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# DESIGN AND DEVELOPMENT OF SMART IRRIGATION SYSTEM FOR WATERING ROOFTOP GARDEN

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## *ABSTRACT*

Rooftop gardening is one of the famous agricultural technology in urban areas of many countries including Bangladesh. Crop water requirement is very high in rooftop due to high temperature and high evapotranspiration. Irrigation as well as water management is the major limitation for this practice. Considering the necessity of rooftop gardening in urban areas and irrigation issue, it is essential to develop a low cost efficient irrigation method that helps to improve production techniques for rooftop garden. From this study, we developed a smart irrigation system for watering rooftop gardening where mainly used programmable digital timer, solenoid valve and electric pump operated drip system. In this irrigation system, programmable digital timer sends a signal to the solenoid valve and electric pump that leads to open or close the whole irrigation system and crop was watered the selected interval and frequency wise. From the results, average discharge (Qavg), distribution efficiency (Ed), application efficiency (Ea), coefficient of variation for emitter flow (cv) and statistical uniformity coefficient (SUC) were achieved good performance and was found meeting American Society of Agricultural Engineers (ASAE) standards. The designed smart irrigation system was operated excellently as the values of emission uniformity.

**Contribution/Originality:** This system having small water pump which connected to roof top water tank and automated off-on the water pump at selectable interval. Automatic system was controlled by digital timer. As a new concept, the study is original.

## 1. INTRODUCTION

Rooftop gardening is popularizing day by day in urban areas of world including Bangladesh. Water is a key element and most vital factor for promoting urban rooftop agriculture [1]. But crop watering method is the major limitation for this practice. Generally, more than 90% of rooftop gardeners applied traditional irrigation method using local traditional tools such as mugs, hose pipes, etc. from their own groundwater source [2-5]. The main obstacles of traditional water application method is manually, time consuming, waste huge valuable water and discourage the rooftop gardening. There are many research suggested that drip irrigation method is more suitable for watering rooftop garden than others. Drip irrigation system where applying irrigational water directly to the root zone, could be an efficient method to increase water use efficiency and irrigation management in the rooftop garden [6, 7]. Drip irrigation could be an efficient method of irrigation for rooftop gardening which has some advantages like reduces human effort for irrigation management in the rooftop garden, applies correct water amounts precisely when required to maintain optimum available soil moisture in the root zone [8] reduces management time required for observing plant water needs and manually controlling irrigation systems [9]. Drip irrigation systems are classified gravity feed and forced feed basis on their water feeding system. Recently, a few number of rooftop gardening irrigation systems are designed by gravity feed system. The main limitation of gravity feed drip irrigation for roof top gardening is having lower pressure that causes to low emitter discharge and watering less number of plant. Besides, the flow of water can be changed due to change in water level in the reservoir tank due to positive hydraulic pressure system. For these motives fixed flow was not possible using conventional drip irrigation system. To get appropriate pressure for this system required to keep the water tank above the 20 to 60 ft height. It is cost effective and need to constructed extra-large structure on the building roof for placement of water tank. This extra-large structure causes destroyed the beatification. Therefore, present study was aimed to design and development of a smart irrigation system for watering rooftop garden and to evaluate the performance of developed system. This system having small water pump which connected to roof top water tank and maintained automated off-on the water pump at specific interval.

## 2. MATERIALS AND METHODS

### *2.1. Architecture of Smart Irrigation System*

The proposed smart irrigation system was designed by the following given flow chart Figure 1. The materials that were successfully used for construction and installation of smart irrigation systems were: Water tank (plastic), Electric pump, Solenoid Valve, Programmable timer, Main line pipes, Elbow Joining, Sub main line pipe, lateral pipes, micro emitters. Digital timer and wi-fi controller switch both are used for controlling solenoid valve and pump. This study, digital timer is used instead to wi-fi controller switch. The wi-fi controller switch also be used this system where internet connection is available.

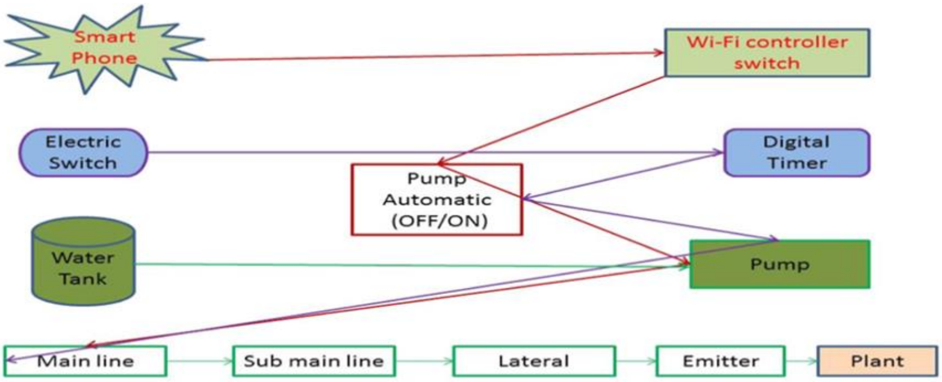


**Figure 1.** Flow chart of proposed smart irrigation system.

### *2.2. Water Reservoir Tank*

Generally water distribution system of building, main water supply line was connected with water source and electric pump was used to pump the water to store in a water reservoir tank on rooftop. The water reservoir tank of this system was placed on a stage or water reservoir basement at rooftop. The basement height is 6 inches. Different size of water tank was selected for this system. The plastic tank was chosen as a water reservoir to reduce the water temperature for beater crop performance. Besides, plastic materials are free from the problem of rust due to stagnant water.

### *2.3. Electric Pump*

In this system electric pump is used to takes water from the source and provides the right pressure for delivery into the pipe system. This pump was automated off-on by programmable digital timer. The programmable timer sends a signal to the pump and it to start or off. At this study used to 0.5hp electric pump to supply water for the plant and connected to water tank.

### 2.4. Water Filter

The quality and cleanliness of the water is a major consideration of drip irrigation system designing. For the dirty water which is coming from ponds, rainwater or any open water catchment tanks must be used water filter. However, the water coming from a municipal water source or storage container free of debris and thoroughly filtered. So, there were no needs to used water filter. If we decided to use filter must be used before valve.

### 2.5. Solenoid Valve

In smart irrigation system, a solenoid valve is designed to be used with a digital timer. Generally, solenoid valves are used for automatic drip systems having arrow of its side that indicates the direction of the flow of water. The solenoid valve is always installed horizontally and downstream side of pump and controlled by electrical power, which is run through the coil. The programmable digital timer sends a signal to the valve telling it to open or close.

**Figure 2.** Solenoid valve.

### 2.6. Programmable Digital Timer

The battery (2A) operated programmable digital timer is used at this system that connects directly to the solenoid valve and electric pump. This timer is manually selector system and simple to program with two dial segments like irrigation frequency 1-2-3-4-6-8-12 hours or 1-2-3 days and irrigation duration 1-3-5-10-15-20-30-60-90-120 minutes. The timer has 4 terminals where 2 terminals for clock (or Power) and 2 terminals for switch. When the rated voltage was connected to clock terminals then clock terminals have power and the switch terminals receive NO power. This simple on-off switch can control any voltage 120V, 240V, 277V, 24V. If connect one hot wire to either switch terminal, and then connect wire going to load to other switch terminal.


**Figure 3.** Programmable digitizing timer.

### 2.7. Main Line and Sub Main Selection

The main line of drip was designed with a 16 mm diameter black flexible low density poly polyethylene (LDPE) pipe with 1.2mm thickness.

### 2.8. Laterals Selection

The lateral lines of drip were designed with a 4 mm diameter black flexible low density poly polyethylene (LDPE) pipe with 1.2mm thickness. The diameter of pipe was reduced to increase the pressure of water flowing through the laterals in the micro tube emitters.

*2.9. Dripper Selection*

Adjustable micro dripper (4mm) was selected at this drip system to easily change the flow rate. Besides, adjustable micro drippers tend to vary greatly in flow and having little pressure compensation.

## 3. RESULTS AND DISCUSSIONS

Programmable digital timer controls the total irrigation system Figures 4-5. In this system, at first program was manually set in the timer, like irrigation frequency and interval based on crop water requirement. Programmable digital timer sends a signal to the solenoid valve and electric pump to open or close and crop was watered selected interval and frequency wise. The main advantage of this system was there was no need manually off-on the pump switch. Besides, no need extra labor for irrigation management. The performance of automation function of the digital timer is excellent. A single sub line is used for one row of peppers (drip lines are therefore also 7 ft apart). Let's say our rooftop garden is 70 ft long and 50 ft wide. Each row contains 10 plants and plant to plant, row to row distance is 7ft and 10ft respectively. The 0.5hp pump is used for this experiment. This system is installed for 50 plants Figures 4-5 and extended to 150 or more plant. Average discharge of emitter should be decreased with increased the number of plant for constant pump discharge. For this condition, we adjust the irrigation duration and interval by using digital timer.

*3.1. Performance Evaluation of Developed Smart Irrigation System*

Developed smart irrigation system for watering rooftop garden is one kind of drip irrigation that controlled by digital programmable timer. As a result, the performance evaluation method of this system is similar to the drip system which was evaluated based on the following parameters:

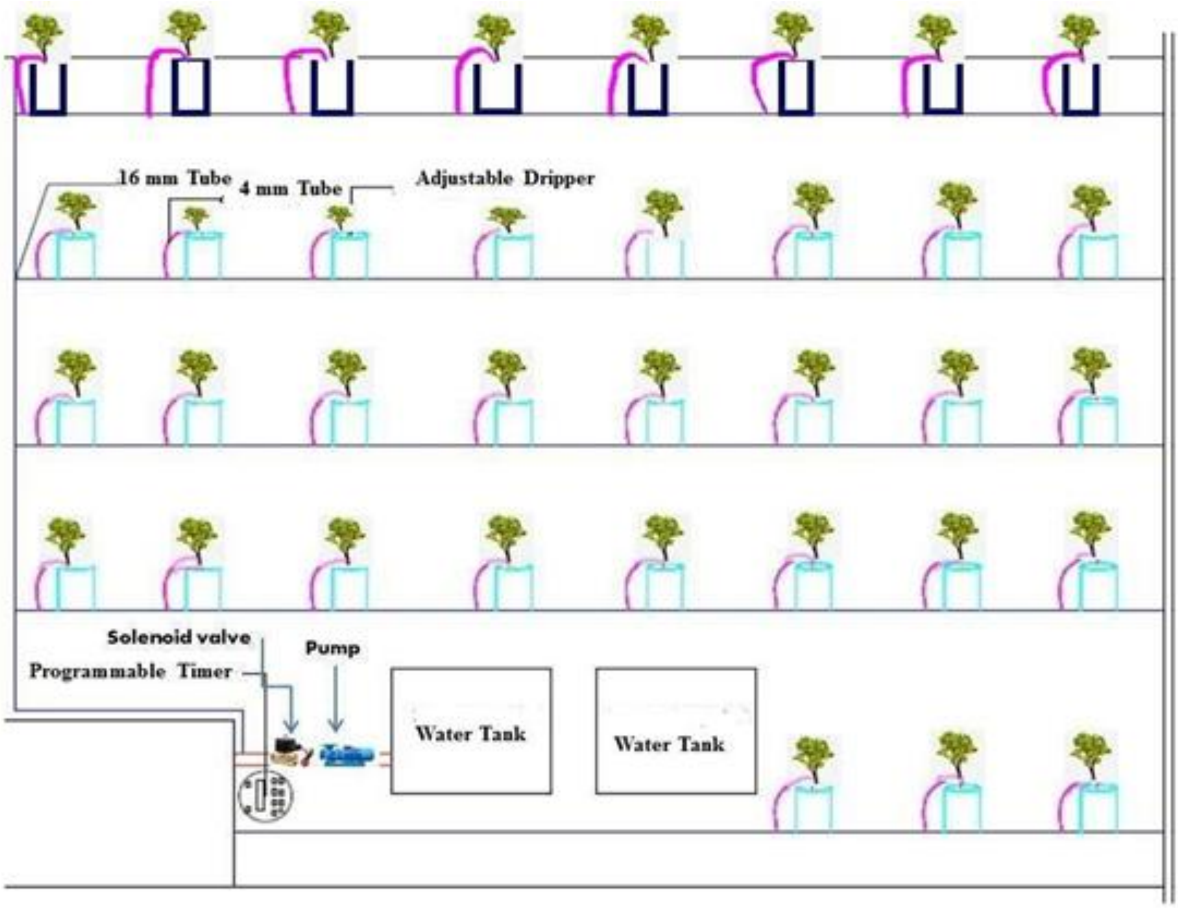


**Figure 4.** Layout of smart irrigation system for rooftop garden.

**Figure 5.** Pictorial view of smart irrigation system for rooftop garden.

### *3.2. Distribution Efficiency*

The distribution efficiency of irrigation system was calculated by used the statistical method which introduced by Wu and Gitlin [10] and suggested by Christiansen. They gave the following equation:

$$Ed\ (\%) = \left(1 - \frac{\Delta qa}{qm}\right) \times 100$$

Where, $\Delta qa$ = Average absolute deviation from the mean discharge rate.

$qm$ = mean discharge rate, (l/h).

### *3.3. Application Efficiency*

The application efficiency is denoted as the ratio of water required in the root zone to the total amount of water applied and expressed by;

$$Ea\ (\%) = \left(\frac{Qmin}{Qavg}\right) \times 100$$

Where, $Ea$ = application efficiency, %.

$Qmin$ = minimum emitter flow rate (l/h).

$Qavg$ = average emitter flow rate (l/h).

The uniformity of water application of drip irrigation system expressed by two parameters namely field emission uniformity (EUf) and absolute emission uniformity (EUa), suggested by Keller and Karmeli [11].

### *3.4. Field Emission Uniformity (EUf)*

This is used to describe the emitter flow variation for a micro irrigation unit. It is expressed by;

$$EUf\,(\%) = \left(\frac{qn}{qa}\right) \times 100$$

Where,

$qn$= average of the lowest 1/4 of the emission point discharges for field data, l/h.

$qa$ = The average of all emitters flow rate (l/h).

Absolute emission uniformity (EUa).

$$EUa\ (\%) = 100 \times \left(\frac{Qmin}{Qavg} + \frac{Qavg}{Qx}\right) \times \frac{1}{2}$$

Where,

$Qmin$ = minimum flow rate through emitter, l/h.

$Qavg$ = average flow rate through emitter (l/h).

$Qx$ = average of the highest 1/8th of the emitters flow rate (l/h).

### 3.5. Coefficient of Variation (Cv)

Coefficient of variation for emitter flow is expressed by;

$$Cv = \frac{Standard\ deviation\ of\ the\ emiter\ flow}{Average\ \ of\ emiter\ flow}$$

### 3.6. Statistical Uniformity Coefficient

Statistical uniformity coefficient of emitter flow;

$$SUC\ (\%) = (1 - Cv) \times 100$$

**Table 1.** Performance parameters to evaluate irrigation system.

| Average emitter discharge $Q_{avg}$ (l/h) | Distribution efficiency $E_d$ (%) | Application efficiency $E_a$ (%) | Field emission uniformity $EU_f$ (%) | Absolute emission uniformity EUa (%) | Coefficient of variation Cv | Statistical uniformity coefficient SUC (%) |
|---|---|---|---|---|---|---|
| 29.55 | 97.06 | 93.16 | 96.85 | 94.10 | 0.029 | 97.05 |

The results of different parameters Table 1 like distribution efficiency (Ed), application efficiency (Ea), field emission uniformity (EUf) , absolute emission uniformity (EUa), coefficient of variation for emitter flow (cv) and statistical uniformity coefficient (SUC) were achieved good performance and was found meeting ASAE standards. The high value of SUC and low value of C*v* was indicated a good performance of the system. The excellent emission uniformity was observed that indicated water is distributed uniformly.

## 4. CONCLUSION

From the results of the installed and tested this smart irrigation system will become easy and comfortable for watering rooftop garden. The electric pump and solenoid valves are successfully OFF-ON by programmable digital timer. The performance of digital timer is perfect to maintain irrigation interval and duration. This smart irrigation system can not only be used in a rooftop garden but can be used in garden.

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