Journal of Soil and Water Conservation **20**(2): 188-194, April-June 2021
ISSN: 022-457X (Print); 2455-7145 (Online); DOI: 10.5958/2455-7145.2021.00023.0

Development and field evaluation of a low-cost automated drip irrigation system

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Received: 17 October 2020; Accepted: 22 February 2021

ABSTRACT

The present study was conducted to design, develop and evaluate a low-cost automated drip irrigation system working on the basis of soil moisture content. In order to get popularity and wider adoption of automated drip irrigation system, it is essential to bring out a cost-effective system. The study involved fabrication of a soil moisture deficit-based drip automation system and testing of the system under field conditions. The system was tested and calibrated based on automatic irrigation scheduling. The automation system developed was simple, precise, sensitive, light weight, cost effective in construction and fast responding. The speed of measurement, cheapness and portability are the key advantages and the system is easily adaptable for use with automatic logging equipment. The automated system based on soil sensors was found to be working efficiently without frequent supervision and maintained the pre-set moisture content in the root zone. The low-cost automated drip irrigation system developed ensures better returns to Indian farmers through considerable savings in labour and other farm inputs. There is scope for further studies on optimization of the electrode geometry and evaluation of electrical conductivity-based soil moisture sensors with different fertilizer and chemical application.

Key words: Soil Moisture, Sensor, Automated Drip Irrigation System and Amaranthus crop

INTRODUCTION

The problem of agricultural water management is today broadly recognized as a major challenge that is frequently linked with development issues. Lack of sufficient water to grow enough crop for meeting the food demand of the increasing population is the major threat to Indian agriculture. As per present situation in India, by 2030, water demand will increase up to 1500 billion m³ (Alexandratos and Bruinsma, 2012). This requires controlled application of water and to achieve it automation of irrigation system being eyed as best alternative. A large number of experiment have been carried out on automated irrigation systems at various levels during last two decades. Automation in micro-irrigation system is gaining momentum slowly in India. This is mainly due to less dependency on labour, smooth operation during day and night hours, as well as saving of energy and water. Mainly Indian farmers choose manually controlled systems or semi-automatic control systems due to low cost and less skills requirement of operating the systems (Patel and Rajput, 2001). Recently, technological advances have been made in soil moisture sensors for efficient and automatic operation of irrigation system based on crop water requirement. The measurement of soil moisture content is a critical factor to achieve precise irrigation schedules, minimize water loss and to maintain optimum level of soil moisture content in the root zone area of plant (Kumari *et al.*, 2017).

In the last two decades with the proliferation of powerful low-cost microprocessors, the computer performances has been enhanced which has further led to mechanization of the irrigation. This increase in the sophistication of automation rationalized the utilization of input, increased production, reduced losses and man power leading to enhance farmer's net income. Soil moisture sensors are integral part of this technology package, which transmits the soil moisture status of the field. To pass the benefit of automation at grass root level, there is a need for low cost logging for information systems and automatic controls in developing countries. Appropriate low-cost technology has to be developed to facilitate high water use efficiency and to enhance the crop productivity. Various efforts have also been made to develop simple and low cost soil moisture sensors. In this endeavor,

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Sharma *et al.* (2015) reports for development of a low cost soil moisture sensors which reported to be simple, precise, sensitive, light weight and cost effective. Abraham *et al.* (1999) developed and tested a low cost, commercially available button type's thermistor was used as the leaf and air temperature sensors.

Current advancement in soil water sensors offer a scientific option which can make the commercial use of this technology possible to automate irrigation management for agriculture production (Singh *et al*., 2019). Soil moisture based automatic irrigation reduced water use range as high as 70% compared to farmer practices with no negative impact on crop yields (Carpena and Dukes, 2005; Singh *et al*., 2018). Morris (2006) surveyed some low-cost soil moisture monitoring tools and methods, including new generation of sophisticated and user-friendly electronic device and explained the process of water detention by soil. Prathyusha and Chaitanya (2012) mention that microcontroller based drip irrigation system which proves to be a real time feedback control system, monitors and controls all the activities of drip irrigation system efficiently. They also reported that using this system one can save the water and manpower to improve production and ultimately profit.

The present study was carried out to overcome the problems in available irrigation automation systems. The aims to automate the irrigation by measuring moisture levels in the field and irrigating the field based on the soil moisture content. In order to get wider adoption and popularity of automated irrigation system, it is imperative to bring out a cost-effective system in this irrigation technique. Hence it is suggested to replace the imported components with the following objective locally designed gadgets. With these views a study was conducted to design and develop a low-cost automated drip irrigation.

MATERIALS AND METHODS

The design and fabrication of drip automation system was done at Soil Water Engineering laboratory of Kelappaji College of Agricultural Engineering and Technology (KCAET), Tavanur, Malappuram, Kerala. The system was developed taking into the considerations portability, corrosiveness, toughness to weather parameters, quick response, easy for installation and fixation of the sensors.

Components of drip automation system

The automation system is designed as simple, light weight and easy to handle. The entire unit developed is moisture proof. Block diagram of controlling system is shown in Fig. 1 and circuit for automatic irrigation system is shown in Fig. 2.

Electrical conductivity type soil moisture sensor

The conductivity sensors are made of high-quality stainless-steel probes for durability. The soil moisture sensor consisted of two electrodes i.e. positive and negative separated by a nonconductor medium that is nylon circular plate. The electrodes of the sensor were built of round cylindrical shape. The complete sensor length is 215 mm and spacing between the electrodes is 55 mm. It is made up of stainless 3 mm thick steel. The weight of the single soil moisture sensor is approximately 100 grams shown in (Fig. 3). The oxidation of the sensor occurred due to contact of water with soil can be avoided by using stainless-steel material. One probe

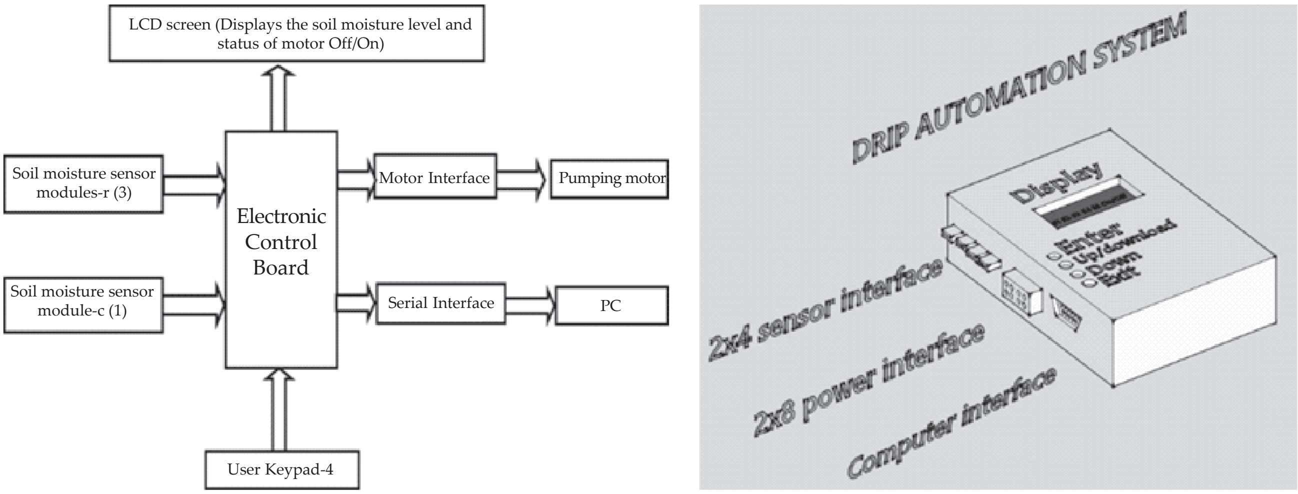

Fig. 1. Block diagram of irrigation control system

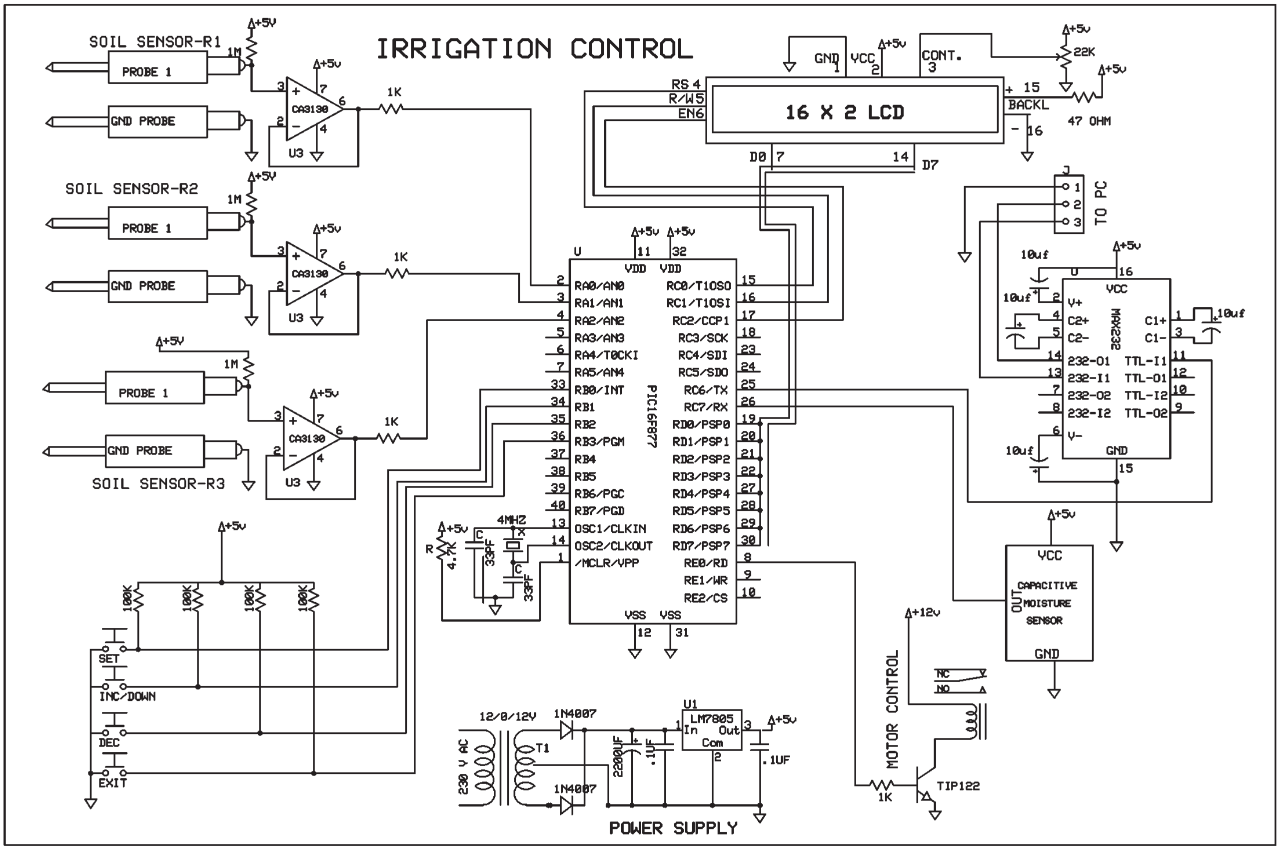

Fig. 2. Controller Board Circuit of automatic irrigation system

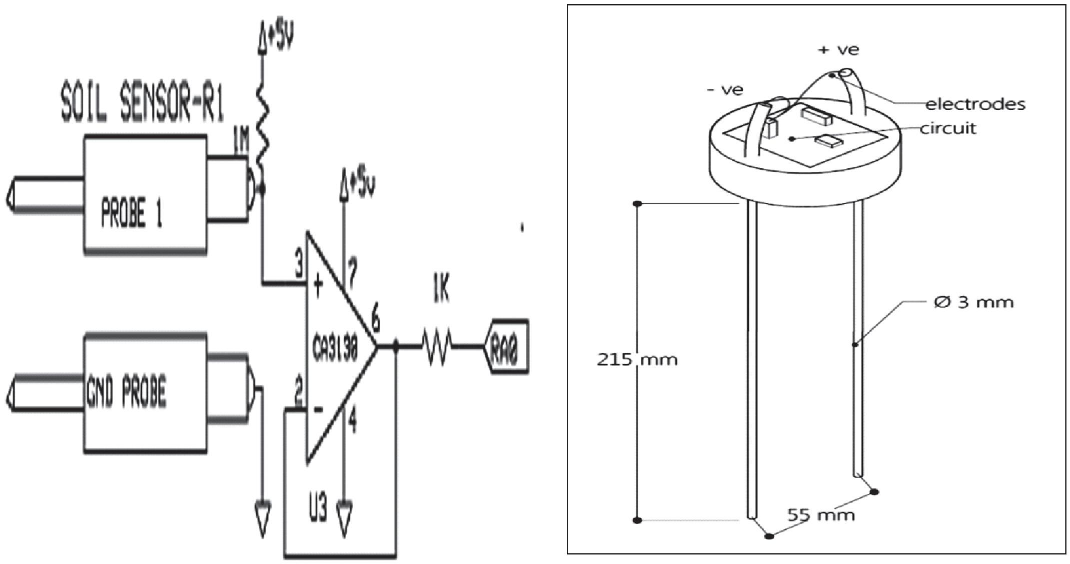

Fig. 3. Circuit and Sketch of Soil Moisture Sensor

is connected to Vcc via a 1.0 M ohm resistor, thus acting as a voltage divider and the other one is grounded. When there is sufficient moisture content in the soil, the conductivity is high, hence the voltage divider output is high. When the soil becomes dry, its conductivity decreases thus decreasing the voltage divider output. This is then given to an op-amp based voltage follower. CA3140 is used here as the operational amplifier. The output of the sensor is connected to MCU through the voltage follower made by the CA3140. Voltage follower is used here for impedance matching purpose.

Capacitive type soil moisture sensor

Sensors measure the volumetric water content of the soil by measuring the dielectric constant of

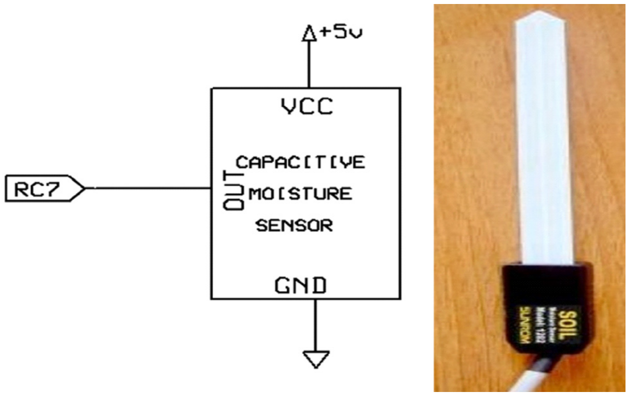

Fig. 4. Circuit of capacitive type soil moisture sensor

the media through the utilization of frequency domain technology. Since the dielectric constant of water is much higher than that of air or soil minerals, the dielectric constant of the soil is a sensitive measure of volumetric water content. The sensor has a low power requirement and very high resolution. The weight of the single soil moisture sensor is approximately 100grams shown in (Fig. 4). This gives the ability to make many measurements (i.e. hourly) over a long period of time with minimal battery usage. In addition, the sensors incorporate a high frequency oscillation, which allows the sensor to accurately measure soil moisture in any soil with minimal salinity and textural effects. The output of the sensor is interfaced to RC7 of the microcontroller.

Microcontroller unit

Microcontroller unit (MCU) is the heart of any automation irrigation system. In this system PIC16F877 is used as the MCU. It is used sensor output and determining the moisture level than send signal to control motor for on/off. The popular microcontroller PIC 16F877 from MICROCHIP Corporation is used as the CPU of the system. PIC microcontrollers are the most popular 8 bit microcontroller in the world. They are available in wide variety in pin outs, memory capacity and have lots of integrated peripherals like ADC, SERIAL modules and EEPROM. The PIC 16F877 is available in 40 pin DIP package and have program memory capacity of 8 Kb, RAM of 368 Bytes and 256 Bytes of EEPROM. Generally, they are low power devices and works in voltage range of 2V to 5.5V. They have 13 interrupt sources like external pulse interrupt and serial receive interrupt etc. These chips are supplied with in circuit serial programming facility and are flash technology also. The flash memory can be rewritten 1000 times.

User keypad

A keypad is interfaced with the system which helps the user to set the high and low limit of the moisture level to start and stop pumping unit. There are four keys connected to the system. A download key is also provided in this keypad, which helps the user to download the stored data to the computer.

Liquid Crystal Display (LCD)

LCD display is used for displaying the state of the unit. It displays the four sensor outputs its average value and the state of the motor. LCD module is a dot matrix liquid crystal display that displays alphanumeric, kana (Japanese character) and symbols. The built-in controller and driver LSI, provide convectional connecting between LCD and most 4- or 8-bit microcontroller.

Motor interface

This is required because the current output from the microcontroller is very small which is not sufficient to magnetize the relay which is used to control the motor. Hence it is necessary to have an amplifying circuit. The output of the micro-controller is fed to the TIP122 IC for current boosting.

Motor control circuit

Electrical relays are interfaced to the MCU via the driving circuits. These relays are used to control the motor pump. Commonly relays are inductive loads and are operated in 12V range. Because of these reasons there is a need of interfacing circuits between these relays and MCU.

Serial interface to PC

MAX232 IC is used to interface the microcontroller with PC. The 11th pin of the MAX232 IC is connected to the serial port TX of the microcontroller i.e. to pin RC6. RS232 connectors were used to connect the MAX232 output to the PC serial port.

PC communication

The microcontroller is interfaced to the PC via serial interface. The stored data can be downloaded and viewed in the PC. The sensor outputs and the average value recorded for every minute .

Simulation software

The whole circuit was simulated by using the simulation software MPLAB. It is a windows program package that makes writing and developing a program easier. It includes a host of software components for application development and debugging. It supports the free software simulator, hardware debug, and programming tools using a single standardized graphical user interface.

Field experiments Using automation system

The field trial was conducted at the experimental plots of KCAET Instructional Farm near to the Bharathapuzha River basin, Tavanur. The study area is situated between 10^0 52' 30" North Latitude and 76^0 East longitude. Agro climatically, the area falls within the border line of Northern zone and Central Zone of Kerala. Major part of the rainfall in this region is obtained from South West monsoon. The total area selected for the study was 20mX10m. The land preparation was done before the installation of the system in the field. Amaranthus (*Amaranthus caudatus* L.) Arun variety with duration of 90 days was used for the study. It is high yielding variety and it is well suited for this soil types and the region.

RESULTS AND DISCUSSION

To set the irrigation time, the conductivity value of soil moisture sensor is required to be pre-set before installation. The upper values (field capacity of soil) were estimated by calibrating the soil moisture sensor. After pre-setting the upper value in the data logger, the soil moisture sensor was kept at the desired depth (10 to 20 cm) within the active root zone of the crop. As the soil gets dried up, conductivity gets decreased and when it reaches the upper limit, the LED in the control panel gets illuminated indicating to start irrigation. The system can be activated by using a single-phase motor for pumping. There is also a manual option for turning the motor ON/OFF. Drip automation system switches ON the irrigation system when the sensors value reaching a pre-set reading. The irrigation system will be operated until the soil moisture content reaches the field capacity of soil. As the soil dries, water content decreases and the conductivity value in data logger decreases. The irrigation system will run until the conductivity reaches the pre-set critical value. In this way soil moisture sensors continuously record the fluctuations in soil water content under field conditions and store the data for every one hour.

Performance assessment in field of automated drip irrigation

The performance of the automation system was evaluated by conducting a field study using the crop Amaranthus. The field layout plan for experiment main plot is shown in (Fig. 5). From the source the water was pumped through a 0.75 HP motor and conveyed to the field using the 40 mm diameter PVC pipes. From main line, 12 mm LDPE lateral lines for each treatment were taken to irrigate the beds. There were a total of 22 beds. Length of main line was 20 m, length of laterals was 10 m, capacity of emitter used was 4 lph and size of plot was 20 mX10m. Automatic drip irrigation performance found satisfactory under field condition for entire crop season. Soil moisture content measured by sensors, then sensors send output of controlling unit to start and stop motor.

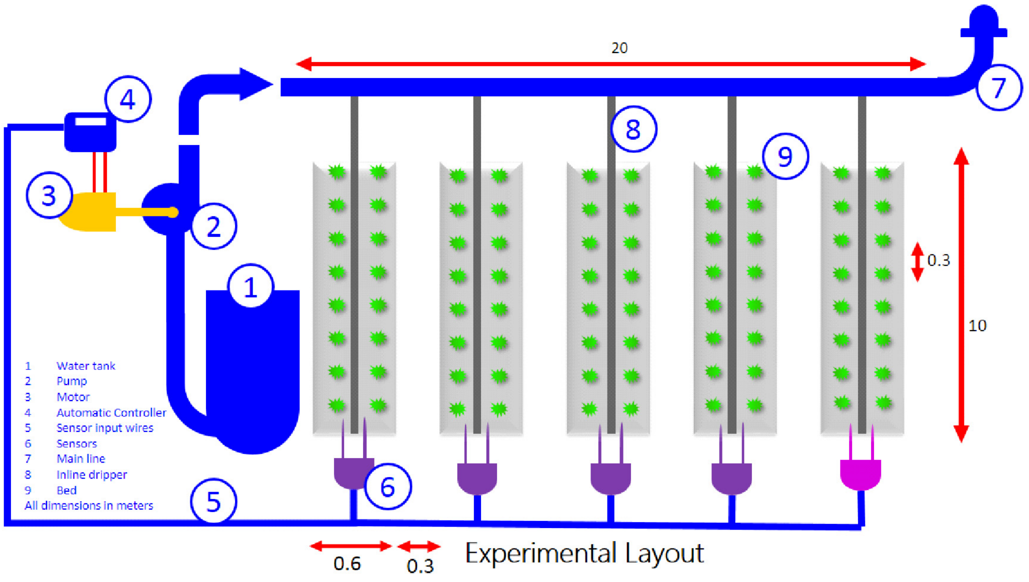

Fig. 5. Layout of field experiment

One month after the installation of the sensors, some deposits were found to form on the electrode plates that reduced the electrical conductivity between the electrode plates. These deposits may be due to the polarisation of certain ions present in the soil. The same trend was found immediately after the addition of fertilizers to the soil. This is in agreement with the observation of Abraham *et al.* (1999). Application of fertilizers or chemicals can change the conductivity-moisture content relationship and therefore calibration of sensor is required after adding fertilizers or chemicals. Such variations are not observed for the system based on capacitor type sensors.

System maintenance

To run the system efficiently, following major steps were followed.

- Positive and negative terminals of the sensor were connected properly to the respective connections provide on the instruments.
- It was ensured that all parts of the sensor were properly fitted so that there existed no gap between the parts of the sensor to avoid entry of water.
- Sensor was properly inserted into the soil to avoid gap between the soil and soil moisture sensor.

Crop Biometric Observations

The observation on stem girth was first taken two weeks after planting. After that, the observations were taken at a weekly interval. The readings were taken upto 7 weeks after transplanting. Stem girth observed was 1.62 cm, 3.41 cm, 4.38 cm, 4.69 cm after sowing of 15, 23, 29 and 36 number of days, respectively. Variation of number of leaf increased with the time. Maximum 130 number of leaf was recorded after the 40 days of sowing and minimum 16 number of leaf after 15days of sowing. As Amaranthus is a leafy vegetable, fertilizer is mainly used for producing more leaves. The maximum root zone of Amaranthus is about 45-60 cm, having fibrous root system, more extraction of water and fertilizer is happening in upper 25% of the root zone area, i.e, upto 15 cm depth and lesser extraction at 20 and 30 cm depths. This result is in agreement with Kant *et al.* (1998) on the results of studies on the soil moisture extraction pattern of spring and summer pruned mulberry gardens. They reported that maximum water was extracted from the upper layer of root zone. The maximum vertical root length was found to be 34 cm and horizontal root length was 19 cm. The observation on yield was first taken after 30 days of planting and later the yield was taken at weekly interval. In the first harvest at 30 days after planting, the high yield was observed (1.358 t/ha). After the first harvest crop left was used for the seed purpose. Total 5 Kg. seed was obtained from the experimental plot (200 m^2) area.

CONCLUSIONS

The soil moisture sensor based automatic drip irrigation system was designed, developed and tested for scheduling irrigation automatically. The developed system is economical, light weight and water proof. The automation unit is simple to install and uninstall, under field conditions. Soil moisture sensors were evaluated with respect to the moisture content. It was observed that as the moisture content decreases, the soil electrical conductivity of sensors decreases. In field evaluation of the sensors in whole crop season at different crop stages, different values with respect to the moisture content was noticed. This might be due to the difference or non-uniformity in the soil texture and air gap between the soil and soil moisture sensor. In soils, cracks can be easily formed which were responsible for the air gap between the soil and the sensor. So, care should be taken while installing the sensors in the field. The system was installed in the field for a season with the crop Amaranthus and the system worked properly and the motor gets switched "ON" and "OFF" automatically with respect to the output of sensors.

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