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Design of Soil Moisture Sensitive Automatic Drip Irrigation System for Roof Top Gardening

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Abstract-*Agriculture sector is the backbone of Sri Lankan economy and it consistently requires technological advancement. In the past, agriculture is concentrated only in rural areas. Rooftop gardening is becoming popular in highly populated urban areas where land for agriculture is scanty. Usually cement or plastic pots are used to grow plants on rooftops or balconies and the moisture in these pots can be easily dried off since they are subjected to harsh weather conditions such as heavy winds and bright sunlight. Hence, close monitoring and frequent watering are necessary steps to keep the plants alive despite they can be time consuming. Therefore, this study attempted to overcome these problems by introducing* ***a soil moisture sensitive automatic drip irrigation system for roof top cultivation****. The irrigation system consisted of a main control unit, gypsum block sensors, soil moisture sensing device, Electronic Sensor Unit (ESU) to detect GBS signals, Oscillator Unit (OU) to make oscillator waves for GBS, Peripheral Interface Controller Unit (PICU) to detect ESU signals and compare the ESU signals with programmed commands, Power controller Unit (PCU) to control irrigation duration and Rain Detector Unit (RDU) to detect rain weather. This irrigation system was compared with sprinkler bucket (manual) irrigation using threecrops, tomato (Solanum lycopersicum L.), Capsicum (Capsicum annuum L.), Brinjols (Solanum melongena L.). This study shows that an automated system can be developed using the basic knowledge on electronics and using the basic electronic items available in the market in a cost effective manner. The study concludes such an irrigation system could save up to 40% of irrigation water and significantly improve growth and yield of the crops grown on rooftops.*

Key Words: Automatic irrigation System, Roof top gardens

Nomenclature

FC - Field Capacity
PWP - Permanent Wilting Point
MCU - Main Controller Unit
ESU - Electronic Sensor Unit
GBS - Gypsum Block Sensors
OMIS - Optimum Moisture Indicator System
IAIS - Irrigation Apply Indicator System
PICU -Peripheral Interface Controller unit
PCU -Power Controller Unit
RDU -Rain Detector Unit
DC -Direct Current
ER -Electrical Resistance
LMIS - Low Moisture Indicator System
IWAS - Irrigation Warning Alarm System
kΩ -Kilo Ohm

1 INTRODUCTION

Rapid urbanization may cause serious environmental destruction finally contributing to the global warming. In urban areas, high night temperature caused by the phenomenon called the heat-island effect may create uncomfortable living conditions for urban population. A practical way to cope this situation is urban greening. However, available space for urban greening is getting limited and a practical way of doing is the rooftop gardening.

Rooftop gardening could significantly reduce heat-island effect (Wong et al,. 2003). In addition vegetation on the roof could also help to reduce dryness in the air through transpiration and to purify the air (Park et al., 2008). Further in developing countries rooftop vegetable gardening could also promote food security by supplying more quantity, variety and the quality to the daily diet while certain instances making it as an income generating activity.

In most of the rooftop gardens, vegetables are grown in pots and the moisture in these pots can be easily dried off since they are subjected to harsh weather conditions such as heavy winds and bright sunlight. Thus water levels of these pots should be closely monitored and maintained at field capacity levels without letting them dry out. Frequent wilting of plants could decrease the productivity and thereby reduce the profitability. Hence watering of plants at adequate levels and correct frequencies are crucial in maintaining a vigorous growth of plants. Uncontrolled frequencies and quantities of watering may also have detrimental effects on the stability of the materials of the rooftop. Further it is a wasting of water leading to an unnecessary cost.

The common practice of watering in the rooftop gardening is the manual watering with a horse pipe or sprinkler buckets. These types of practices are labor intensive, time consuming and costly due to unnecessary wastage of water. Drip irrigation on the other hand could increase the water use efficiency thereby saving the water[1], increase the yield and the labor requirement. Therefore this study was to design an automatic drip irrigation system using available electronic devices in the local market and to find the applicability of the automatic irrigation system with pot experiment.

2 METHODOLOGY

Automated irrigation systems have been developed and used for several years using different devices. Fangmier *et al.* (1990) have developed an automated irrigation system using plant and soil sensors. Their system consisted of two infrared thermometers, an aspirated psychrometer, four soil resistance blocks, a data logger, a solar panel, and a 12 V-DC battery. In this system the data logger was programmed to collect measurements from the sensors and determine the irrigation requirement. The study indicated that the hardware performed well but that inadequate criteria for determining the crop water stress index prevented the system from automatically starting irrigation. Later Araya *et al.* (1991) have designed an automated drip irrigation system for Chilean conditions

[1] This is very significant in rooftop gardening since expensive tap water is being used.

based on the use of a low-cost personal computer. Wanjura *et al.* (1991) have also developed and tested an automated irrigation system for cotton. It consisted of sensors located within irrigation scheduling treatments and a PC which controlled individual irrigation lines through MS-DOS operations. More recently, Testezlaf *et al.* (1997) developed an automated irrigation computer control system for management of greenhouse container plants. This system consisted of soil moisture sensors, a hardware input/output interface, a computer with a software interface, and actuators. Koc *et al.* (1997) and Ribeiro *et al.* (1998) used the Fuzzy Logic System in automated irrigation and found that it provides a very useful approach to simplify the automation process. Based on the above facts the following irrigation system was developed.

2.1 Irrigation system

The automatic drip irrigation system used in the study consisted of Main Control Unit (MCU), Gypsum Block Sensors (GBS) as the soil moisture sensing devices, Electronic Sensor Unit (ESU) to detect GBS signals, Oscillator Unit (OU) to make oscillator waves for GBS, Peripheral Interface Controller Unit (PICU) to detect ESU signals and compare the ESU signals with programmed commands, Power controller Unit (PCU) to control irrigation duration and Rain Detector Unit (RDU) to detect rain weather. The irrigation system was arranged as three zones demarcating one zone for each crop as given in Figure 2.1. The system was also supported with optimum and low moisture indicator systems for each zone, Irrigation application and warning alarms and emergency system bypass valves. The system was controlled by solenoid valves.

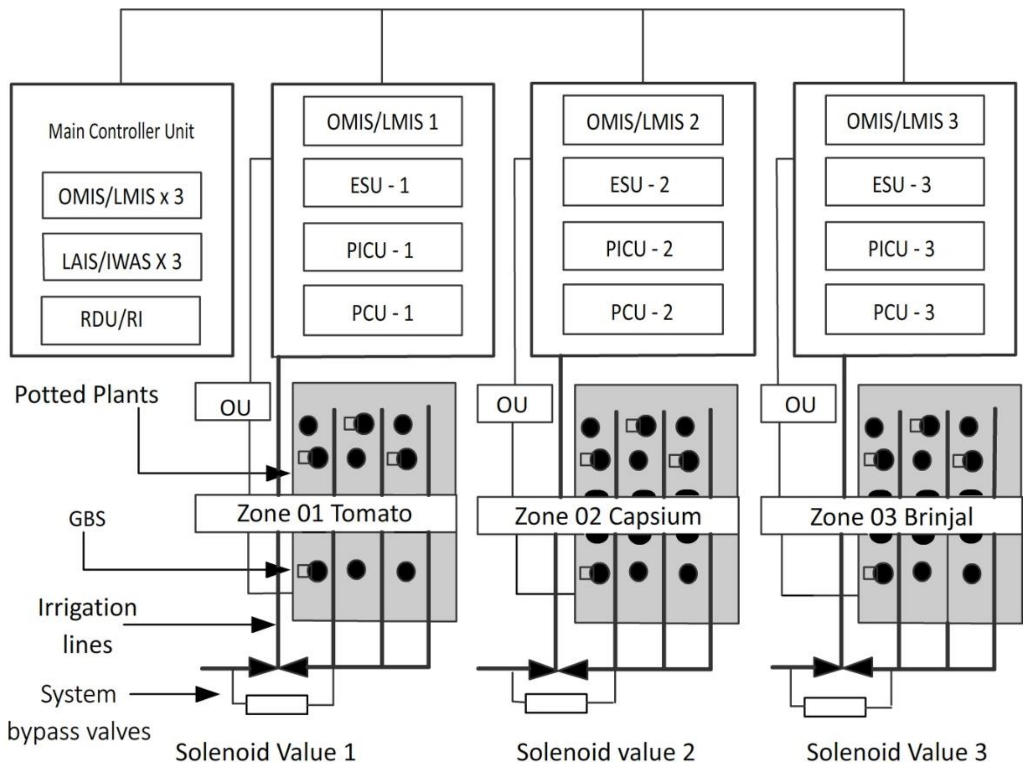

Figure 1 Schematics of the Automatic irrigation system

Tomato (*Solanum lycopersicum* L.), Capsicum (*Capsicum annuum* L.), and Brinjols (*Solanum melongena* L.) were used in the experiment and verities used were Padma, CA-8 and Amanda respectively. Thirty plants from each crop i.e. in each zone were used in the experiments. Each zone was divided into two sub zones to apply two different watering systems used as the treatments in the experiment (TR1=Manual irrigation and TR2=Automatic irrigation).

The experiment was conducted at the rooftop garden of the Science and Technology building of the Open University of Sri Lanka, Nawala, Nugegoda.

2.2 How the system works

The experimental results shows the FC and the PWP of the potted media are 28.53% and 17.15% respectively. When soil moisture level reached to midpoint of FC and PWP of potted media, which is around 23%, the electrical resistance values of the GBS increase with soil moisture depletion and it reaches to the set point. The set point is the electrical resistance of GBS at the required moisture level, which is 20 kΩ. The ESU detects when the moisture level reaches to the set point value according to the electrical resistance.

ESU detects six GBS signals and directs them to PICU. The PICU analyses these six signals with operating instructions programmed on microcontroller. If the signals are matching with the working instructions, PICU generates a signal and it sends to the Power controller unit (PCU).

The PCU is then receives PICU signal and turn on the solenoid valves and also turn off after specific time duration. This time duration can be adjusted from two seconds to a maximum of three hours, which mainly depends on the size of the pot, infiltration characteristics, water flow rate and the soil type of the potting media. When raining, the irrigation system is totally cut off by rain detector unit.

2.3 Determination of moisture content at which irrigation has to be induced

The irrigation system is automatically activated when soil moisture of a pot reduced to the 50% of the field capacity (FC). Moisture content at the FC was measured using the gravimetric method and pressure plate apparatus. Then amount of moisture at the permanent wilting point (PWP) was calculated by oven drying the soil and finally the soil moisture content at 50% of the FC is calculated[2]. Amount of water needed to bring the soil media to 50% of FC was back calculated after adding that amount of water and allowing time settle it down the resistance at 50% FC was then determined. This was repeated for six times to obtain the accurate Electrical Resistance (ER) value corresponding to the 50% FC and the average values are given in Table 1.

[2] $Soil\ Moisture\ Content\ at\ 50\%\ FC = \frac{Moisture\ content\ at\ FC - Moisture\ Content\ at\ PWP}{50}\ \%$

Table 1 Gypsum block resistant values for gravimetric method and pressure plate soil moisture testing methods

Method	Moisture content at the midpoint of FC and PWP	ER of GBS (R_{Test}) kΩ
Gravimetric Method	22.98%	19.7 (Approximately)
Pressure Plate Method	22.83%	20.3 (Approximately)
Average	22.90%	20

The amount of water needed to bring it into 50% of the field capacity was calculated depending on the amount of weight of the potting media and the volume of the pot.

2.4 Pot experiment

Two irrigation systems (TR1 = Manual irrigation; TR2 = Automatic Irrigation) and three crops (Tomato, Capsicum and Brinjal) were used in the pot experiment. The treatments (TR1 and TR2) were arranged in a Complete Randomized Design (CRD) for each crop with three replicates. Amount of water irrigated through micro irrigation was measured at randomly selected pots at each zone. Then number of times the system operates was observed and the amount of water needed per day for irrigating each crop was calculated. Then the amount of water needed for each crop month was extrapolated. Amount of water needed to water the plants for crop was also recorded.

2.5 Measurements

2.4.1 Water requirement

Growth and yield measurements

Plant height and stem girth at weekly intervals, days to first flowering and yield were recorded.

3. RESULTS & DISCUSSION

3.1 Impacts of two irrigation methods on water usage, plant growth and yield

3.1.1 Total water usage

It was observed that the amount of water irrigated through the automatic irrigation system did not vary significantly among crop species. Since the same amount of water applied for each plot manually, calculation of total water requirement was done based on average values of all three crops. The daily and monthly water requirements for two different treatments are given in Fig 3.1. The weekly and monthly water requirement in the automatic irrigation system is significantly lower than that for manual watering. It is calculated that the irrigation efficiency is 40% higher in automatic irrigation than the manual sprinkler bucket irrigation. This may be attributed to the application of water at right quantities when only it is exactly needed in the automatic system.

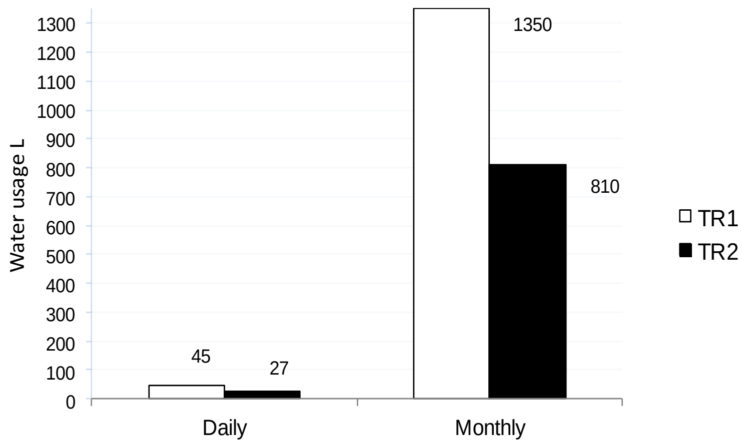

Figure 2 Water requirements of different irrigation systems

3.2 Effect of automatic irrigation on growth of plants

Fig 3.2 shows the impact of two different irrigation methods on plant height measured at weekly intervals of the three crops. Automatically irrigated plants showed a better growth at the latter stages of growth and it was significantly higher in tomato and capsicum. In contrast even though stem girth also showed a better growth in automatically irrigated plants at the later stages of growth, significantly higher growth was only observed in tomatoes (Fig 3.3). The higher growth in automatically irrigated plants may be attributed to the optimal growth conditions provided through higher irrigation efficiency. Thus by using automated irrigation system, significant amount of water can be saved while minimizing the watering time and effort.

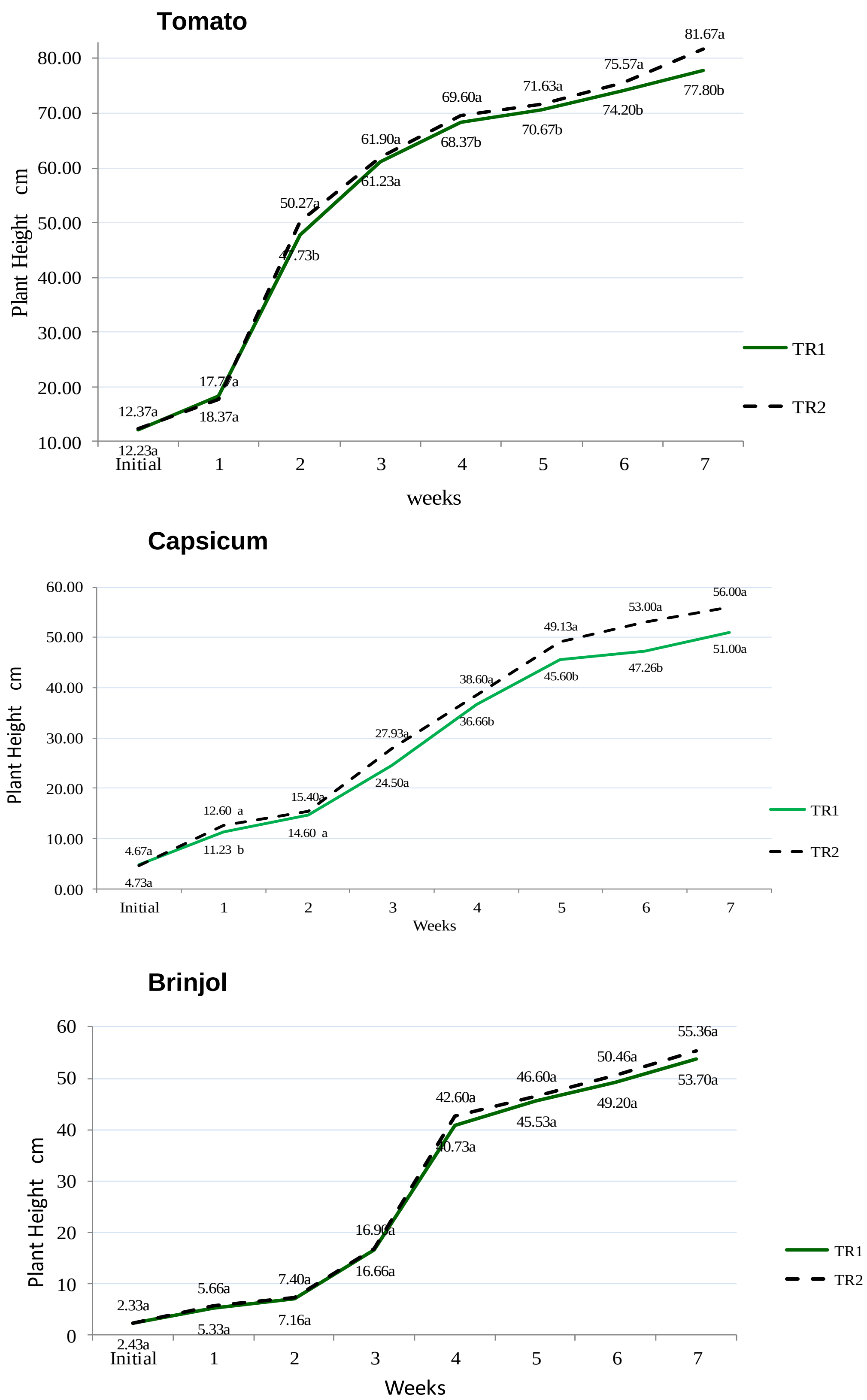

Figure 3 Effect of two irrigation systems on plant height of different crops

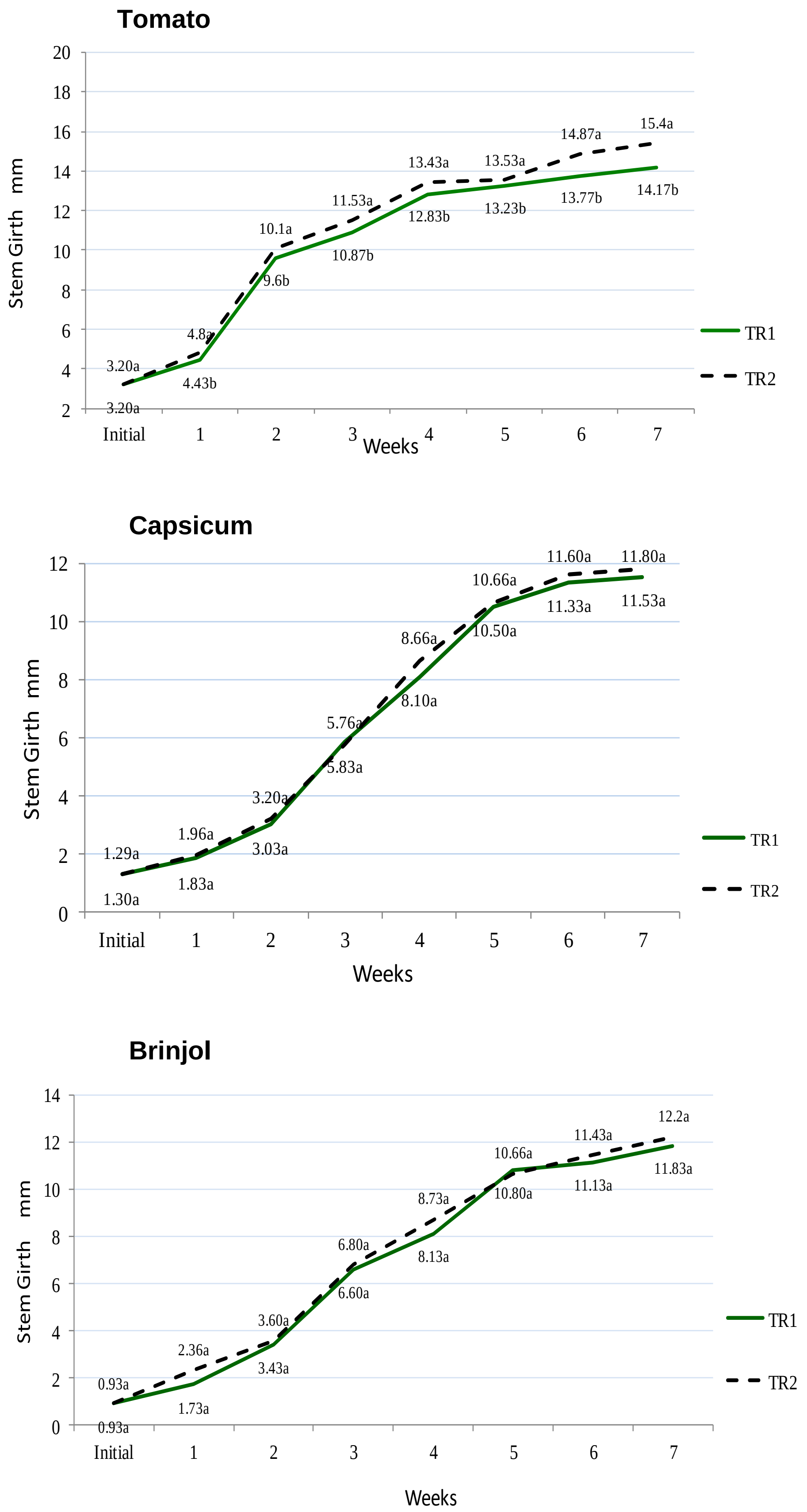

Figure 4 Effect of two irrigation systems on plant girth of different crops

Figure 5 depicts the effect of two irrigation systems on number of days to flowering of three crops. In consistence with the growth of the plants, all three species showed early maturity when they were treated with automatic irrigation. However, the treatments were not significant.

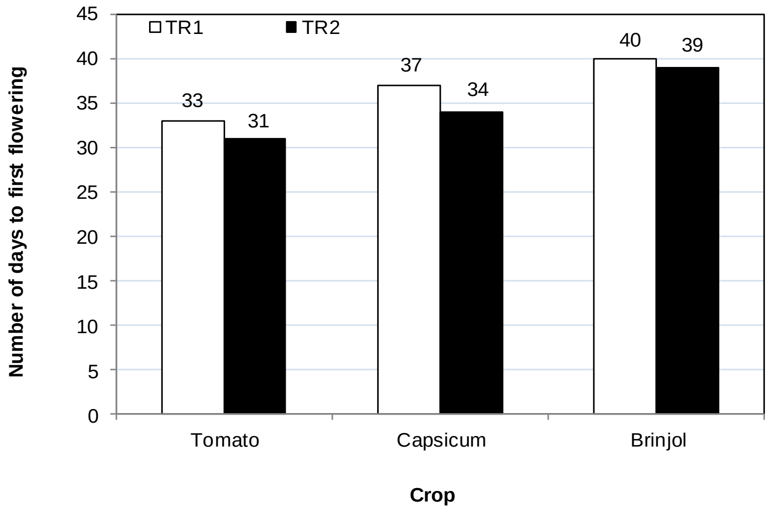

Figure 5 Number of days to first flowering as affected by two irrigation systems

3.3 Crop yield

Yield of each sub plot was recorded and the average yield of each treatment was calculated (Figure 6). The crops showed higher yields in automatic irrigation system. It showed a significant difference in crop yield in manual and automatic irrigation for tomato. The automatic drip irrigation provides better condition for crop growth.

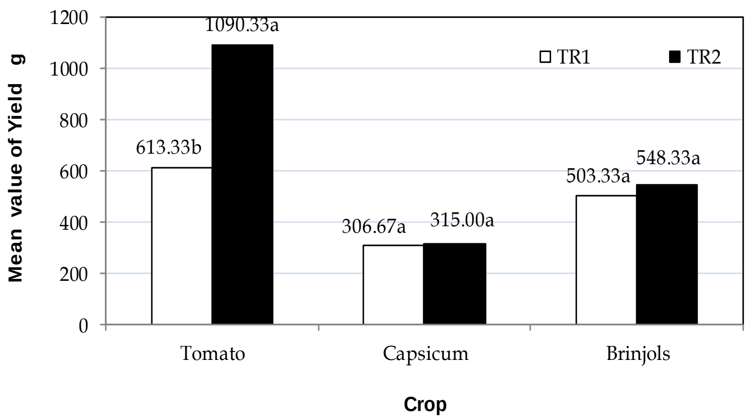

Figure 6 Effect of automatic irrigation on crop yield

Note- Means with the same letter are not significantly different at $p = 0.05$

4 CONCLUSIONS

This study concludes that automated irrigation system can be set up with a basic knowledge on electrical circuits and agriculture using the basic electronic items. These systems not only reduce the cost of water (in general we use pipe born water in rooftop gardening) but also the time required for watering rooftop gardens. These systems can increase the irrigation efficiency and water the plants when only required and at right dosages. Subsequently plant growth can be improved thereby increasing the final yield of the crops.

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