Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(6): 2271-2275
Received: 12-10-2020
Accepted: 10-11-2020

B Naveena
Ph. D scholar, Department of Post Harvest Process & Food Engineering, JNKVV, Jabalpur, Madhya Pradesh, India

G Ravi Babu
Associate Professor, Department of Soil & Water Conservation Engineering, College of Agricultural Engineering, Bapatla, ANGRAU, Andhra Pradesh, India

Corresponding Author:
B Naveena
Ph. D scholar, Department of Post Harvest Process & Food Engineering, JNKVV, Jabalpur, Madhya Pradesh, India

The effects of different irrigation systems on plant height and root depth of sweet corn crop

B Naveena and G Ravi Babu

Abstract
Drip irrigation, one of the micro irrigation methods, is an efficient method of providing irrigation water directly into soil at the root zone of plants 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 amount of water applied in single row and paired row drip irrigation systems is less compared to flood irrigation. The plant height and root depth are observed to be more in soil moisture sensor based irrigation with single row spacing compared to paired row spacing and flood irrigation.

Keywords: drip irrigation, micro irrigation, automation systems, single row, paired row, flood irrigation, plant height, root depth

1. Introduction
Irrigation has been considered essential for the fast growth of agriculture which consumes 80 percent of the country's exploitable water resources. Micro irrigation technology is now widely accepted by most of the farmers in the world. In this system water is applied close to the root of the plants which provides right amount of water required for the growth of the plant and avoids excessive wastage of water, unlike surface and flood irrigation, which wets the whole soil profile and sometime causes soil erosion and soil nutrient loss. 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 (Seckler *et al.*, 1998) [6]. 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. Hence, there is no life without water. 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 (Boaz 2015) [2]. Agriculture marks the beginning of 'civilized' or 'sedentary' society. India had a stagnant performance of Agriculture in during the colonial period which turned into a sustained growth then with a stronger performance in India especially in terms of per capita food production the Indian Agricultural Industry grew.
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. There are lots of benefits of automation in drip irrigation- the real time useful controlling system for monitoring and controlling all activities of drip irrigation more efficiently. 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 (Qureshi *et al.*, 2001; Namara *et al.*, 2005) [5, 3].
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 (Vittum *et al.*, 1963) [7]. 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 (Assouline, 2002) [1]. The aim of the present work was to determine the crop growth characteristics of sweet corn under single row and paired row drip irrigation systems.

2. Methods and Materials

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 m^2 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/cm^2) was used.
- **Sub main:** To convey water from main lines to laterals a PVC pipe of 50 mm diameter (Class 3, 6 kgf/cm^2) 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 the following specifications.
  Outer diameter - 16 mm
  Wall thickness - 0.80 mm
  Flow rate - 2.00 lph at 1kg/cm^2 pressure
  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. Specifications are as follows.
Maximum flow capacity - 27m^3/hr
Nominal size - 50 mm
Nominal pressure - 2 kg/cm^2
Size of aperture - 120 mesh
Clean pressure drop - 0.5 kg/cm^2 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 Other accessories on the main line

- **Ball valve:** It was located at the upstream end of main line, to provide on- off service to the downstream sub main pipe.
- **Flush-out:** It was connected at the end of main and sub main pipes for flushing out sediment and debris from them.
- **End caps:** These were kept at the end of all lateral lines which were connected to stop the flow of water further.
- **Plugs:** These were kept to holes made to laterals by squirrels, rats etc for controlling wastage of water.
- **Start connector:** These were used to connect the lateral to the sub main.
- **Jointer:** These were used to connect the two lateral pipes when the lateral pipe was end in the middle of the crop row.
- **Rubber grommet:** These were placed in holes made to the sub main for connecting lateral lines.
- **Pressure regulator:** For regulating pressure when the water passing through the irrigation system.
- **Pressure gauge:** For measuring pressure in the system, a pressure gauge is used.
- **Air release valve:** Air release valve is fitted for the purpose of removal of entrapped air when filling pipe lines with water and remove air pockets at high points in the system.

2.7 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. The electrical conductivity of the probes can be related to the soil moisture of the soil. Usually the electrical conductivity is read manually from a multimeter.

In this experiment, sensors which detect the soil 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 and 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.

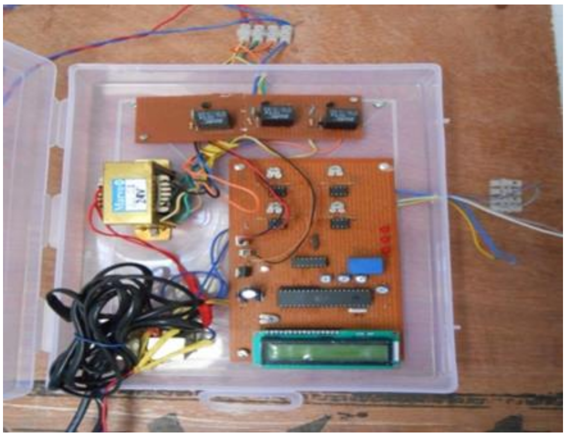


Plate 2: Microcontroller based soil moisture sensor

3. Results and discussion

3.1 Crop water requirement

3.1.1 Crop water requirement

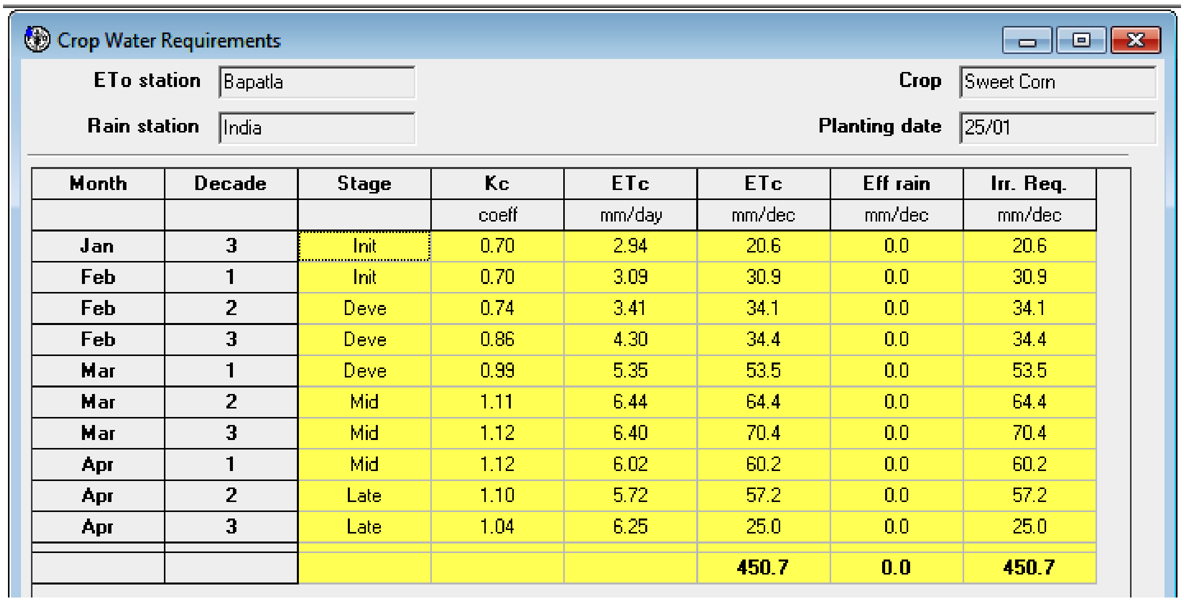
The total water requirement of sweet corn crop based on ten years climate data is 466.4mm from sowing of the seed (January 25th) to harvest of the crop (April 24th). The rainfall is not considered in irrigation calculations (effective rainfall=0) as there is no rainfall in the growing period as shown in Fig 1.

ETo station: Bapatla | Crop: sweet corn
Rain station: Bapatla | Planting date: 25/01

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jan	3	Init	1.15	4.79	33.5	0.0	33.5
Feb	1	Init	1.15	5.04	50.4	0.0	50.4
Feb	2	Deve	1.15	5.27	52.7	0.0	52.7
Feb	3	Deve	1.13	5.56	44.4	0.0	44.4
Mar	1	Mid	1.12	5.84	58.4	0.0	58.4
Mar	2	Mid	1.12	6.18	61.8	0.0	61.8
Mar	3	Mid	1.12	6.51	71.6	0.0	71.6
Apr	1	Late	1.09	6.71	67.1	0.0	67.1
Apr	2	Late	1.03	6.60	26.4	0.0	26.4
					466.4	**0.0**	**466.4**

Fig 1: Crop water requirement for sweet corn by using ten years average weather data

The total water requirement is also calculated for the present climate data from January 2015 to April 2015. It shows a total water requirement 450.7 mm as shown in Fig 2 from sowing of the seed (January 25th) to harvest of the crop (April 24th). There is a difference in variation of only 15.7 mm of total water requirement from previous ten years data to the present four months data.



Crop Water Requirements

ETo station: Bapatla | Crop: Sweet Corn
Rain station: India | Planting date: 25/01

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jan	3	Init	0.70	2.94	20.6	0.0	20.6
Feb	1	Init	0.70	3.09	30.9	0.0	30.9
Feb	2	Deve	0.74	3.41	34.1	0.0	34.1
Feb	3	Deve	0.86	4.30	34.4	0.0	34.4
Mar	1	Deve	0.99	5.35	53.5	0.0	53.5
Mar	2	Mid	1.11	6.44	64.4	0.0	64.4
Mar	3	Mid	1.12	6.40	70.4	0.0	70.4
Apr	1	Mid	1.12	6.02	60.2	0.0	60.2
Apr	2	Late	1.10	5.72	57.2	0.0	57.2
Apr	3	Late	1.04	6.25	25.0	0.0	25.0
					450.7	**0.0**	**450.7**

Fig 2: Crop water requirement of sweet corn based on present data

3.1.2 Actual water applied in different irrigation systems

The amount of water applied in flood irrigation system for sweet corn crop was based on CROPWAT data (470 mm) in addition to 50 mm water used at the time of sowing. Hence, totally 520 mm of water used in flood method. Where as in drip method, water applied is based on the operation of automatic soil moisture sensor. When the soil is reached to field capacity the irrigation was automatically stopped and the system starts giving irrigation, when the soil moisture is reached to 70 % of field capacity. It was found that water applied for sweet corn crop in alternative days in both methods of drip system at the initial stage and daily from the development stage to one week before harvesting. The amount of water applied measured regularly with the help of time-discharge relation and total water applied in different irrigation systems was presented in Table 1. It was observed that 332 mm of water applied in drip instead of 520 mm in flood method for sweet corn and 64 % water saved in drip method.

Table 1: Actual water applied for sweet corn crop in different irrigation systems

S. No	Irrigation Treatment	Water applied during sowing (mm)	Water applied during crop growth (mm)	Total water applied (mm)	% of water saving
1	Flood	50	470	520	-
2	Single row drip	50	282	332	64
3	Paired row drip	50	282	332	64

3.2 Crop growth characteristics

3.2.1 Plant height for sweet corn crop in different irrigation treatments

The height of sweet corn plant is measured by using scale from the selected 1m^2 for an interval of 14 days in all three treatments and average value from each plot is taken. The trend of the final height of the plant in relation to the irrigation method is indicated in Fig 3.

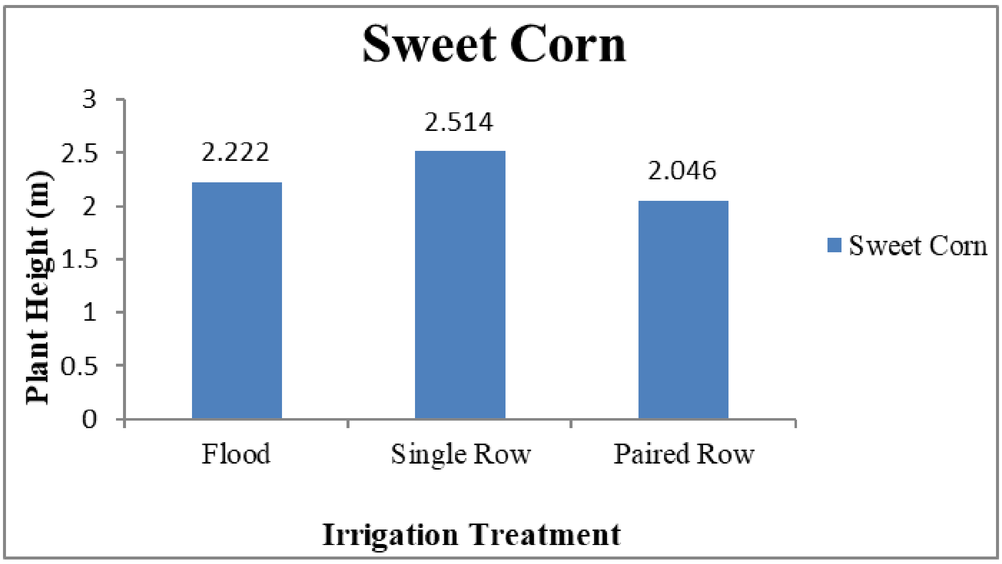


Fig 3: Relationship between plant height and irrigation treatment

It was observed that the plant height of sweet corn was varies in different treatments of irrigation. The plant height of single row drip system is 2.514 m gives good result than paired row 2.046 m and flood 2.222 m. The height of the plant is more in single row because of efficient application of water to the plant at correct time based on soil moisture sensor.

3.2.2 Root depth for sweet corn crop in different irrigation treatments

It is well known that the water application regime and water distribution pattern in the soil affect the pattern of root system development. As the water is applied with drip system, the root distribution pattern is mainly concentrated under and beside the laterals.

It was found that the plant root depth of sweet corn was varies in different treatments of irrigation. As compared the root depth, single row drip method having more root depth i.e. 28 cm as water is applied near by the plant based on soil moisture sensor and followed by flood irrigation having 24 cm and by next paired row drip having 22 cm. The relation between root depth and irrigation treatments were shown in Fig 4.

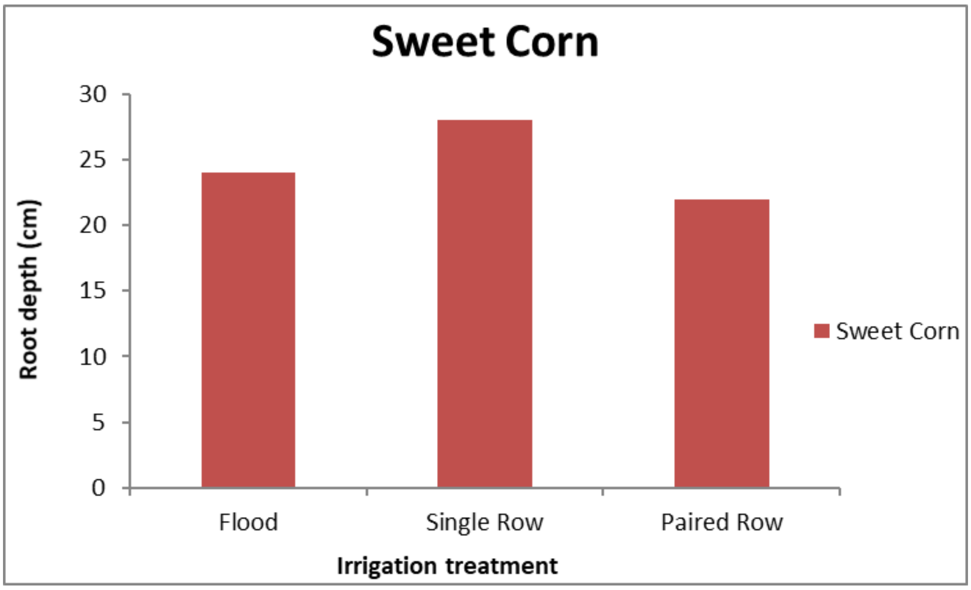


Fig 4: Relationship between root depth and irrigation treatment

4. Conclusion

A low cost, commercially available button type thermistor was used as the leaf and air temperature sensors for the study area. The sensor with washed sand as porous medium was found to be the most efficient one. The amount of water applied per day, leaf-air temperature and soil moisture content were monitored (Noble *et al*., 2000). The amount of water applied was less in drip irrigation system compared to flood irrigation. The plant height, plant root depth of sweet corn were observed to be more in single row as compared to flood irrigation and paired row drip irrigation systems. Overall, in soil moisture sensor based irrigation with single row spacing, the yield response was observed to be best.

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