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Effect of sensor based irrigation scheduling practices under drip and furrow method of irrigation on growth parameters,shelling percentage and test weight of *Rabi* maize

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Abstract
A field experiment was conducted for field evaluation of soil moisture sensors for irrigation scheduling in *rabi* maizeat Water Technology Centre,PJTSAU,Hyderabad.The experiment was laid out in a split plot design replicated thrice with 12 treatment combinations. Maize (*Zea mays* L.) is known as miracle crop or queen of cereals due to its high productivity among the cereal crops of *Graminae*family and is a staple food in many regions of the world. 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. Moisture sensors *viz.*,tensiometer, gypsum block, profile probe, nano sensor (IITB), soil moisture indicator have been 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 schedulingsensors, 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 number of leaves (16.3) leaf area (5068cm^2), shelling percentage (79.73)andtest weight (38.76) over other sensors under drip irrigation method.

Keywords: Maize, drip and surface furrow irrigation methods, nano sensors, irrigation scheduling,gypsum blocks,tensiometer

Introduction
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). 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)[4]. Most of the commercially available soil moisture sensors are accurate but their high cost is prohibiting its use by farming community (Lekshmi*et al*., 2014)[8]. Irrigation scheduling offers an opportunity for improving water use efficiency at a farm level. Now a days monitoring soil moisture levels is carried out by using soil moisture sensors. Some of the soil moisture monitoring devices that are used in the field of water and irrigation management are *viz*., tensiometers,gypsumblocks,profile probe,etc.Irrigation scheduling helps to schedule irrigation by giving an idea regarding when to irrigate,how to irrigate and how much to irrigate.

The widely used soil moisture monitoring method is by gravimetric process.In this method the soil is collected from each plot and is oven dried and later we will find the percentage moisture content in the given sample. But these gravimetric moisture measurements are time consuming and cumbersome processes and not real time readings for scheduling irrigation.So to avoid these problems thenew sensor based technologies are checked in field level with already existing sensor technologies and compared with gravimetric method.On farm comparison of scheduling of irrigation is important.

Materials and methods
A field experiment was conducted during *rabi*,2017-18 at Water Technology Centre, College Farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad. The climate of Hyderabad is classified under 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 andirrigation scheduling based on sensors as sub treatments. Irrigation was scheduled based on the sensor readings.

Moisture retention capacity of the experimental field was estimated at -0.1MPa (field capacity) and -1.5 MPa (PWP) using pressure plate apparatus (Richards, 1949) 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. Soil moisture sensors were installed along the drip tape and in between two plant rows in drip and surface irrigated plots for imposition of irrigation schedules from S_1 to S_5 treatments. The protocols followed for the installations and calibrations of sensors were drawn from the sensor manually. In treatment S_1 to S_5, based on sensor triggered value irrigation was scheduled both in surface furrow irrigation and drip irrigation. The irrigation was rescheduled when the tension reached to 60-70 cbars in tensiometer (S_1), 40-50 centi bars in gypsum block (S_2), and when volumetric water content was registered as 20-25% in profile probe (S_3), gravimetric moisture content of 14-15% in nano sensor (IIT-B) (S_4) and Red glow light indication in soil moisture indicator (S_5).

Results and discussion

Table 1: Effect of irrigation methods and irrigation schedules on number of leaves at different growth stages of maize during *rabi*, 2017-18

Treatment	30 DAS	60 DAS	90 DAS	Harvest
Main plots : Irrigation methods (M)				
M_1-Surface furrow irrigation	6.2	11.5	14.9	10.6
M_2-Drip irrigation	6.3	12.1	16.2	11.5
SEm±	0.1	0.1	0.5	0.4
CD (P = 0.05)	NS	NS	NS	NS
Sub Plots: -Sensor based irrigation schedules (S)				
S_1-Tensiometer(irrometer)	5.9	11.8	14.5	10.5
S_2-Granulated gypsum blocks (Water mark sensors)	6.4	11.7	16.1	11.2
S3-Profile probe (Delta-T)	6.3	11.6	15.8	11.0
S_4-Nanosensors (IITB)	6.5	12.2	16.3	11.9
S_5-Soil moisture indicator(ICAR)	6.1	11.5	15.2	10.8
S_6-IW/CPE ratio or Epan	6.3	11.8	15.6	10.9
SEm±	0.2	0.4	0.4	0.4
CD (P = 0.05)	NS	NS	NS	NS
Interaction				
S at same level of M				
SEm±	0.3	0.5	0.6	0.6
CD (P = 0.05)	NS	NS	NS	NS
M at same or different level of S				
SEm±	0.3	0.5	0.7	0.7
CD (P = 0.05)	NS	NS	NS	NS

Number of leaves

The data on number of leaves as influenced by irrigation methods and sensor based irrigation schedules are presented in Table 1. Perusal of data indicates that the number of leaves was not significantly influenced by irrigation methods, irrigation schedules and their interaction effect. The number of leaves increased progressively with advancement in age of the maize crop up to 90 days and then it decreased irrespective of the treatment imposed at harvest due to senescence. The number of leaves observed in surface method and drip irrigated treatments range between 6.2 and 14.9 and 6.3 and 16.2 respectively. The marginal higher number of functional leaves recorded at drip irrigation could be traced to favourable soil water balance due to high frequency irrigations under drip system.

Among the sub treatments in nano sensors (IITB) recorded relatively higher number of leaves at all stages of crop growth and the low number of leaves in irrigation scheduled by tensiometer.

Table 2: Effect of irrigation methods and irrigation schedules on leaf area (cm^2)at different growth stages of maize during *rabi,* 2017-18

Treatment	30 DAS	60 DAS	90 DAS	Harvest
Main plots : Irrigation methods (M)				
M_1-Surface furrow irrigation	1516	4524	4443	3904
M_2-Drip irrigation	1679	5294	5308	4532
SEm±	17.2	49.5	106.8	47.0
CD (P = 0.05)	51.6	138.7	320.6	141.1
Sub Plots: -Sensor based irrigation schedules (S)				
S_1-Tensiometers (irrometer)	1508	4569	4430	3891
S_2-Granulated gypsum blocks (Water mark sensors)	1624	5170	5068	4405
S_3-Profile probe (Delta-T)	1604	5078	4931	4318
S_4-Nano sensors (IITB)	1652	5246	5204	4526
S_5-Soil moisture indicator (ICAR)	1579	4763	4700	4057
S_6-IW/CPE ratio or Epan	1617	4767	4783	4113
SEm±	15.5	85.5	74.5	57.2
CD (P = 0.05)	45.9	252.3	219.9	168.7
Interaction				
S at same level of M				
SEm±	21.9	120.9	105.4	80.9
CD (P = 0.05)	NS	NS	NS	238.6
M at same or different level of S				
SEm±	21.8	112.8	109.7	77.4
CD (P = 0.05)	NS	NS	NS	250.1

The data obtained on the leaf area of maize are presented in Table 2.Perusal of data revealed that the leaf area progressively increased with maize growth stages irrespective of the treatments up to 60 DAS and there after decreased in surface furrow irrigation methods. Whereas it increased up to 90 DAS and there after decreased in drip irrigated plots. Similar to plant height and dry matter production plant^{-1}, the leaf area was significantly affected by irrigation methods and irrigation schedules at all the growth stages of crop.

Significantly higher leaf area (cm^2) was associated with drip irrigated maize compared to surface furrow method at all stages of study. Hebbar *et al*.,2004 observed higher growth in drip irrigated plot than surface method because of higher water use efficiency.

Surface furrow irrigated plot recorded 1516, 4524, 4443 and 3904 cm^2 of leaf area at 30, 60, 90 DAS and at harvest respectively. Whereas, leaf area of 1679, 5924, 5308, 4532 cm^2 at 30, 60, 90 DAS and at harvest respectively was obtained in drip irrigated method.

Significant difference in leaf area of maize at all the growth stages studied was observed with irrigation schedules. Significantly higher leaf area 1652, 5246, 5204 and 4526 cm^2 at 30, 60, 90 DAS and at harvest respectively of maize was observed in irrigation schedule based on nano sensors (IIT-B) compared to all other irrigation schedules except irrigation scheduled based on gypsum block and IW/CPE ratio. Whereas the leaf area recorded at 30 DAS with irrigation scheduled based on gypsum block (1624 cm^2) and IW/CPE ratio (1617 cm^2) were on par with leaf area obtained based on nano sensor based irrigation scheduling. Leaf area (1508 cm^2) obtained with the irrigation scheduled using tensiometer was found to be inferior among all the treatments at 30 DAS

At 60 DAS significantly higher leaf area (5246 cm^2) of maize was observed with irrigation scheduled based on nano sensors (IITB) compared to all other irrigation schedules except irrigation scheduled based on gypsum blocks and profile probe. The leaf area obtained with irrigation scheduled by gypsum blocks (5170 cm^2) and profile probe (5078 cm^2) was on par with irrigation scheduled by nano sensors. Leaf area obtained by the irrigation scheduled using tensiometer (4569 cm^2) was found to be inferior among all the irrigation schedules studied.

At 90 DAS, significantly higher leaf area (5204 cm^2) of maize was observed in irrigation scheduled based on nano sensors (IITB) compared to all other irrigation schedules except irrigation scheduled with gypsum blocks. Whereas, the leaf area(5068 cm^2) noticed with irrigation scheduled based on gypsum blocks was on par with irrigation scheduled by nano sensors. Leaf area (4430 cm^2) obtained by the irrigation scheduled using tensiometer was found to be inferior among all the treatments studied. The plant cell enlargement is very sensitive to water deficits and the consequence is a marked reduction in leaf area (Kramer, 1983). At harvest leaf area followed the same trend as noticed at 90 DAS.

Leaf area (cm^2) of maize was significantly influenced by the interaction effect of irrigation methods and sensor based irrigation schedules only at harvest. The highest leaf area (4996 cm^2) was observed with nano sensors under drip irrigation closely followed by gypsum blocks under drip irrigation (4807 cm^2) which is significantly superior among irrigation schedules and irrigation methods combination**.**

Shelling Percentage and Test Weight

Table 3: Effect of irrigation methods and irrigation schedules on shelling percentage and test weight of maize during *Rabi*, 2017-18

Treatment	Shelling percentage (%)	Test weight (g)
Main plots : Irrigation methods (M)		
M_1-Surface furrow irrigation	73.30	32.80
M_2-Drip irrigation	75.40	38.30
SEm±	0.96	0.62
CD (P = 0.05)	NS	3.79
Sub Plots: -Sensor based irrigation schedules (S)		
S_1-Tensiometers (irrometer)	68.46	32.06
S_2-Granulated gypsum blocks (Water mark sensors)	77.07	39.57
S_3-Profile probe (Delta-T)	76.69	35.41
S_4-Nano sensors (IITB)	79.73	38.76
S_5-Soil moisture indicator (ICAR)	73.47	33.12
S_6-IW/CPE ratio or Epan	70.95	34.22
SEm±	3.87	1.49
CD (P = 0.05)	NS	4.40
Interaction		
S at same level of M		
SEm±	5.47	2.11
CD (P = 0.05)	NS	NS
M at same or different level of S		
SEm±	5.08	2.02
CD (P = 0.05)	NS	NS

Shelling Percentage (%)

The data pertaining to the influence of irrigation methods and sensor based irrigation schedules on shelling Percentage of maize are presented in Table 3.Perusal of data indicates that the shelling percentage of maize was not significantly influenced by both irrigation methods and irrigation schedules. The shelling percentage observed among the various sub treatments ranged between68.46– 79.73%.

The shelling percentage of maize was also not significantly influenced by the interaction effect of irrigation methods and irrigation schedules.

Test weight (g)

The data pertaining to the influence of irrigation methods and irrigation schedules on test weight of maize are presented in Table 3.

The influence of irrigation methods and irrigation schedules on test weight of maize was found to be significant. Significantly higher test weight of the maize (38.30 g) obtained under drip irrigation compared to surface furrow irrigation (32.80 g). Higher frequency of irrigation under drip resulted in more test weight as compared to low frequencies of irrigation (Prasad and Prasad, 1988)[5].

Higher test weight (39.57 g) was observed with gypsum block based irrigation scheduling closely followed by nano sensors (38.76 g) and profile probe (35.97 g) and differ significantly over other schedules. However irrigation scheduled based on, tensiometer recorded the lowest test weight (32.06 g). Less irrigation frequency might be the reason in IW/CPE, soil moisture indicator and tensiometer based irrigation schedules as plant experienced stress at low soil moisture availability leading to poor translocation of photosynthates in to grain resulting in shriveled and small sized grains (Sanjeev *et al*., 2006.)[7]

The test weight of maize was not significantly influenced by the interaction effect of irrigation methods and irrigation schedules.

Conclusion

Leaf area was significantly higher with drip irrigationand among the schedules nano sensor (IITB)based irrigation scheduled at 30, 60, 90 DAS and at harvest found superior to rest of the schedules except irrigation scheduled based on gypsum block and IW/CPE ratio..

The highest number of leaves was observed with nano sensors and gypsum blocks based irrigation scheduling under drip irrigation and differ non-significantly over all other treatment combination. Shelling per cent of maize was not significantly influenced by irrigation methods and irrigation schedules. Significantly highest test weight (38.30 g) of maize was recorded with drip irrigation and among the schedules with gypsum block based irrigation scheduling (39.57 g) closely followed by nano sensor (IITB) (38.76 g) and profile probe (35.97 g) and differed significantly over other schedules.

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