	F_6	F_7
HEIGHT(cm)	6.8	7.3	7.3	7.5	6.5	6.8	7.5
EMERGENCE	13	17	20	19	18	16	20
NO. OF LEAVES	2	2	2	2	2	2	2
CHANNEL G							
PARAMETERS	G_1	G_2	G_3	G_4	G_5	G_6	G_7
HEIGHT(cm)	7.2	7.2	6.9	6.8	7.1	7.0	6.8
EMERGENCE	18	18	17	18	20	18	17
NO. OF LEAVES	2	2	2	2	2	2	2
CHANNEL H							
PARAMETERS	H_1	H_2	H_3	H_4	H_5	H_6	H_7
HEIGHT (cm)	7.2	6.9	7.6	7.5	7.0	6.8	7.0
EMERGENCE	19	20	16	17	19	16	19
NO. OF LEAVES	2	2	2	2	2	2	2

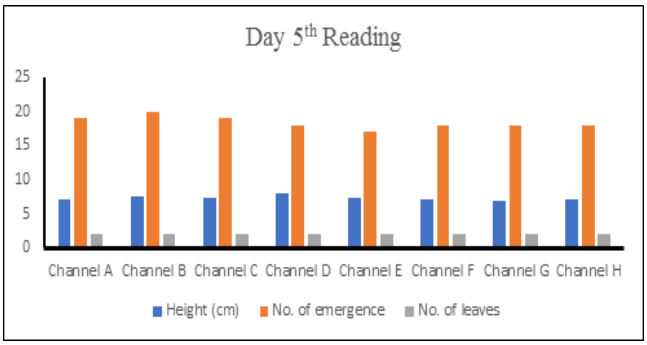

Fig. 7: Count of height, emergence and number of leaves after 05 days

The above graph shows that height, emergence and number of leaves readings of fenugreek crop 5 days after sowing.

Table 8. Height, Emergence and Number of leaves count after 10 days

CHANNEL A							
PARAMETERS	A_1	A_2	A_3	A_4	A_5	A_6	A_7
HEIGHT(cm)	8.5	9.0	8.4	8.3	8.0	8.3	8.4

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EMERGENCE	19	12	13	06	12	10	12
NO. OF LEAVES	2	2	2	2	2	2	2
CHANNEL B							
PARAMETERS	B_1	B_2	B_3	B_4	B_5	B_6	B_7
HEIGHT(cm)	8.4	8.3	8.5	9.1	8.7	8.9	8.6
EMERGENCE	19	15	15	16	19	17	08
NO. OF LEAVES	2	2	2	2	2	2	2
CHANNEL C							
PARAMETERS	C_1	C_2	C_3	C_4	C_5	C_6	C_7
HEIGHT(cm)	9.3	8.2	8.7	7.9	8.8	8.1	8.8
EMERGENCE	15	12	04	09	13	10	15
NO. OF LEAVES	2	2	2	2	2	2	2
CHANNEL D							
PARAMETERS	D_1	D_2	D_3	D_4	D_5	D_6	D_7
HEIGHT(cm)	09	8.5	8.9	09	8.9	8.7	09
EMERGENCE	12	05	09	08	10	05	10
NO. OF LEAVES	2	2	2	2	2	2	2
CHANNEL E							
PARAMETERS	E_1	E_2	E_3	E_4	E_5	E_6	E_7
HEIGHT(cm)	08	8.4	8.2	8.7	8.4	8.6	09
EMERGENCE	10	05	06	10	07	06	02
NO. OF LEAVES	2	2	2	2	2	2	2
CHANNEL F							
PARAMETERS	F_1	F_2	F_3	F_4	F_5	F_6	F_7
HEIGHT(cm)	8.3	8.6	8.7	8.4	8.7	8.5	8.3
EMERGENCE	09	09	07	16	16	12	17
NO. OF LEAVES	3	3	2	2	2	2	2
CHANNEL G							
PARAMETERS	G_1	G_2	G_3	G_4	G_5	G_6	G_7
HEIGHT(cm)	7.9	7.8	8.0	8.3	8.3	7.9	8.0
EMERGENCE	04	03	05	10	03	03	04
NO. OF LEAVES	2	3	3	2	3	3	3
CHANNEL H							
PARAMETERS	H_1	H_2	H_3	H_4	H_5	H_6	H_7
HEIGHT (cm)	8.1	8.5	8.0	8.2	8.0	8.0	7.9
EMERGENCE	03	04	02	07	11	02	11
NO. OF LEAVES	2	3	2	2	2	2	2

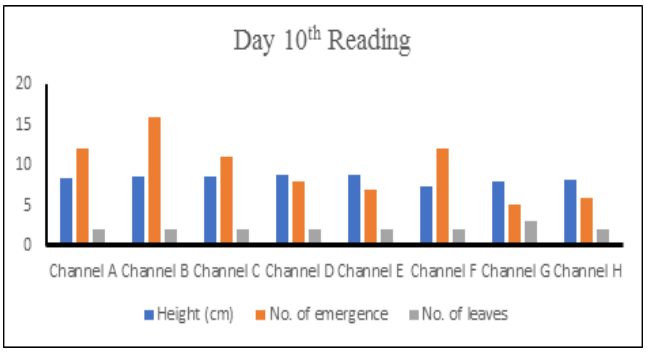

Fig. 8: Count of height, emergence and number of leaves after 10 days

The above graph shows that height, emergence and number of leaves readings of fenugreek crop 10 days after sowing.

Table 9. Height, Emergence and Number of leaves count after 15 days

CHANNEL A							
PARAMETERS	A_1	A_2	A_3	A_4	A_5	A_6	A_7
HEIGHT (cm)	12	13	10.5	10.2	10	11.1	12.5
EMERGENCE	15	08	09	03	07	07	08
NO. OF LEAVES	04	03	03	03	04	03	02
CHANNEL B							
PARAMETERS	B_1	B_2	B_3	B_4	B_5	B_6	B_7
HEIGHT (cm)	11	10.7	12.1	10.8	11.6	12.4	11.9
EMERGENCE	13	09	09	10	12	12	04
NO. OF LEAVES	03	03	04	04	04	03	03
CHANNEL C							
PARAMETERS	C_1	C_2	C_3	C_4	C_5	C_6	C_7
HEIGHT (cm)	12	11.6	9.9	10.1	12.4	12.2	13
EMERGENCE	09	06	01	05	07	07	08
NO. OF LEAVES	03	03	03	04	03	03	03
CHANNEL D							
PARAMETERS	D_1	D_2	D_3	D_4	D_5	D_6	D_7
HEIGHT (cm)	11.8	12	12.4	10.8	12.2	10.7	11.6
EMERGENCE	08	03	04	05	07	02	05
NO. OF LEAVES	03	03	04	04	04	03	03
CHANNEL E							
PARAMETERS	E_1	E_2	E_3	E_4	E_5	E_6	E_7
HEIGHT (cm)	12	11.8	10.7	11.6	10.1	12	11.7
EMERGENCE	07	03	04	06	04	03	01
NO. OF LEAVES	03	04	04	04	03	04	03
CHANNEL F							
PARAMETERS	F_1	F_2	F_3	F_4	F_5	F_6	F_7
HEIGHT (cm)	11	10.6	12.4	12.2	10.8	11.3	12.7
EMERGENCE	05	06	03	08	07	04	11
NO. OF LEAVES	05	04	03	03	04	04	03
CHANNEL G							
PARAMETERS	G_1	G_2	G_3	G_4	G_5	G_6	G_7
HEIGHT (cm)	10.3	10.8	11.3	11.1	10.2	11.8	10.6
EMERGENCE	02	01	03	06	01	01	02
NO. OF LEAVES	03	04	05	03	04	04	03
CHANNEL H							
PARAMETERS	H_1	H_2	H_3	H_4	H_5	H_6	H_7
HEIGHT (cm)	10.2	11.2	10.8	12	12.4	11.7	10.7
EMERGENCE	01	02	01	04	05	01	04
NO. OF LEAVES	03	05	04	03	04	03	03

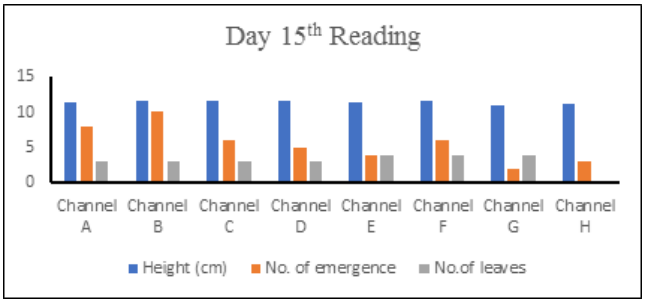

Fig. 9: Count of height, emergence and number of leaves after 15 days

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The above graph shows that height, emergence and number of leaves readings of fenugreek crop 15 days after sowing.

4. Conclusion

The following conclusions can be drawn from the results:

- The tower prototype hydroponic structure was designed and fabricated successfully.
- This type of hydroponic structure maximizes the use of space.
- The area utilization efficiency was found to be 64.28% in comparison with conventional farming.
- It can be effectively used for urban areas as it is space and water conserving method.
- The results of the study also revealed that hydroponically grown fenugreek in a tower type prototype hydroponic structure did not thrives well in an open field conditions.

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