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Evaluation of soil moisture sensors and irrigation scheduling in *Rabi* maize

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Abstract
Maize (*Zea mays* L.) is a staple food in many regions of the world. In India, maize occupies an area of 10.2million hectares with a productivity of 3057 kg/ha. The per capita water resource availability in the country has been declined from 5300 m^3 $year^{-1}$ in 1951 to 1700 m^3 $year^{-1}$ by the year 2017. Irrigation scheduling using different sensors is important parameter to increase yield of maize crop by saving water. Moisture sensors *viz.,* tensiometer, gypsum block, profile probe, nano sensor (IITB), Soil moisture indicator and IW/CPE ratio installed both under surface and drip irrigation methods. Drip irrigation method was found significantly superior than surface furrow irrigation in terms of growth parameters of maize. Among irrigation scheduling sensors, nano sensors recorded highest growth parameters both under drip and surface irrigation system closely followed by gypsum block. Irrigation scheduled based on nano sensors recorded highest plant height (228.7 cm), highest dry matter production (264.8 g $plant^{-1}$) over other sensors under drip irrigation method.

Keywords: maize, drip and surface furrow irrigation methods, nano sensors, irrigation scheduling practices

Introduction

Maize (*Zea mays* L.) is a staple food in many regions of the world and known as queen of cereals due to its high productivity among the cereal crops of *Graminacea* family. In India, maize occupies an area of 10.2 million hectares with a production of 17.51 lakh tonnes and productivity of 3057 kg ha^{-1} (FAOSTAT, 2015-2016). Whereas, in Telangana it is grown in an area of 0.573 million hectares with production of 23.08 lakh tonnes and productivity of 3338 kg ha^{-1} (Directorate of Economics and Statistics Government of Telangana, 2015 -2016). To safeguard and sustain the food security in India, it is quite important to increase the productivity of maize under limited water resources. As per the concepts of water foot print and virtual water, 1 kg of maize needs 900 litres of water. Scheduling irrigation is important for achieving crop-specific water requirements which would help to achieve targeted yield without the wastage of water. (Leib *et al*., 2002) [10]. Soil moisture sensor technologies which have proven to be efficient in scheduling irrigation (Mohamed *et al*., 2011) [11]. Most of the commercially available soil moisture sensors are accurate but their high cost is prohibiting its use by farming community. Irrigation scheduling offers an opportunity for improving water use efficiency at a farm level. Monitoring soil moisture levels through sensors are categorized in to two main groups, one that give information on soil moisture content and others which measures soil moisture tension. Some of the soil moisture monitoring devices that are used in the field of water and irrigation management are *viz*., tension meters, theta probe and water mark sensors. These instruments help in timely scheduling of water to be delivered in each irrigation execution. Scientific irrigation scheduling (SIS) is distinct in using crop evaporation and transpiration data, as well as soil moisture based sensor technologies to precisely calculate when and how much to irrigate. This technology has proven more effective in water management, especially for large corporate farms. Where in continuous soil moisture monitoring by using soil moisture sensors in the field or indirectly by measuring climatic parameters for calculating evapotranspiration and water balance to predict moisture in the root zone (Leib *et al*., 2002) [10] are done.

Gravimetric moisture measurements are time consuming and cumbersome processes for scheduling irrigation. However, the focus is to provide low cost sensing solutions for timely and accurate deficit irrigation scheduling with easy access to data and expert interpretation. Currently irrigated areas are less instrumented mainly due to the high cost and prevalence of alternatives such as visual inspection and judgment, even though this is seldom accurate. Now some of the Indian institutions are working on development of accurate and low cost sensors to overcome the elaborate and cumbersome soil moisture estimation methods (gravimetric, volumetric) for irrigation scheduling. On-farm comparison and evaluation of soil moisture sensors to determine the timing and amount of irrigation water need of crops is very much needed.

Materials and Methods

A field experiment was conducted during *rabi*, 2017-18. The experiment was carried out at Water Technology Centre, College Farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad. The climate of Hyderabad is classified as dry tropical and semi-arid. The experiment was laid out in Split Plot Design with surface furrow irrigation and drip irrigation methods as main treatments and irrigation scheduling sensors as sub treatments. Before laying out the experiment, initial soil samples were drawn at random spots in the experimental field from 0-15 cm soil depth and analysed for initial characteristics of soil adopting standard procedures (Table 1). Moisture retention capacity of the experimental field was estimated at -0.1 MPa (field capacity) and -1.5 MPa (pwp) using pressure plate apparatus and the bulk density of the experimental soil was estimated for each 15 cm soil depth up to 60 cm by following the standard procedures.

Results and Discussion

Table 1: Physical, physico-chemical and chemical properties of the experimental soil

Sl. No.	Particulars	Value	Method / Reference
I	**Physical properties**		
1	Mechanical analysis		Bouyoucoshydrometer method (Piper,1966) [14]
	A Sand (%)	53.3	
	B Silt (%)	32.0	
	C Clay (%)	14.7	
2	Textural class	Sandy loam	
3	Infiltration rate (cm h^{-1})	2.5	Double ring infiltrometer (Rao *et al.*, 2005) [15]
II	**Physico – chemical properties**		
1	pH [1: 2.5 soil : water]	8.1	ELICO, LI 612 pH analyser (Jackson, 1973) [10]
2	Electrical conductivity [dS m^{-1}] [1:2:5 soil : water]	0.22	SYSTRONICS Conductivity TDS meter 308 (Jackson, 1973) [10]
3	Organic carbon (%)	1.2	Walkley and Black's modified method (Jackson, 1967) [9]
III. Chemical properties			
1	Available nitrogen (kg ha^{-1})	162.5	Alkaline permanganate method using KELPLUS SUPRAUL N – analyser (Subbaiah and Asija, 1956) [19]
2	Available phosphorus (kg ha^{-1})	31.18	Olsen's method for extraction and Ascorbic acid method for estimation by using UV-VIS UV5704SS spectrophotometer- 420nm (Olsen's *et al.*, 1954)
3	Available potassium (kg ha^{-1})	348.32	Neutral normal ammonium acetate method using ELICO CL361 Flame photometer (Piper,1966) [14]

The experimental soil was sandy loam in texture, slightly alkaline in reaction and non-saline. The soil was high in organic carbon and low in available nitrogen, medium in available phosphorus and high in available potassium with moderate infiltration rate.

Plant height

Table 2: Effect of irrigation methods and irrigation schedules on plant height (cm) of maize during rabi, 2017-18

Treatment	30 DAS	60 DAS	90 DAS	Harvest
Main plots: Irrigation methods (M)				
M_1-Surface irrigation	41.6	110.7	177.0	188.0
M_2-Drip irrigation	43.7	159.0	220.0	226.0
SEm ±	1.1	8.0	11.2	7.37
CD (P = 0.05)	NS	24.12	33.81	23.13
Sub Plots: -Sensor based irrigation schedules (S)				
S_1-Tensiometer (irrometer)	40.3	108.2	179.4	193.3
S_2-Granulated gypsum blocks (Water mark sensors)	44.0	147.1	208.8	217.6
S3-Profile probe (Delta-T)	42.7	139.0	196.6	213.5
S_4-Nanosensors (IITB)	45.2	150.4	224.9	228.7
S_5-Soil moisture indicator (ICAR)	41.9	130.7	193.5	199.2
S_6-IW/CPE ratio or Epan	41.8	133.9	187.4	195.8
SEm ±	1.2	6.6	8.7	6.8
CD (P = 0.05)	NS	19.5	25.8	20.0
Interaction				
S at same level of M				
SEm ±	1.7	9.4	12.4	9.6
CD (P = 0.05)	NS	NS	NS	NS
M at same or different level of S				
SEm ±	1.9	9.4	12.6	9.5
CD (P = 0.05)	NS	NS	NS	NS

Plant height is a direct index to measure the growth and vigor of the plant. The data pertaining to the plant height of maize as influenced by irrigation methods and irrigation schedules is presented in Table 2 and depicted through Fig 1. Perusal of data indicates that the plant height of maize has progressively increased with the advancement of crop age up to harvest, irrespective of the treatments. The plant height of maize was significantly influenced by irrigation methods and irrigation schedules. Among irrigation methods, significantly higher plant height was recorded at 60, 90 DAS and at harvest (159.0, 220.0, 226.0 cm, respectively) in drip irrigated plots over surface irrigation method at 60, 90 DAS and at harvest (110.7, 177.0 and 188.0 cm respectively). This finding was supported by Antony *et al*. (2004) [2] who described the effect of plant height in drip and surface irrigated plots. Favourable soil-plant-water balance under these drip irrigation treatments might have stimulated increased activity of meristematic cells and cell elongation of internodes resulting in higher growth rate of stem in turn promoting the higher plant height of maize as compared to surface furrow irrigation (Gardner *et al*., 1985 and Amos, 2009) [6, 1].

Among the sub treatments studied significantly highest plant height was observed in nano sensor based irrigation scheduling (228.7 cm at harvest) and lowest in tension meter (193.30 cm) based irrigation scheduling. The reason for inferior performance by irrigation scheduled by tension meter, may be due to less frequent irrigation scheduled. This finding was supported by Alemi (1981) [1].

Drymatter Production (g plant^{-1})

Table 3: Effect of irrigation methods and irrigation schedules on dry matter production (g plant $^{-1}$) of maize during *rabi*, 2017-18.

Treatment	30 DAS	60 DAS	90 DAS	Harvest
Main plots :Irrigation methods (M)				
M_1-Surface irrigation	56.5	86.8	234.0	226.0
M_2-Drip irrigation	68.7	99.1	280.0	267.0
SEm ±	1.9	3.9	6.7	7.8
CD (P = 0.05)	NS	11.8	20.2	23.5
Sub Plots: -Sensor based irrigation schedules (S)				
S_1-Tensiometers (irrometer)	56.7	88.2	238.5	226.6
S_2-Granulated gypsum blocks (Water mark sensors)	64.8	94.2	272.8	258.1
S_3-Profile probe (Delta-T)	63.2	93.9	259.0	248.8
S_4-Nano sensors (IITB)	66.3	97.1	274.3	264.8
S_5-Soil moisture indicator (ICAR)	62.3	91.8	247.8	238.9
S_6-IW/CPE ratio or Epan	62.2	92.4	250.3	242.5
SEm ±	2.2	1.9	5.4	7.3
CD (P = 0.05)	NS	NS	16.1	22.0
Interaction				
S at same level of M				
SEm ±	3.1	2.6	7.7	7.5
CD (P = 0.05)	NS	NS	NS	NS
M at same or different level of S				
SEm ±	3.4	3.1	7.8	7.8
CD (P = 0.05)	NS	NS	NS	NS

The data on dry matter production (g plant^{-1}) of maize as influenced by different irrigation methods and sensor-based irrigation schedules is presented in Table 3. The dry matter production increased sequentially from 30 DAS to 90 DAS, and then it decreased as the crop attained maturity. The dry matter production obtained with drip method of irrigation was found to be significantly superior than surface furrow method at all stages studied except at 30 DAS. Surface furrow irrigated method recorded 86.8, 234.0 and 226.0 g plant^{-1} and in drip irrigated plots registered 99.1, 280.0 and 267.0 g plant^{-1} of dry matter at 60, 90 DAS and at harvest respectively.

Among the sub treatments studied, highest dry matter production was associated with nano sensor (IITB) based irrigation scheduling at 90 DAS and at harvest. The dry matter production recorded was significantly higher (274.3 and 264.8 g plant $^{-1}$) at 90 DAS and at harvest respectively in nano sensor (IITB) over irrigation scheduled based on tensiometer, soil moisture indicator and IW/CPE ratio.

Dry matter production which reflects the total plant growth increased with increasing plant height and LAI which might be due to availability of more sink and larger photosynthetic apparatus of the crop at high frequency irrigation, consequently influencing assimilates production which have a direct bearing on dry matter production per plant and per unit area. These results corroborate with findings of Garofalo and Rinaldi (2013) [8]. The reduction in dry matter production in tensiometer based irrigation scheduling may be due to less frequent irrigation associated with tensiometer. This finding was in line with Bharati *et al*. (2007) [4] who observed that decrease in DMP with reduced frequency of irrigation might be due to decreased photosynthetic activity as a result of partial closure of stomata and decreased supply of CO_2 under water stress conditions.

Conclusion

Plant height progressively increased irrespective of treatments up to harvest and significantly influenced by irrigation methods and irrigation schedules at all growth stages except at 30 DAS. Significantly higher plant height was observed in drip irrigation method over surface furrow irrigation and in irrigation schedules nano sensor showed higher plant height closely followed by gypsum block. Similar trend was observed with dry matter production.

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