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An Automatic Family Drip System (FDS) to Boost Urban Vegetable Production

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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Short Research Article

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ABSTRACT

Farm fresh vegetable production is gaining much importance in urban areas. This is a turning point for agriculture in urban and peri-urban areas, to introduce new technology like Drip Irrigation System (DIS). Nowadays, urban people take due care by cultivating vegetables on their roof–top, because of high pesticide residues in market produce. But, urban farming initiatives lack supervision and guidance in whole cultivation practices especially in irrigation. Here comes the role of low-cost drip irrigation system to solve acute water shortage and labor problem.

Keeping in view of the above few facts, a field experiment was conducted on automatic drip irrigation for grow bag cultivation to evaluate yield, water-use- efficiency and economic feasibility of a commonly used vegetable, okra. Comparison was done with the manual hose irrigation for grow bags.

A comparative study was conducted to evaluate the performance of time-based automatic drip irrigation system and manual hose irrigation in okra. Irrigation time optimized at 15minutes provided 250 ml of water per plant. Based on the growth stage, crop water requirement of vegetables was

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estimated to be 0.6 to 2 litre/day. To meet this crop water requirement, irrigation was done at four time intervals viz., morning twice and evening twice in such a manner one litre water was irrigated per grow bag. Thus, drip irrigation conserved 50% water compared to manual hose irrigation. It was found that drip irrigation gave 37.70% higher yield than that obtained with the manual drip irrigation system. Automatic DIS increased irrigation efficiency up to 95% than that of conventional method of irrigation. BCR using automated DIS was observed to be 1.45.
Time based Automatic Family Drip System (FDS) is observed to be user-friendly, economical and cost effective as compared to conventional hose irrigation for farming on terraces in cities. Time saving, low energy consumption and low pressure low cost DIS had been widely accepted among urban farmers to promote vegetable cultivation in their own houses.

Keywords: DIS; water use efficiency; crop yield; water savings.

1. INTRODUCTION

The world's population is now increasingly urban, with more than half living in urban areas. Urban population has out-numbered the rural one with the share 54.29% (3.9 billion) globally (2016). In India as well, the urban population escalated to 35% in 2020 from a miniscule 18% in 1960 (Batty, 2015; World Bank, n.d.). Besides, the population of urban areas is expected to grow to nearly 60% and 40% in the world and India, respectively by 2030 (First Post, 2014). With more and more people migrating to towns, the people engaged in farming is progressively declining. This leads to lack of hands to take up agriculture as a profession leading to increase of produce in market. Also, with people becoming more health conscious, are inclined to make use of their roof tops for small scale farming (Vincent et al., 2018).

The 96% of operational holdings in Kerala is below one hectare. Kerala promotes urban agriculture like roof-top farming and gardening. The majority of urbaner are either senior citizens or part-time workers. The whole agricultural operations to follow found to be difficult for them since the cropping is at roof-top. The major constraint is especially observed for doing irrigation during summer seasons. Minimum of 25 to 200 grow bags were maintained by them. During irrigation they will provide large quantity of water which was not measurable from their end. During summer season, the temperature will be high and thereby, irrigation during morning and evening hours is must. Generally, they lack in irrigating the crops which led to wilting of crops resulting in crop loss too. This conventional method of giving water is very ineffective and inefficient.

Drip irrigation system is the solution for this. Drip irrigation (also known as trickle irrigation or micro-irrigation) is an irrigation method that allows precisely controlled application of water and fertilizer by allowing water to drip near the plant roots through a network of valves, pipes, tubing, and emitters. Here most suitable method is automation.

An automated irrigation system refers to the operation of the system with no or just a minimum of manual intervention beside the surveillance. Almost every system (drip, sprinkler, surface) can be automated with help of timers, sensors or computers or mechanical appliances. It makes the irrigation process more efficient and with this, workers can concentrate on other important farming tasks. On the other hand, such a system can be expensive and very complex in its design and may needs experts to plan and implement it.

2. MATERIALS AND METHODS

Okra crop requires adequate moisture during summer months for faster growth. The daily water requirement of okra crop is 2.4 l/day/4 plants during early growth stage and 7.6 l/day/4 plants during the peak growth stage. The irrigation system should be operated daily for 75 minutes during initial growth stage and for 228 minutes during peak growth of the crop with an emitter capacity of 2 lph. Irrigation on each day or on alternate days with on-line type of drippers is preferred (Tiwari, 2015).

Drip irrigation involves placing tubing with emitters on the ground alongside the plants. The emitters slowly drip water into the soil at the root zone. Because moisture levels are kept at an optimal range, plant productivity and quality improve. Plant is watered at its root at rate of 2-20 liters/hour from the emitters placed close to it with a more frequent irrigation interval for better growth of crops (Shareef et al., 2019). In another study for vegetables, water is delivered in small controlled drips, typically at a rate of 1-4 liter/hour (Mansingh et al., 2023). Drip irrigation has the highest water use efficiency ie, 95 per cent and the highest water saving potential (80 per cent) than other irrigation systems (Reddy & Reddy, 1992).

Drip irrigation also gave the highest yield with 319 mm of water use as compared to surface irrigation and drip irrigation system with LLDPE plastic mulch increased yield by 57 % over surface irrigation with same quantity of irrigation water (Paul et al., 2013). Similar results have been obtained by Tiwari et al. (1998) for okra crop at Kharagpur, West Bengal. Paul et al. (2013) conducted a study on drip irrigation with plastic mulching; this system increased yield by 57% and net seasonal income by 54%. Sivanappan et al. (1987) conducted a study on drip irrigation for okra and the results revealed that water saved was as high as 84.7% and noted a slight increase in yield by 7.6%.

In one study on tomato crop (Muñoz-Carpena et al., 2003), automated irrigation system with feedback from soil moisture sensors resulted in 73% reduction in water use, when compared with standard commercial practices, without any effect on the yield. In drip irrigation, there is a conspicuous reduction in water consumption over the surface irrigation method varying from 30 to 70 percent for different crops. Increase in productivity between 20 to 90 percent has also been reported for different crops (Rathakrishnan & Padma, 2012).

In micro irrigation sector, manual interventions are automated to perform all operations, starting from watering to fertigation as per the prescribed schedule. Development of automated system has resulted in lot of developments in crop production like improvement in water saving, increase in crop yield, enhancement in water as well as fertilizer use efficiencies and greater benefit-cost ratio as well, in comparison to general micro irrigation system Suresh (Suresh, 2016). According to Rajkumar et al automated timer-based system is comparatively cheaper and hence gaining more popularity than the volume-based system (Rajkumar et al., 2008).

Automatic drip irrigation system involves digital timer, a pump and drip irrigation materials. For household purpose, we have adopted digital timer rather than volume-based irrigation method. Cost of the equipment also plays a major role to adopt this mechanism at farmers' level. Hence all the inputs are affordable to them. The advantages are shown in below.

2.1 Advantages

1. Possibility to change frequency of irrigation and fertigation processes and to optimise these processes
2. Adoption of advanced crop systems and new technologies, especially new crop systems that are complex and difficult to operate manually
3. Increased efficiency in water and fertiliser use
4. System can be operated at night, water loss from evaporation is thus minimised
5. Irrigation process starts and stops exactly when required, thus optimising energy requirements

2.2 Schematic Diagram

Fig. 1 gives the schematic of drip irrigation system (DIS) used in the current study. A Submersible pump with timer connected to the circuit is used. The main and lateral lines are of Φ16mm and made of linear low density poly ethylene (LLDPE) material. The main line pipe is directly connected to a 35W pump. A screen filter and control valve is connected downstream of the main line ahead of the lateral. The lateral is provided with on line turbokey dripper of 4 ltr/hr discharge capacity. Four-way assembly with four microtubes are fitted on dripper and inserted into the 4 grow bags. Fifteen drippers can irrigate 60 grow bags with a discharge rate of 1LPH / Poly bag when the grow bags are arranged side by side. Drip kit will last for more than five years.

2.3 Operation Procedure

The crop water requirement of vegetable okra is 0.6- 2 ltr/day. Irrigation was scheduled at 0700hrs,1100hrs, 1500hrs and 1700hrs for fifteen minutes each with drip discharge rate of 250ml/hr. By this, the daily requirement of 1 litre of water for each of plant would be met. The purpose of irrigation scheduling is to determine the exact amount of water to apply to the field and the time for application thereby maximizing irrigation efficiencies. Irrigation scheduling saves water and energy (Palada et al., 2011).

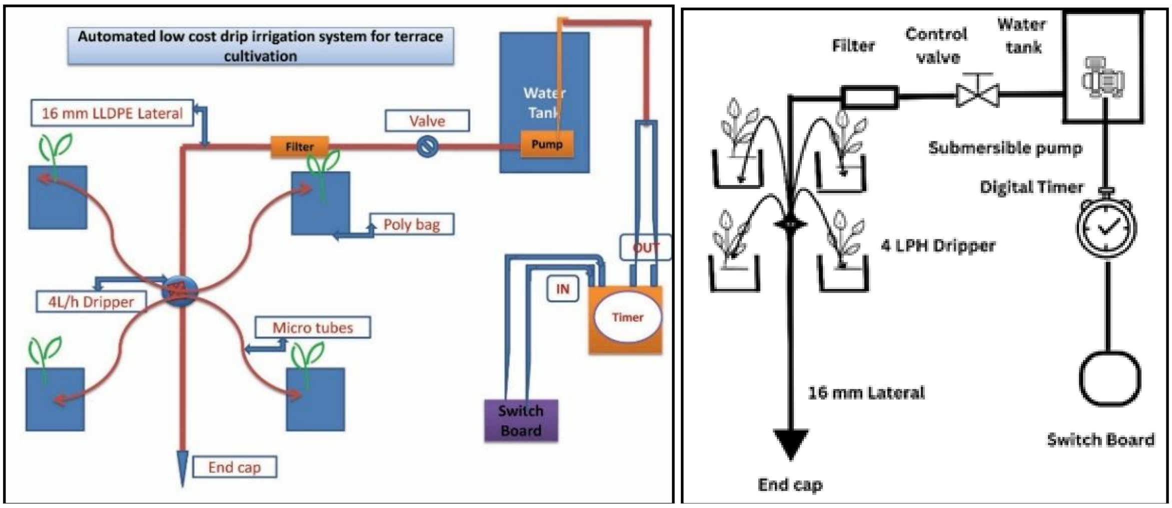

Fig. 1. Schematic diagram of Automated DIS

2.3.1 Irrigation scheduling

Crop usable water from soil moisture can range from 2% by irrigated volume on very sandy soils to more than 10% on heavier, fine-textured soils. Irrigation schedules based on parameters like soil conditions, crop evapotranspiration, tubing discharge characteristics, and other system properties can range from three cycles per day to once every 3 days (Clark & Smajstrla, 1996).

Irrigation schedule and water level in the reservoir can be set by having a time-based automatic irrigation system for cultivation of crops, which uses an Arduino-based system to control drip and sprinkler irrigation. Precise water irrigates the plants in scheduled times by using solenoid pumps and DC pumps. This study was more beneficial, cost effective to farmers (Sudarmaji et al., 2018).

Fig. 2 shows the automated DIS installed at two houses.

2.4 Parameters Monitored during the Study

2.4.1 Crop yield

The yield was recorded for three crop seasons. Weight of vegetables obtained from 60 grow bags has been measured as the total crop yield.

2.4.2 Water use efficiency

Water use efficiency was determined using Eq. (1),

$$E_u = C/W_c \qquad (1)$$

Where C = Crop yield in Kg/ha cm/m^2

W_c = Water consumed by the crop in ha cm per unit area

Since the drip irrigation was used for grow bag vegetable cultivation; based on the experimental study conducted by Babu et al. (2015), the consumptive water use for okra was fixed as 309.8 mm for drip irrigation and for manual irrigation 535 mm based on the study of Sivanappan et al. (1987).

2.4.3 Economic analysis

Benefit-cost ratio and net profit were carried out to determine the economic feasibility of the crop using surface and drip irrigation in accordance with Tiwari et al. (1998). The fixed cost of the drip irrigation system was Rs. 3750/unit. The useful life of the drip system was considered to be five years. The system cost was evaluated by distributing the fixed cost of system over life period of drip irrigation set. In addition to this the cost of cultivation includes expenses incurred for grow bags, porting mixture, intercultural operation, fertilizer, crop protection measures, irrigation water and harvesting with labor charge.

Fig. 2. Automatic Drip Irrigation System at Roof-top and Homestead

3. RESULTS AND DISCUSSION

The experimental study was conducted at Thiruvananthapuram in 2018 covering five household roof top cultivation kit growing okra. Water was applied equally in all bags. Germination was highest in grow bags that were irrigated through DIS. The use of a drip irrigation system prompted flowering one month sooner in plants compared to a control group that received manual hose watering. The yield was recorded for three crop periods. The yield obtained per plant, for okra, was 3.58 kg in drip compared to hose irrigation.

3.1 Water Use Efficiency

On an average, water consumption was observed to be 50% less as compared to conventional irrigation. The amount of water required was further less during rainy seasons. Irrigation was programmed for 15 minutes duration at four different timings to meet the per day water requirement of 1 ltr/ plant. Table 1 gives the water use and yield for drip irrigated and control methods for cultivation of okra (average of two-year period).

It may be observed that maximum water use efficiency was observed to be 6.94 t/ha-cm at plot 4 compared to hose irrigation. The water use efficiency between conventional and drip irrigation is given in Fig. 3.

3.2 Water Savings

It was observed that there was substantial water saving ranging from 50% compared to conventional hose irrigation.

3.3 Economic Feasibility

Maximum net return of Rs. 3425 for 60 grow bags with B:C ratio of 1.54 was recorded at P4 and lowest net profit of Rs.1845 for 60 grow bags with B:C ratio of 1.25 in P1 (Table 2). At the same time for conventional irrigation, net income varies from Rs. 250 – 575 for 60 grow bags with B: C ratio 1.04 to 1.08. The lower B.C ratio is attributed to lower yield as a result of improper irrigation and thereby low gross income.

Table 1. Water use and yield in drip irrigated and control method for cultivation of okra (average of two-year period)

Plot No.	Water use efficiency (t/ha-cm)		Yield (Kg/60 Nos. of Grow bags)		% increase in yield
	Control	Drip	Control	Drip	
1	2.34	6.62	125	205	64
2	2.30	6.29	123	195	58.54
3	2.06	6.08	110	188	70.91
4	3.08	6.94	165	215	30.30
5	1.77	6.10	95	189	98.95

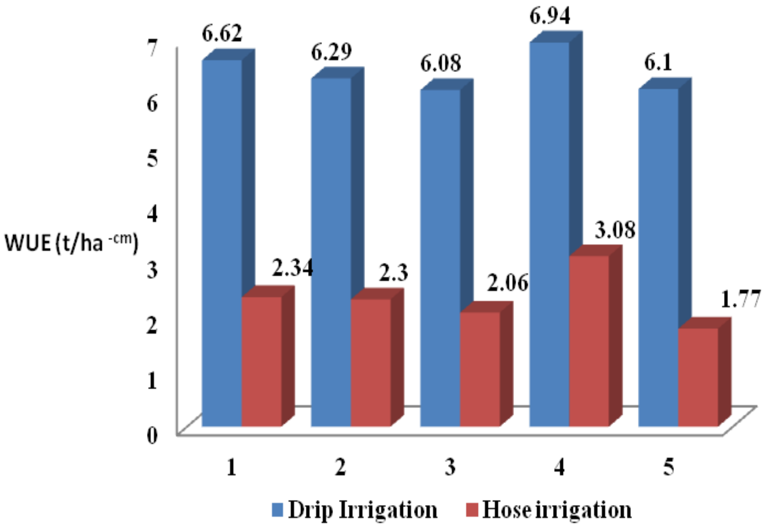

Fig. 3. Water use efficiency of DIS and hose irrigation during cultivation of okra at five terraces

Table 2. Water use and yield in drip irrigated and control method

	Drip				Control			
Plots	**Gross cost (Rs.)**	**Gross income (Rs.)**	**Net income (Rs.)**	**BCR**	**Gross cost (Rs.)**	**Gross income (Rs.)**	**Net income (Rs.)**	**BCR**
P1	7380	9225	1845	1.25	5200	5625	425	1.08
P2	6680	9750	3070	1.45	6150	5800	350	1.06
P3	6000	9400	3400	1.56	5500	5250	250	1.04
P4	6250	9675	3425	1.54	7425	6850	575	1.08
P5	6500	9450	2950	1.45	4750	4500	250	1.05

4. CONCLUSIONS

Timer-based Automatic Family Drip System (FDS) is observed to be user-friendly, economical and cost effective as compared TO conventional hose irrigation for farming on roof-tops in cities. An average 37.70% increase in yield was obtained against 6.41 t/ha-cm water use efficiency. Water savings to the tune of 50% was observed with drip irrigation by avoiding the wetting of terrace with over-run water loss. Automatic DIS increased irrigation efficiency up to 95% than that of conventional method of irrigation. BCR using automated DIS was observed to be 1.45. The widespread adoption of affordable, low-pressure drip irrigation systems (DIS) among urban farmers is attributed to its higher efficiency, larger savings in time and reducing manual labour. It thus fosters household vegetable cultivation.

CONFERENCE DISCLAIMER

Some part of this manuscript was previously presented and published in the conference: 35th Indian Engineering Congress 2020 - The Digital Experience dated from December 18-20, 2020 India, Web Link of the proceeding: https://www.ieindia.org/WebUI/ajax/Downloads/WebUI_PDF/IEC/IEC_35.pdf?v20210205.1

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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