



Evaluation of Moisture Content of Soil at Different Stages of Plant Growth under Different Irrigation Treatments

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Drip irrigation is artificial technique of providing water to the roots of the plant at very low rates (2-20 litres/hour) from a system of small diameter plastic pipes fitted with emitters or drippers. A few low cost automation systems were developed and evaluated their performance with drip irrigation on sweet corn on the sandy soils of College of Agricultural Engineering, Bapatla. It was observed that single row drip irrigation showed better results compared to flood irrigation and paired row drip irrigation. The results indicated that the soil water distribution pattern showed the highest water content near the drip line for all scheduling techniques. As increase in time of operation Wetting diameter and Penetration depth increased in relative to time. With comparison of different irrigation systems, the soil moisture content value of before irrigation and after irrigation is better in single row drip system.

Keywords: *Drip irrigation; micro irrigation; automation systems; wetting diameter; penetration depth.*

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1. INTRODUCTION

Developing infrastructure for the water resources and their management have been the common policy agenda in many developing economies, particularly in the arid and semi-arid tropical countries like India. Land and water are the basic needs for agriculture and economic development of the country. A study by the International Water Management Institute (IWMI) has shown that around 50 per cent of the increase in demand for water by the year 2025 can be met by increasing the effectiveness of irrigation [1]. Plants and animals cannot live without water and to ensure food security, feed live stock, maintain organic life, and take up industrial production and to conserve the bio-diversity and environment water is needed. Although India is not a water poor country, due to growing human population severe neglect and over exploitation of this resource, water is becoming a scarce commodity.

Major consumption of water is for agriculture, industrial production and domestic purposes, apart from being used for fishery, hydro power generation, transportation and maintaining bio-diversity and ecological balance. The proportion of water is used for agriculture and an industry varies from country to country depending on the lifestyle. While the per capita water use in India will increase from the current level of 99 litres per day to 167 litres per day in 2050 then India will be the highest water demanding country, needing 2413 billion litres per day [2]. Agriculture marks the beginning of 'civilized' or 'sedentary' society. Irrigation has been considered essential for the fast growth of agriculture which consumes 80 percent of the country's exploitable water resources. To date agricultural sector is the largest consumer of water in the world (Patel et al., 2014). Under the conditions of increasing water scarcity, the challenge to satisfy the irrigation water demand in both developed and emerging countries is to conserve water and improve the efficiency of water use through better water management and policy reforms (Lazarova and Asano, 2005).

Micro irrigation technology is now widely accepted by most of the farmers in the world. Micro irrigation systems are usually defined in terms of installation method, emitter discharge rate, wetted soil surface area or mode of operation [3]. According to ASAE (2001) micro irrigation is the slow application of water on, above, or below the soil by surface drip, subsurface drip, bubbler and micro sprinkler

systems. Drip irrigation is an efficient method of providing irrigation water directly into soil at the root zone of plants and thus, minimizes conventional losses such as deep percolation, runoff and soil erosion. With drip irrigation water applications are more frequent than with other methods and this provides a very favourable high moisture level in the soil in which plants can flourish. Drip method helps in achieving saving in irrigation water, increased water-use efficiency, higher quality products, decreased tillage requirement, increased crop yields and higher fertilizer-use efficiency [4].

The amount of water accumulated in the unsaturated soil zone is referred to as soil moisture. Soil moisture and its movement are important factors in a variety of agricultural applications and vegetation growth monitoring, hydrology, climate system and stream flow prediction (Quesney et al., 2000 and Seneviratne et al., 2010 and Kumar et al., 2014). Soil moisture measurement has always been an important part of effective farm management. The rate of change in soil moisture can be used to predict the time and duration of the next irrigation cycle. The amount of moisture presents in the soil depends on the particle size distribution, porosity, depth of the soil, structure of the soil, salinity, presence of contaminants, degree of compaction, organic content, humidity and temperature (Lekshmi et al. 2014).

Sweet corn is a high moisture commodity and sold on the basis of high quality alone. It is very succulents, has a rather shallow root system and does not yield well if adequate soil water is not readily available [5]. With sweet corn, drip irrigation has shown to have competitive advantages over other approaches over time. When domestic waste effluent was used, there was less interaction between the effluent and the crop in drip irrigation compared to other methods thus reducing the risk of pathogen contamination (Pescod et al., 1984). Irrigating sweet corn with micro-drip (emitter discharge of less than 0.5l/h) irrigation may improve yield, reduce drainage flux (excess water removal) and affect the water content distribution within the root zone especially within 0.6-0.9 m soil layer when compared with the conventional drip irrigation [6]. The aim of the present work was to valueate the moisture distribution curves and moisture content of soil at different stages of plant growth under different irrigation treatments.

2. MATERIALS AND METHODS

2.1 Preparation of the Field

The experiment was conducted in the field irrigation laboratory, Department of Soil and Water Engineering, College of Agricultural Engineering, Bapatla. The experimental site lies in humid sub tropical area. The summers are dry and hot, where as winter is cool. The experimental site consists of sandy soil with well drained conditions. The field was prepared by cultivator and rotavator for loosening the soil and for removal of weeds prior to sowing the sweet corn seeds. After one week of applying about 100 kg of farm yard manure throughout the field having an area of 1330 m² for sweet corn plot, once again the plot was tilled with rotavator to mix the dried farm yard manure thoroughly in the soil.

2.2 Water Source

For supplying the water, an existing open well near the experimental site was utilized. To know the suitability of water for irrigation, the quality of water was assessed and found that pH and EC of water is 7.2 and 4 dS/m respectively.

2.3 Irrigation Accessories

- **Main pipe:** To convey water from source to the experimental site through sub mains a PVC pipe of 63 mm diameter (Class 2, 4 kgf/cm²) was used.
- **Sub main:** To convey water from main lines to laterals a PVC pipe of 50 mm

diameter (Class 3, 6 kgf/cm²) was used as sub main pipe.

- **Lateral pipe:** To supply water directly to the plant root zone from sub main pipes, a LLDPE pipe was used. The laterals are of inline type with specifications as: Outer diameter - 16 mm, Wall thickness - 0.80 mm, Flow rate - 2.00 lph at 1kg/cm² pressure and Spacing of drippers - 40 cm.
- **Pump:** For pumping water a centrifugal mono block pump of 1 hp capacity is used.

2.4 Screen Filter

The screen filter normally consists of stainless steel screen of 120 mesh (0.13mm) size, which is enclosed in a mild steel body. Filtration is achieved by the movement of water through the stainless steel mesh with specifications as: Maximum flow capacity - 27m³/hr, Nominal size - 50 mm, Nominal pressure - 2 kg/cm², Size of aperture - 120 mesh and Clean pressure drop - 0.5 kg/cm² maximum.

2.5 Sand Filter

Media filters consist of fine gravel or coarse quartz sand, of selected sizes (usually 1.5 – 4 mm in diameter) free of calcium carbonate placed in a cylindrical tank. These filters are effective in removing light suspended materials, such as algae and other organic materials, fine sand and silt particles. This type of filtration is essential for primary filtration of irrigation water from open water reservoirs, canals or reservoirs in which algae may develop.



Plate 1. Water distribution system with sand filter, screen filter and other accessories

2.6 Working Principle Involved in the Soil Moisture Sensor

The basic working principle involved in the development of soil moisture sensor circuits is electrical conductivity. As the moisture content of the soil increases, the electrical conductivity of the soil increases.

In this experiment, sensors detect the moisture in the soil (agricultural field) and supply water to the field which requires irrigation water. The developed sensor as shown in Plate 2. is 8051 microcontroller based design which controls the water supply in the field to be irrigated using solenoid valves. The sensor present in each field stops the pump automatically through microcontroller when the field reached to its field capacity. Once the field reaches to 70% of field capacity, sensors sense the requirement of water in the field and send a signal to the microcontroller. Microcontrollers then supply water to that particular field for which water requires, till the sensors are deactivated again.

2.7 Scheme of the Experiments

Sweet corn (*Zea mays*) of variety sugar 75 was chosen as the test crop. The plot was kept ready by adding the required farm yard manure as per the recommended dose to sow the sweet corn seed. The plot was thoroughly wetted for 2 days while sowing. The plot having area of 1330 sq m, is divided into three sub plots as 12x35 m each to conduct experiments.

PLOT I

The first plot is paired row, the plant to plant spacing is 0.2m, paired row spacing of 0.4x1.1 m. Between dripper to plant is 0.2m on both sides of the lateral and lateral spacing is 1.5m with recommended dose of fertigation application manually.

PLOT II

The second plot is single row, the plant to plant spacing is 0.2m and row to row spacing is 0.75m with recommended dose of fertigation application manually.

PLOT III

The third plot is flood, the plant to plant spacing is 0.2m and row to row spacing is 0.75m with recommended dose of fertigation application manually.

The sweet corn seeds were sown in the experimental field with recommended seed rate of 4 kg/ha as per the recommended spacing in the three plots and the drip system were arranged. In order to study the moisture distribution pattern around the plant the soil moisture content was measured at different depths below the soil surfaces at varying radial distances from the plant. To measure the moisture distribution after irrigation in all three treatments, one set of measurements was taken 30 min after irrigation, the other was 60 min after irrigation and last one measurement was taken 90 min after irrigation.

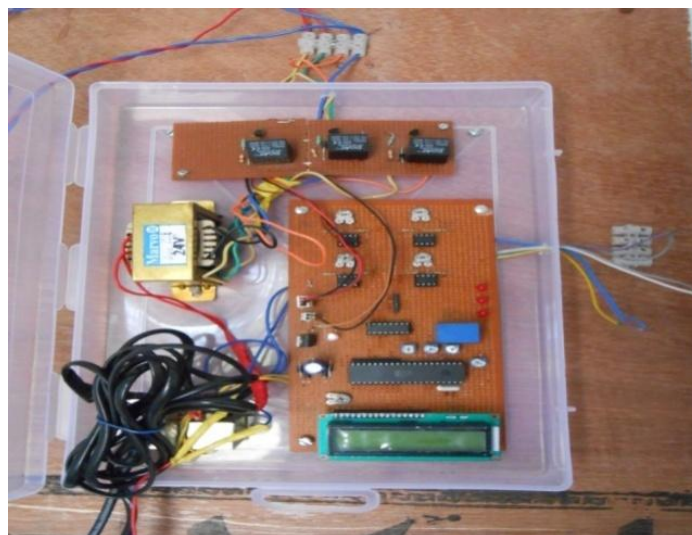


Plate 2. Microcontroller based soil moisture sensor

3. RESULTS AND DISCUSSION

3.1 Moisture Distribution Pattern in Different Treatments

3.1.1 Wetting spread

The surface wetted diameter and depth of percolation of water were recorded in all the three treatments during the process of application of water. The water was applied according to soil moisture sensor in drip systems. The moisture front advances were recorded horizontally and vertically at an interval of every 30 min to know the spreading pattern.

The observations were shown in Fig. 1. In sweet corn, the wetted circle diameter increased gradually from 17 cm after application of water in the first 30 min to 38 cm at the end of irrigation i.e. after 180 min.

As increase in time of operation, the wetted diameter and penetration depth increases in relative to time. The penetration depth increases from 30 cm after application of water in first 30 min to 59 cm at the end of irrigation i.e. after 180 min.

3.1.2 Moisture content of soil at different stages of plant growth

Moisture content of soil at different stages of plant growth of sweet corn is shown in the Fig. 2. With comparison of different irrigation systems, the soil moisture content value of before irrigation and after irrigation is better in single row drip system even though at certain depths it is decreasing. This is because of loosening the top soil by rotovator, the infiltration of water taking place quickly and as the depth is increasing, the moisture content is high because of compactness of soil, water is stagnating and lateral movement takes place faster than the infiltration.

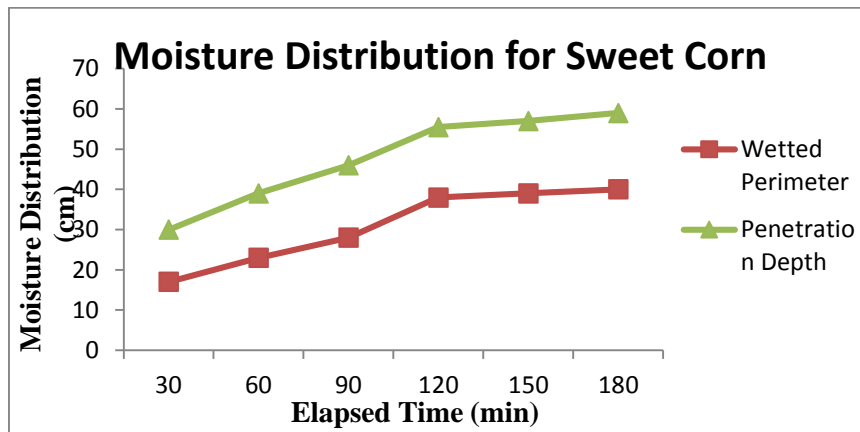
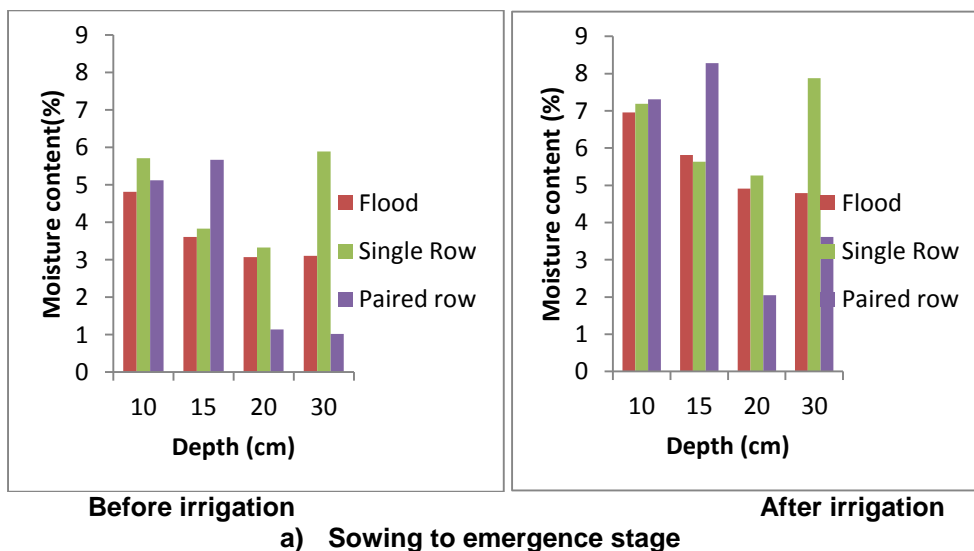
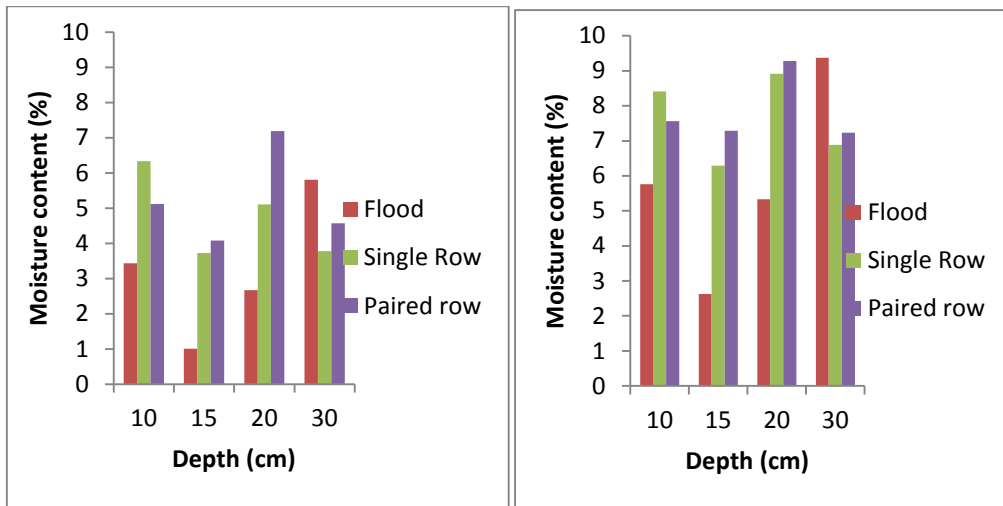


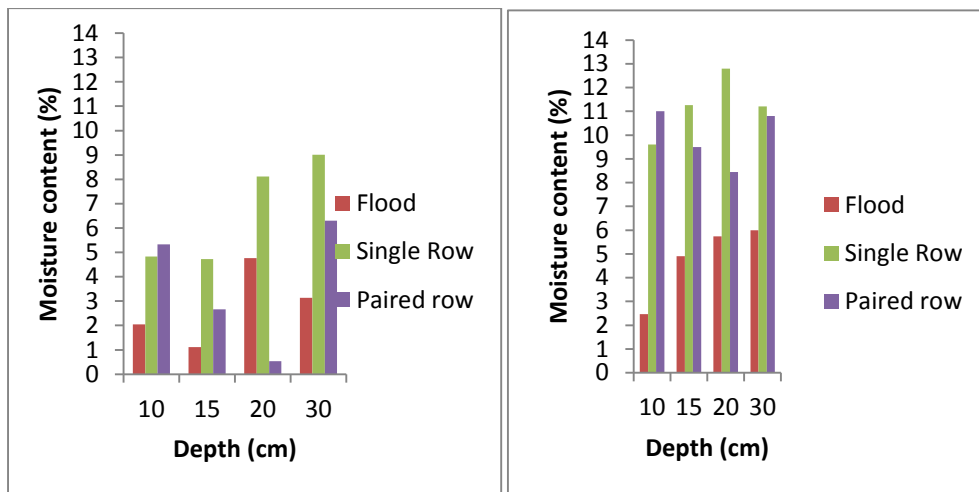
Fig. 1. Relationship between wetted perimeter and penetration depth with elapsed time



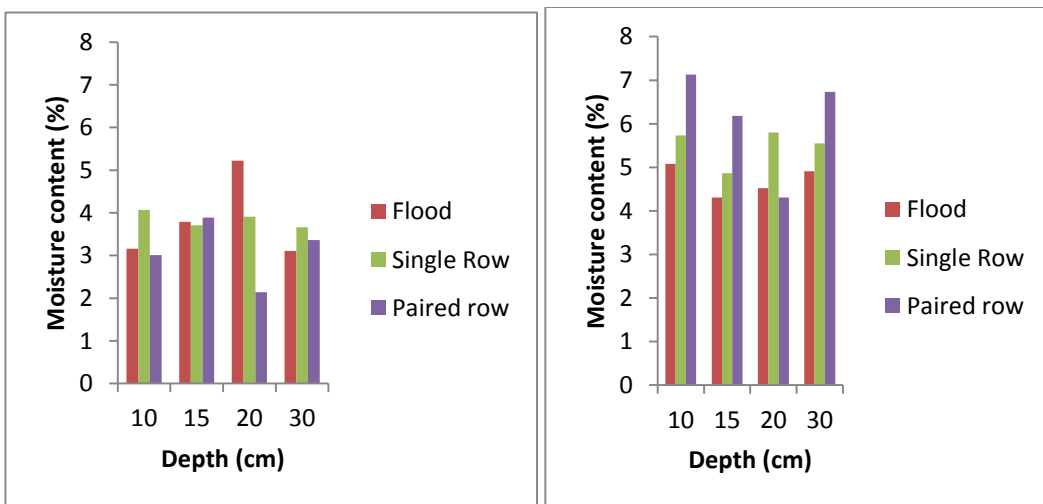
a) Sowing to emergence stage



b) Emergence to tasselling stage



c) Tasselling to end of silking stage



d) End of silking to harvest stage

Fig. 2. Moisture content of soil at different stages of plant growth

3.1.3 Moisture distribution curves for sweet corn

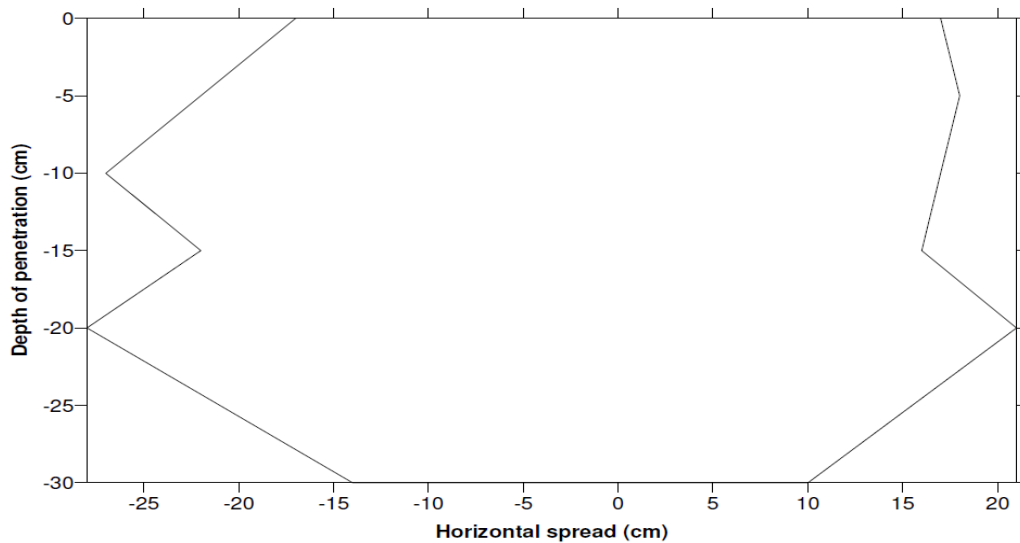
It was observed that the shape of the soil moisture distribution was close to conical for all the irrigation scheduling techniques. The soil water distribution pattern showed the highest water content near the drip line for all scheduling techniques.

3.1.3.1 Soil moisture distribution pattern in contours

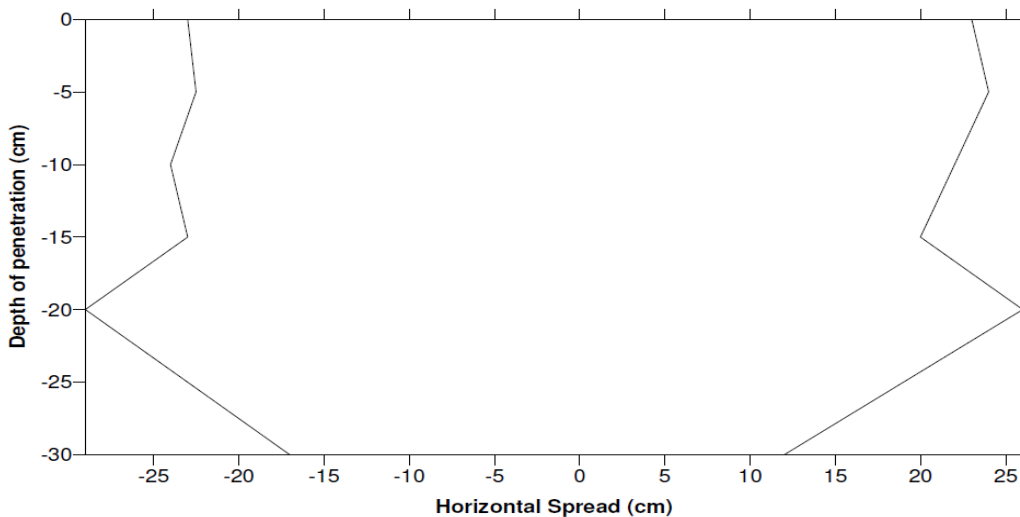
Soil moisture distribution pattern for the 30 min, 60 min and 90 min after irrigation is shown in Fig. 4, Figs. 5 and 6. At 30 min after irrigation, amount of moisture content decreased as the distance from the plant increased due to lateral

spacing and the moisture content near the plant was 8.3 per cent. The moisture content at 10 cm depth near the plant was 7.56%. The moisture content reduced from 7.56% to 5.4% at a depth of 10 cm to 30 cm. The percentage decrease in moisture content near the plant was 53.7%. The percentage decrease in moisture content at a distance of 10, 20 and 30 cm from the plant are 34.2, 196.7 and 24.36%.

At 60 min after irrigation, the moisture content near the plant is 7.61 % and reduction in moisture content near the plant is 20.7 %. At a depth of 20 cm near the plant the moisture content is increased from 7.61 to 8.3 %. The percentage decrease in moisture content at a distance of 10, 20 and 30 cm from the plant are 72, 175.6 and 43.12 per cent.



a) Moisture distribution for 30 min



b) Moisture distribution for 60 min

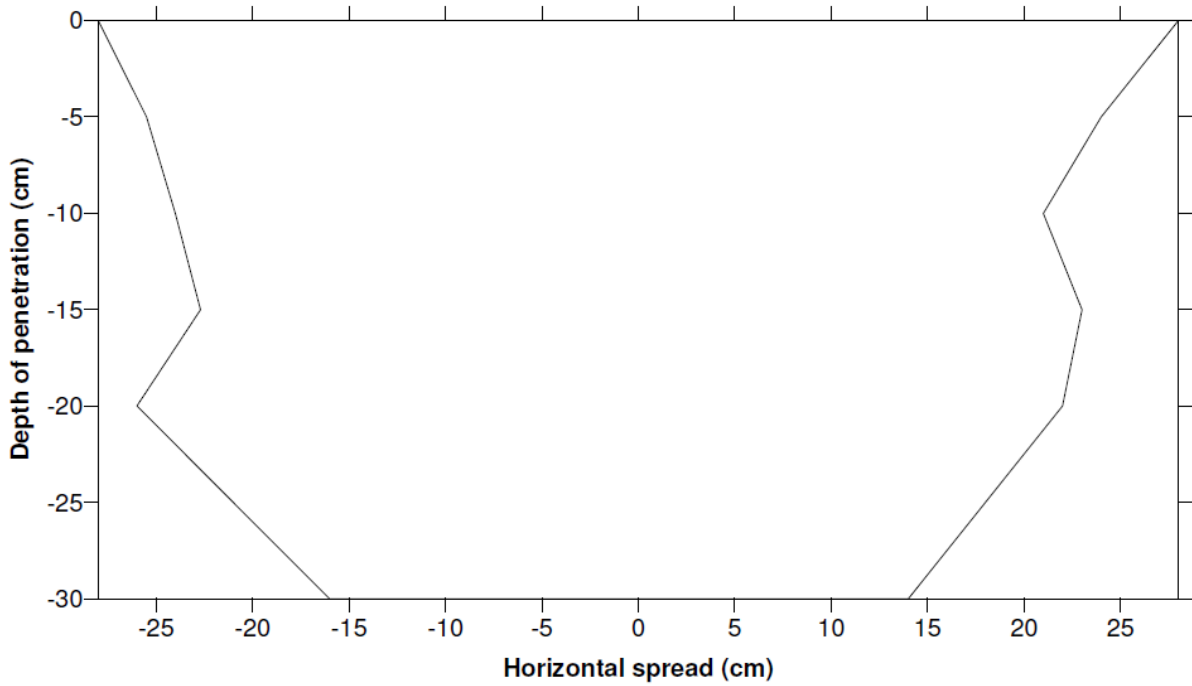


Fig. 3. Moisture distribution curves for sweet corn

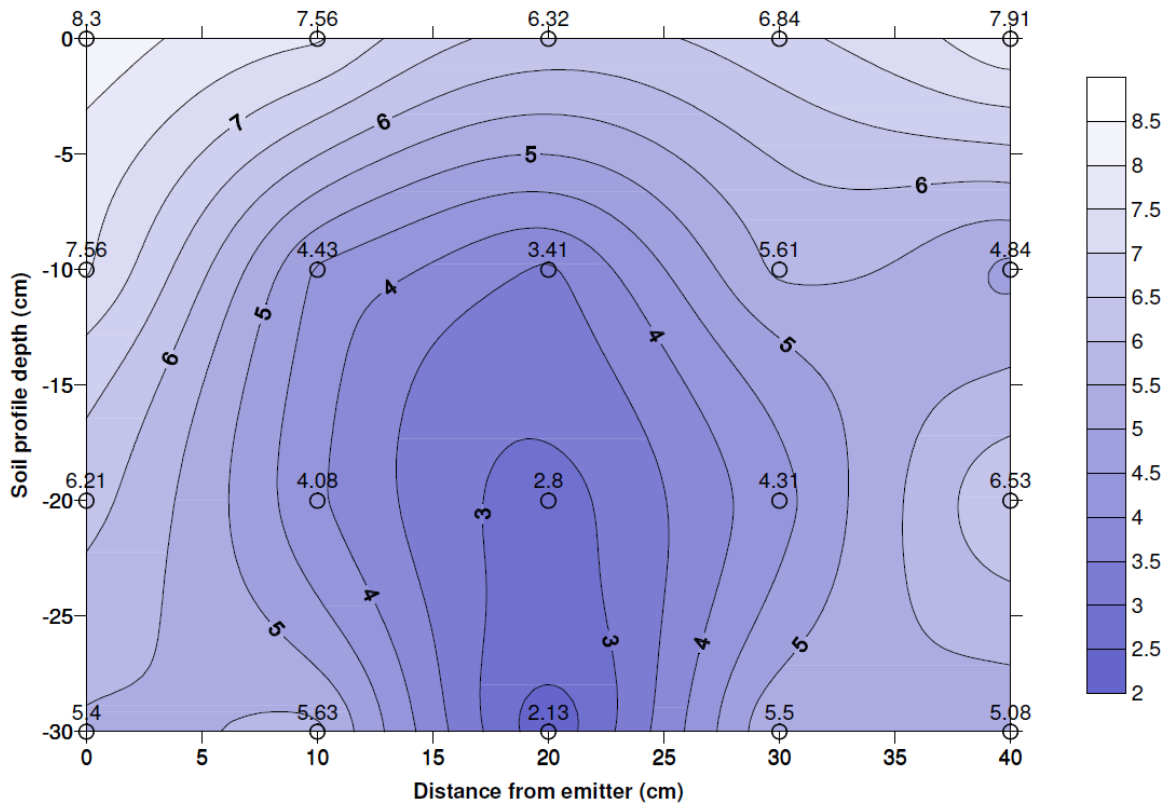


Fig. 4. Soil moisture distribution pattern at 30 min after irrigation

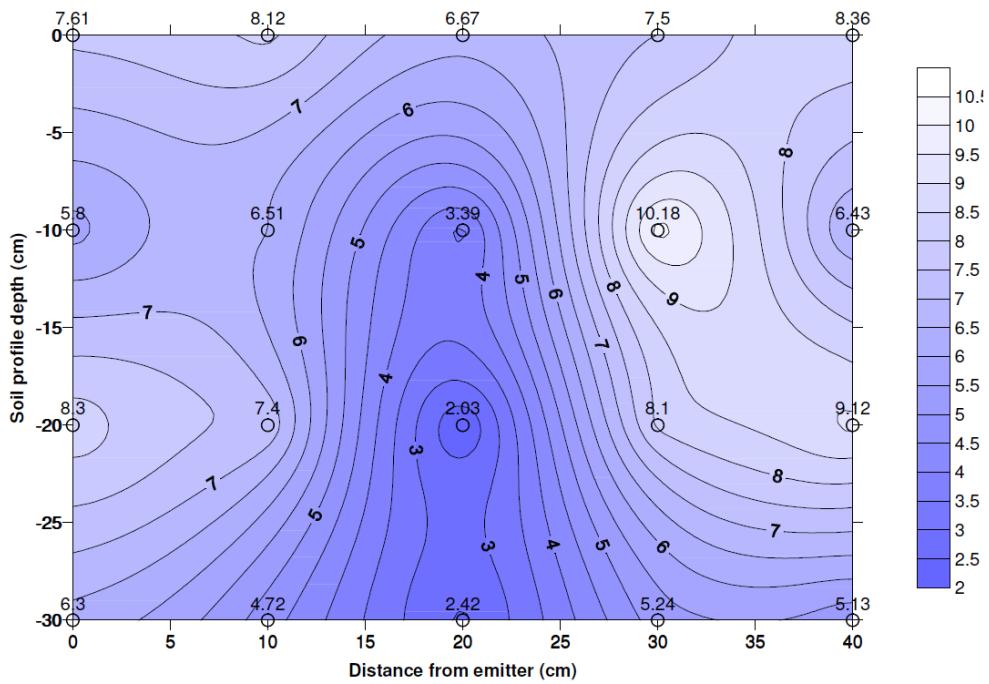


Fig. 5. Soil moisture distribution pattern at 60 min after irrigation

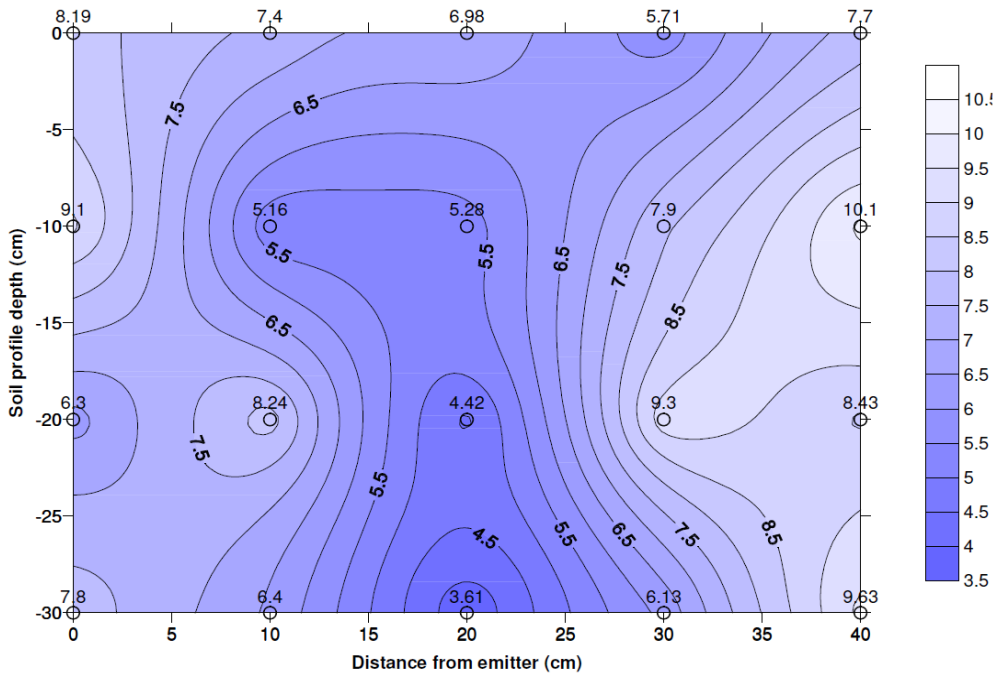


Fig. 6. Soil moisture distribution pattern 90 min after irrigation

At 90 min after irrigation, the moisture content near the plant is 8.19 % and reduction in moisture content near the plant is 5 %. At a distance of 30 cm and 40 cm from the plant the moisture content increased from 5.71 to 6.13 % and 7.7 to 9.63 % at a depth of 30 cm from the surface. The percentage decrease in moisture

content at a distance of 10 cm and 20 cm from the plant is 15.62 and 93.35 per cent.

4. CONCLUSION

This research reveals variations in moisture content of soil at different stages of plant growth

under different irrigation treatments. With comparison of different irrigation systems, the soil moisture content value of before irrigation and after irrigation is better in single row drip system. The shape of the soil moisture distribution was close to conical for all the irrigation scheduling techniques. The soil water distribution pattern showed the highest water content near the drip line for all scheduling techniques because experimental field are in sandy soil [7]. As increase in time of operation Wetting diameter and Penetration depth increased in relative to time, moisture content is found to be more after irrigation than before irrigation. The wetted circle diameter increased gradually from 17 cm after application of water in the first 30 min to 38 cm at the end of irrigation [8].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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