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DESIGN OF FLOOD AND DRAIN VERTICAL HYDROPONIC SYSTEM

Ashwini Patwardhan*

K. K. Wagh College of Agricultural Engineering,
Department of Irrigation and Drainage Engineering, Nashik.
Affiliated to Mahatma Phule Krishi Vidyapeeth, Rahuri, India

Abstract: The study was conducted by installing the Flood and Drain Vertical Hydroponic System for cultivating Chinese leafy vegetable Pak-choi (var. Choko) of family Brassicaceae. The system was designed in the department of Irrigation and Drainage Engineering, K. K. Wagh College of Agricultural Engineering and Technology with the help of *CATIA* software. 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. The average *pH* readings before and after each irrigation was 6.40 and 6.76 and the average values of *EC* before and after each irrigation was 0.79 $\text{mmhos}\cdot\text{cm}^{-1}$ and 0.97 $\text{mmhos}\cdot\text{cm}^{-1}$, respectively. Also the average moisture content of media before and after each irrigation was noted, which was 18% and 71% respectively, available moisture content for complete growth of crop ranged from 46.73 to 57.05%. The water requirement of Pak-choi crop was 2.63 cm.

The fertilizer applied was 1.9 gm *N:P:K* for overall growth of crop. The harvesting of crop was done after 70 days from sowing and the yield of crop was 7 kg from 1.8 m^2 area. The total cost of system was estimated to be *Rs*.3400 /-. Highest germination of 96% was achieved with our hydroponic system, which was 26% more than germination percentage quoted by the manufacturing company of seeds. Yield of Pak-choi crop in hydroponic system was twice than the yield obtained from field conditions. Therefore, the Flood and Drain Vertical Hydroponic System designed gave 66% more cropping area than the open field.

Key words: *flood and drain vertical hydroponic system, pak-choi, irrigation*

* Corresponding author. E-mail: satputeaa@yahoo.co.in

INTRODUCTION

With the advent of civilization, open field/soil-based agriculture is facing some major challenges, most importantly decrease in per capita land availability. In 1960 with 3 billion population over the World, per capita land was 0.5 ha but presently, with 6 billion people it is only 0.25 ha in 2013 and by 2050, it will reach at 0.16 ha. due to rapid urbanization and industrialization [4]. Also soil fertility status has attained a saturation level and productivity is not increasing further with increased level of fertilizer application. Besides, poor soil fertility in some of the cultivable areas, less chance of natural soil fertility build-up by microbes due to continuous cultivation, frequent drought conditions and unpredictability of climate and weather patterns, rise in temperature etc. Under such circumstances, in near future it will become impossible to feed the entire population using open field system of agricultural production only. To cope with these challenges naturally, soil-less culture is becoming more relevant in the present scenario. In soil-less culture, plants are raised without soil. Growing plant in solution culture is easier than soil culture because there is no need of soil, no soil born disease or pest, irrigation is less frequent in solution culture than in soil culture [3]. Roots are visible and root zone environment is easily monitored and controlled. Improved space and water conserving methods of food production under soil-less culture have shown some promising results all over the World.

Basically, there are five types of hydroponics systems and Flood and Drain system of hydroponics (also called Deep Flow Technique) is one of the hydroponics system that works by temporarily flooding the bed 2-3 cm deep with nutrient solution [2] that flows through 10 cm diameter PVC pipes to which plastic net pots with plants are fitted. The excess amount of nutrient solution is drained back into the reservoir. This action is normally done with a submerged pump. The plastic pots containing planting materials and their bottoms touch the nutrient solution that flows in the pipes. The PVC pipes may be arranged in one plane or in zigzag shape depending on the types of crops grown. This is a versatile system that can be used with a variety of growing mediums. The entire bed can be filled with pro-mix, vermiculite, gravel or coco-pit. Many people like to use individual pots filled with growing medium, this makes it easier to move plants around or even move them in or out of the system. Considering the advantages of hydroponics, it was proposed to design and fabricate flood and drain vertical hydroponic system.

MATERIAL AND METHODS

The system was designed in the department of Irrigation and Drainage Engineering, K. K. Wagh College of Agril. Engg. & Technology, Nashik with help of *CATIA* software as shown in Fig.1 to Fig.4. The Flood and Drain Vertical Hydroponic system was fabricated in the workshop of our College consisted of main components as shown in Tab.1.

Fabrication of flood and drain system. For fabrication of flood and drain system, initially the frame was fabricated, then on frame pipes were placed on hooks which were welded on frame with the help of spot welding. The following procedure was followed for fabrication of frame:

a) measuring and marking on material.
b) cutting of material with the help of power saw and hack saw.
c) welding of frame with the help of arc welding machine.
d) welding of hooks with spot welding.
e) coloring of the frame.

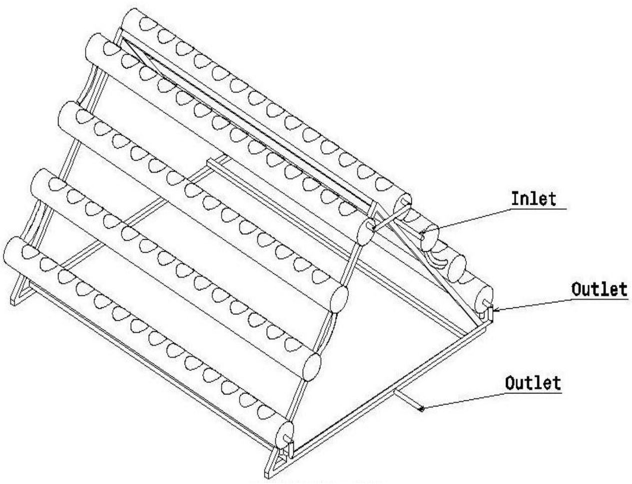

Figure 1. Isometric view

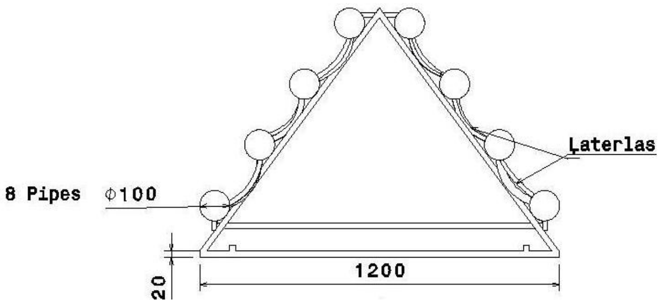

Figure 2. Side view

Table 1. Main components of flood and drain vertical hydroponic system

Material	*Size*	*Quantity*
PVC pipe	*10 cm diameter*	*40 ft*
CRC pipe	*2x2 cm*	*65 ft*
G.I Hooks	*10cm diameter*	*16 Nos.*
PVC End cap	*10 cm*	*16 Nos.*
LDPE lateral	*8 mm*	*12 ft*
Grommet takeoff	*8 mm*	*16 Nos.*
Net pot	*15 cm*	*112 Nos.*
Submersible pump	*2.5 m Head*	*1 Nos.*
Media	*Pro mix*	*16 kg*

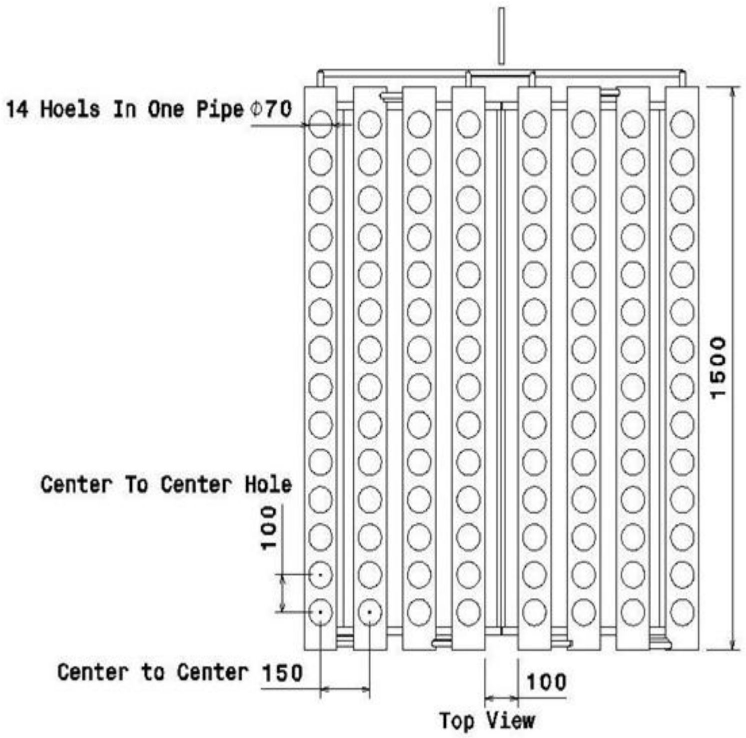

Figure 3. Top view

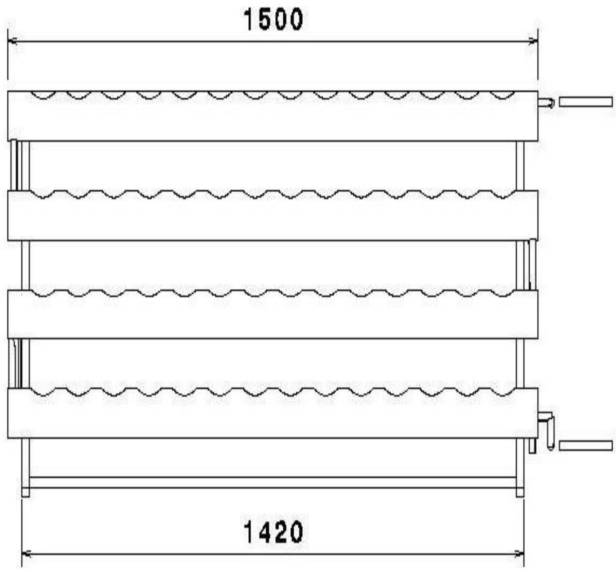

Figure.4 Front view

Preparation of bed and media. System beds were made of 4 inch *PVC* pipes which were sealed with end cap on both ends having 5ft length. Eight numbers of pipes were mounted on the frame. Each pipe bed contained 14 pot holding holes of 7 cm diameter and spaced at 10 cm distance from each other. Net pot was made up of plastic material of 7 cm diameter and 10.5 cm depth. Pot was perforated upto 3 cm height from its bottom.

Media consisted of composition of coco-pit (8% *N: P: K*) [5] and vermiculite in proportion of 1:1. Total mass of media used was 16 kg (coco-pit and vermiculite each 8 kg) to fill up 112 pots, each pot content 71.42 gm of media.

Sowing of seeds and irrigation. The sowing of Pak-choi chinese leafy vegetable (var. Choko) seeds of *Brassicaceae* family was done 2-3 cm deep in net pots on 23rd September 2014 with crop spacing was 10x15 cm. Total 112 seeds were sown in perforated net pots containing media.

First irrigation was provided immediately after sowing of seeds on 23rd September 2014 and then after every 15 days, irrigation was given to the crop. The amount of water applied was 20 liter per irrigation for 5 min. Before and after every irrigation, EC and pH readings of water sample were determined using standard procedures. The water requirement of crop was determined using soil moisture depletion studies by using the formula:

$$D = [(M.C \text{ after irrigation} - M.C \text{ before irrigation})/100] \times B.D \times d \qquad (1)$$

where:

D [cm] - water requirement of crop,
M.C. [%] - moisture content,
B.D. [$g \cdot cm^{-3}$] - bulk density,
D [cm] - root zone depth.

A submersible pump of 0.5 watt was used for lifting water, having 2.1 m head & discharge capacity of 1100 lph. *LDPE* lateral of 16 mm size was used having length 12 ft. for recirculating the irrigation water throughout the system. Total 16 joiners of 16 mm size made up of poly ethylene (PE) material were used. Water tank of capacity 35 litres was used for irrigation which was made up of plastic material.

Fertilizer application. On 13th October 2014, fertilizer grade 19:19 was mixed with water and applied to the crop. The fertilizer solution was prepared by adding 4 gm of fertilizer in 2 liters of water.

The media content 8% *N:P:K* and from 8 kg of coco-pit 213.33 gm of nitrogen, phosphorus and potassium each was obtained. From 8 kg of vermiculite, 160 gm of nitrogen, 120 gm of phosphorus and 80 gm of potassium was applied to crop. Also from fertilizer 19:19, 1.33 gm of phosphorus and potassium each was applied.

Cost estimation of flood and drain vertical hydroponic system. Cost of flood and drain vertical hydroponic system was estimated for 1.8 m^2 area (area of model). Operating cost is negligible because 0.5 watt pump was operated only for 5 min, for each irrigation.

RESULTS AND DISCUSSION

Germination of seeds occurred after 4 days from sowing. Germination percentage of seeds obtained with the present (Flood and Drain) system was 96%, which was 26% more [1] than the standard values mentioned on seed packet of the company (Tokita Seed India).

First irrigation was provided immediately after sowing seeds then after every 15 days irrigation was given to the crop. The amount of water applied was 20 litres per irrigation for 5 min. Actual water applied to the crop was 20 litres per 15 days of interval, 4 irrigations were provided to the plants through flood and drain system. Water applied to all the plants per day was 1.33 litre/day and per plant was 0.01199 litre/day. Hence total water applied to plant throughout its growth period was 80 litres. Water requirement of Pak-choi crop was 2.63 cm.

Table 2. PH and EC readings of water sample

Date	*Before Irrigation*		*After Irrigation*	
	pH	*EC (mmhos·cm^{-1})*	*pH*	*EC (mmhos·cm^{-1})*
23/09/2014	*6.36*	*0.78*	*6.70*	*0.91*
13/10/2014	*6.41*	*0.80*	*6.60*	*0.87*
04/11/2014	*6.40*	*0.80*	*6.90*	*1.1*
25/11/2015	*6.44*	*0.80*	*6.84*	*1.0*

Before and after every irrigation *EC* and *pH* readings of water sample were noted as shown in Tab. 2.

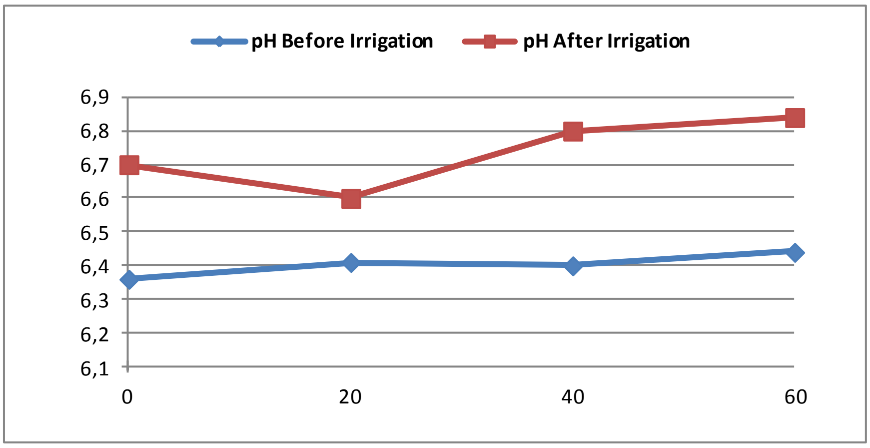

Figure 5. Variations in pH of water sample

The Fig. 5 shows variations in pH of water sample taken before and after irrigation. The pH values varied from 6.36 to 6.44 for water sample before irrigation and it ranged from 6.66 to 6.84 for water sample after irrigation. The variation in the *pH* values was very less and was also within permissible limit for specified crop. It was also observed that *pH* value of water after irrigation has increased due to passage of water from treated media (8% *N:P:K*). Optimum nutrients are available for growth of Pak-choi crop at *pH* value of 7 was reported by the website hydroponicexpress.com.

The Fig. 6 shows variations in *EC* values of water sample before and after irrigation. The EC values varied from 0.78 to 0.80 mmhos·cm^{-1} for water sample before irrigation and it ranged from 0.87 to 1 mmhos·cm^{-1} for water sample after irrigation. The variations in *EC* values were very less. It was also observed that the EC values increased after every irrigation which was due to passage of water from treated media (8% *N:P:K*).

Moisture content readings were taken at an interval of 20 days before and after irrigation as shown in Tab. 3.

The Fig. 7 shows the variations in moisture content of media. The moisture content of media was measured before & after each irrigation. The moisture content of media before irrigation was less and it was more after irrigation, which was due to application of water through the system. Media absorbed water during irrigation, resulting in increase in moisture content. The average available moisture content that was available to the crop throughout its growth period ranged from 46.73% to 57.05%.

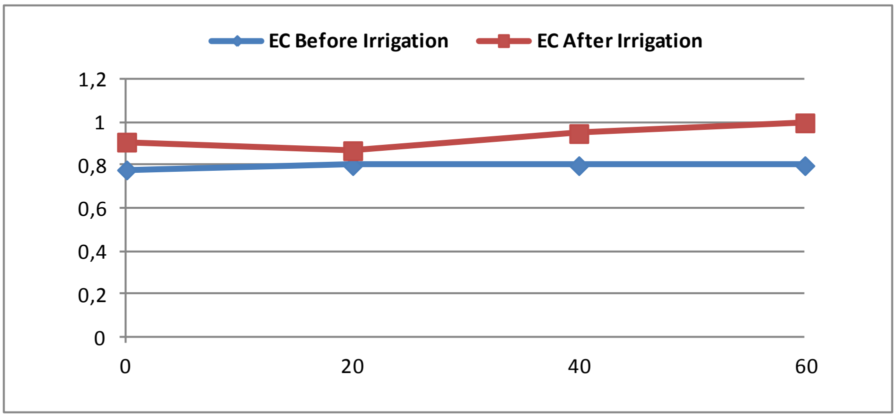

Figure 6. Variations in EC of water sample

Table 3. Moisture content of media before and after irrigation

Date	*Moisture Content (%)*	
	Before Irrigation	*After Irrigation*
23/09/2014	*25*	*71.73*
13/10/2014	*16*	*73.05*
04/11/2014	*18.5*	*72.00*
25/11/2014	*15*	*68.00*

The actual fertilizer applied to Pak-choi crop was 1.9 gm/plant (N:P:K). Also the total fertilizer applied to total number (112 Nos.) of Pak-choi crop planted was 213.33 gm of N:P:K each.

The crop growth after sowing was observed. The crop had two leaves with an average height of 3 cm initially after 7 days from sowing and prior to harvesting the crop had 8 leaves with an average height of 25 cm 60 days after sowing as shown in Fig 8.

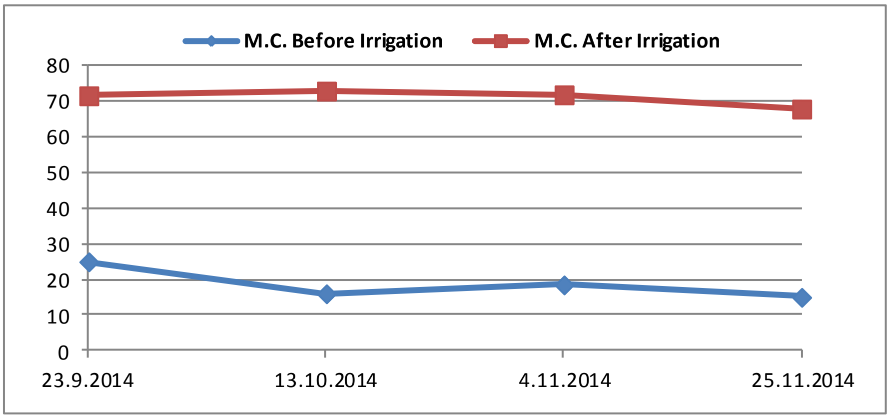

Figure.7. Variations in moisture content of media

Figure 8. Growth of Pak-choi crop after 60 days from sowing

The crop was harvested after 70 days from sowing. The yield of Pak-choi crop obtained was 7 kg from 1.8 m^2 area. Thus, Flood and Drain Vertical Hydroponic System designed by us gave 66% more cropping area than on the field. The estimated cost of the Flood and Drain Vertical Hydroponic system was Rs. 3400/- .

CONCLUSIONS

The Flood and Drain Vertical Hydroponic System was designed and installed successfully. Highest germination percentage was achieved i.e. 96% with our designed hydroponic system. The taste and flavour of crop grown in flood & drain vertical hydroponics system is good as compared to crop grown in soil. No chance of transfer of soil borne diseases to crop. Yield of Pak-choi crop in hydroponic system was twice than the yield obtained from field conditions also system gives 66% more cropping area than the area required on the field.

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KONSTRUKCIJA PRELIVNOG I ODLIVNOG VERTIKALNOG HIDROPONIČKOG SISTEMA

Ashwini Patwardhan

Fakultet za poljoprivrednu tehniku i tehnologiju K. K. Wagh,
Institut za navodnjavanje i odvodnjavanje, Nashik.
Mahatma Phule Krishi Vidyapeeth, Rahuri, India

Sažetak: Istraživanje je izvedeno na instalaciji prelivnog i odlivnog hidroponičkog sistema za uzgoj kineskog kupusa (var. Choko) iz familije *Brassicaceae*. Sistem je konstruisan u Institutu za navodnjavanje i odvodnjavanje Fakulteta za poljoprivrednu tehniku i tehnologiju K. K. Wagh, pomoću programa *CATIA*. 112 semena kupusa je posejano u perforirana gnezda sa podlogom od kokosovih vlakana (tertian sa 8% *N:P:K*) i vermikulita u odnosu 1:1. Biljke su navodnjavane tehnikom dubokog toka kroz podloge. Srednje vrednosti *pH* pre i posle svakog navodnjavanja iznosile su 6.40 i 6.76, a srednje vrednosti *EC* pre i posle svakog navodnjavanja iznosile su 0.79 $mmhos \cdot cm^{-1}$ i 0.97 $mmhos \cdot cm^{-1}$, redom. Srednji sadržaj vlage u podlozi pre i posle svakog navodnjavanja iznosio je 18% i 71%, redom, a dostupna vlaga za potpuni porast biljaka varirala je od 46.73% do 57.05%. Zahtev biljaka za vodom iznosio je 2.63 cm.

Za ukupni porast biljaka primenjeno je 1.9 gm *N:P:K* đubriva. Biljke su ubrane 70 dana posle setve, a prinos je iznosio 7 kg sa površine od 1.8 m^2. Ukupna cena sistema procenjena je na *Rs*.3400 /-. Najveća kliavost koja je postignuta ovim hidroponičkim sistemom bila je 96%, što je 26% više od procenta klijavosti koji garantuje proizvođač semena. Prinos kineskog kupusa u hidroponičkom sistemu bio je dvostruko veći od prinosa postignutog u poljskim uslovima.

Ključne reči: *prelivni i odlivni vertikalni hidroponični system, kineski kupus, navodnjavanje*

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