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Sensor and SMI based Irrigation Management in Maize [*Zea mays* (L.)] to Enhance Growth, Yield and Water Use Efficiency

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ABSTRACT: Maize is popularly referred as the "Queen of Cereals" due to its high yielding potential among the cereal crop. The increasing demand along with increments in water and energy costs have made it necessary to develop new technologies for the adequate management of water. With emerging water scarcity, the traditional way of cultivation can no longer be sustained to meet the demands of ever growing populations. Keeping the above facts in view. The field experiment on "Sensor and SMI based irrigation management in Maize [*Zea mays* (L.)] to enhance growth, yield and water use efficiency" " was conducted during *Kharif*-2019 at 'L' Block, ZARS, University of Agricultural Sciences, GKVK, Bangalore 560065. The experiment comprised of seven treatments *viz*., T_1: Surface irrigation, T_2: Drip irrigation at three days interval, T_3: Green Soil Moisture Indicator (GSMI) based drip irrigation, T_4: Yellow soil moisture indicator based drip irrigation (YSMI), T_5: Sensor based drip irrigation at 25% depletion of available soil moisture (DASM), T_6: Sensor based drip irrigation at 50% DASM and T_7: Sensor based drip irrigation at 75% DASM. These were laid out in RCBD and replicated thrice. The results found that sensor based drip irrigation at 25% DASM recorded significantly higher growth parameters, kernel yield (10,676 kg ha^{-1}), and Stover yield (12,273 kg ha^{-1}). However, GSMI based drip irrigation (10441 and 11975kg ha^{-1}, respectively) recorded on par yield. The same treatment also recorded higher water use efficiency (219.2kg ha-cm^{-1}). Whereas, the lower grain yield (6551 kg ha^{-1}), stover yield (8007 kg ha^{-1}) and water use efficiency (131.8 kg ha-cm^{-1}) was observed in surface irrigation.

Keywords: Drip irrigation, Maize, GSMI, Sensor and YSMI.

INTRODUCTION

Maize (*Zea mays* L.) is the third most dominant cereal crop cultivated throughout the world, both for food and economic purposes, after wheat and rice. It is popularly known as the "Queen of Cereals" due to its high yielding potential among the cereal groups of the Graminae family. In India, it occupies a cropped area of 9.63 million hectares with an annual production of 25.89 million tonnes. Whereas in Karnataka, it is cultivated in an area of 1.37 million hectares with an annual production of 3.31 million tonnes with a mean productivity of 3000 kg ha^{-1} (Anon., 2018).

Increasing demand from livestock and poultry production is known to increase the demand for maize further, due to urbanization; there is no scope to increase the area under maize. As a result, increasing yield per unit area through agronomic practices, particularly by managing water and time, may be a viable solution to meeting the world's ever-increasing food demand.

Maize is sensitive to moisture stress. Extended water stress during the kernel setting and grain filling period could cause over 50% of grain production loss (Liu *et al*., 2018). Irrigation method and water quality both had a significant impact on maize crop yield (Irfan *et al*., 2014). Conventionally, irrigation scheduling is mainly based on soil moisture measurement or by using the soil water balance calculation method, which is tiresome and laborious. Sensors are the modern devices or gadgets employed to determine the soil moisture content at different growth stages of the crop to judiciously meet the crop's water requirement by estimating moisture content as a percentage depletion of available soil moisture (DASM). To know the precise water requirement of crops and to attain elevated water use efficiency (WUE), sensors are to be used in crop cultivation. So, utilising different sensors in irrigation schedules could be a possible solution to enhance the yield of maize crops by saving water.

The sensors are mainly of two types: one estimates the soil moisture content while the other determines soil moisture tension. Soil moisture probes and soil moisture indicator (SMI) sensors are used to estimate the available moisture in the soil in order to supply the scarce resource water indefinitely and at the appropriate time of plant growth and development stages (Hussain *et al*., 2013). The use of soil moisture sensors helps growers with irrigation scheduling by providing information about when to water the crops (Anchit *et al.*, 2016). The precision and accuracy of the sensors are crucial to getting precision in irrigation scheduling. Sensors accompanied by drip irrigation could be an effective management practise to increase water productivity.

MATERIALS AND METHODS

A field experiment entitled "Sensor and SMI based irrigation management in Maize [*Zea mays* (L.)] to enhance growth, yield and water use efficiency" was conducted at M-block, Agroforestry unit, ZARS, GKVK, Bengaluru during *Kharif*-2019. The experimental site is situated in the Eastern Dry Zone (Zone-5) of Karnataka**,** which is located between 12º 51′N Latitude and 77º35′E Longitude at an altitude of 930 m above mean sea level (MSL). The experiment was comprised of seven treatments**,** *viz*., T_1: Surface irrigation, T_2: Drip irrigation at three-day interval**s**, T_3: Green Soil Moisture Indicator (GSMI) based drip irrigation, T_4: Yellow soil moisture indicator based drip irrigation (YSMI), T5: Sensor based drip irrigation at 25% depletion of available soil moisture (DASM), T6: Sensor based drip irrigation at 50% DASM, and T7: Sensor based drip irrigation at 75% DASM were laid in a randomised block design with three replications.

Five plants are chosen at random from each treatment to record the observation**s** for the traits of plant height, number of leaves, leaf area, dry matter production, yield parameters**,** *etc*. Plant height was recorded from the base of the plant to the fully opened top leaf and a mean of five was presented as plant height (cm). Average values of fully opened green leaves from five randomly selected plants were noted. The green leaves from the selected plants were fed to the leaf area meter and expressed as cm^2 plant^{-1} (Model Li-300 from Licor Co Nebraska). Dry matter accumulation was recorded for the leaves, stem, and roots of the plant. Five plants from each treatment were selected randomly and uprooted without damaging the roots up to 15 cm depth and parts like leaf, stem, and root and oven dried at 65-70°C. These samples were weighed and noted as gram (g) plant^{-1}. These data were used to calculate the total dry weight per plant. Cob length obtained from selected five plants was measured and the average of five cobs was considered as cob length in centimeters. Kernels from the net plot was randomly counted and 100 kernel weight is expressed as test weight in grams. Harvested kernel from the net plot were dried and weighed. The grain yield per hectare was computed based on grain weight from the net plot, and expressed in kilogram per hectare. Plant dry matter from the net plot was recorded, after sun drying for 8-10 days. Stover yield was computed and expressed in kg ha^{-1}.

Water use efficiency (WUE) was computed from the yield of maize and the amount of water used (Viets, 1972) and expressed in kg ha-cm^{-1}.

$$\text{WUE} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Quantity of total water applied (ha-cm)}}$$

The percentage of water saved over surface irrigation was calculated for the remaining treatments. The data collected from the experimental plots was analyzed statistically by following the procedure as given by Gomez and Gomez (1984). The level of significance used in 'F' and't' test was P=0.05. Critical differences were calculated wherever 'F' test was significant.

RESULTS AND DISCUSSION

Growth analysis elucidated the impact of sensor based irrigation levels on all growth attributing parameters. Sensor based drip irrigation at 25% DASM recorded taller plants (203.4 cm), total number of leaves (13.3), leaf area (9083 cm^2 plant^{-1}), as well as dry matter accumulation (479.5 g plant^{-1}) at harvest. Irrigation scheduling based on soil sensors (soil moisture sensor and tensiometer) led to greater leaf area and accumulations of fresh and dry biomass (Gordin *et al*. 2019). It was mainly due to irrigating the crop at the required time, which resulted in the continuous availability of required moisture near the root zone**,** which might have helped in higher nutrient uptake, resulted in greater cell division and elongation. On the other hand, stress found at surface irrigation has reduced plant height to an extent of 9.2 per cent. Similar results were noticed by Durga *et al*. (2018); Kumar *et al*., (2018).

Irrigation play**s** an imperative role in deciding the potential ability of maize to produce an economic yield. Characters like cob length, number of kernels per pod, and 100 kernel weight, as well as the growth of maize**,** are drastically affected by moisture stress. In the present study, sensor-based drip irrigation at 25% DASM recorded lengthy cobs (19.0 cm), 100 kernel weight (30.5 g), kernel weight (192.1 g cob^{-1}), and cob weight (245.6 g). Higher kernel (10679 kg ha^{-1}) and Stover yield (12273 kg ha^{-1}) were also recorded in sensor based drip irrigation at 25% DASM. The higher kernel yield with sensor based drip irrigation at 25% DASM was due to the production of longer cob**s**, kernels per row, and test weight (Table 2). The increase in these yield parameters was due to the availability of sufficient moisture in the soil, which also favored photosynthetic production and translocation of photosynthates to the sink and improved 100-seed weight. Significantly lower grain yield in surface irrigation was associated with the non-availability of required moisture at all times**,** creating stress near the crop root zone. Similar findings were reported by Khanna *et al.* (2018); Lathashree, (2019).

Table 1: Influence of sensor based irrigation on growth parameters of maize.

Treatment	Plant height (cm) at harvest	Number of leaves at harvest	Leaf area(cm^2 $plant^{-1}$) at harvest	Dry matter production (g $plant^{-1}$) at harvest
T_1 : Surface irrigation	184.6	9.67	7390	350.3
T_2 : Drip irrigation at 3 days interval	194.1	12.0	8052	416.0
T_3 : Green SMI based drip irrigation	200.0	12.6	9013	436.0
T_4 : Yellow SMI based drip irrigation	194.7	11.3	8598	365.7
T_5 : Sensor based drip irrigation at 25% DASM	203.4	13.3	9083	479.5
T_6 : Sensor based drip irrigation at 50% DASM	195.6	12.3	8375	432.6
T_7 : Sensor based drip irrigation at 75% DASM	187.3	10.3	7550	354.4
F – test	**	**	**	**
S.Em.±	2.19	0.57	162	15.10
CD (p=0.05 or 0.01)	6.76	1.74	501	46.5

* Significant at 5 % ** Significant at 1 %

Table 2: Influence of sensor based irrigation on yield parameters of maize.

Treatment	Cob length (cm)	100 kernel weight (g)	Kernel yield (kg ha^{-1})	Stover yield (kg ha^{-1})
T_1 : Surface irrigation	15.6	27.7	6551	8007
T_2 : Drip irrigation at 3 days interval	17.3	28.0	8331	9485
T_3 : Green SMI based drip irrigation	18.1	30.3	10441	11975
T_4 : Yellow SMI based drip irrigation	16.1	27.8	7548	9145
T_5 : Sensor based drip irrigation at 25% DASM	19.0	30.5	10676	12273
T_6 : Sensor based drip irrigation at 50% DASM	17.5	28.6	8436	9690
T_7 : Sensor based drip irrigation at 75% DASM	15.8	27.3	6555	8033
F – test	*	*	**	*
S.Em.±	0.62	0.23	421	810
CD (p=0.05 or 0.01)	1.90	0.71	1299	2498

* Significant at 5 % ** Significant at 1 %

Table 3: Total water used, Water Use Efficiency (WUE), Water saved in maize as influenced by sensor based irrigation

Treatment	Total water used (ha-cm)			Water use efficiency (kg ha-cm^{-1})	Water saved (%)
	Effective Rainfall	Irrigated	Total		
T_1 : Surface irrigation	21.7	28.0	49.7	131.8	-
T_2 : Drip irrigation at 3 days interval	21.7	19.5	41.2	202.2	30.4
T_3 : Green SMI based drip irrigation	21.7	27.0	48.7	214.4	3.6
T_4 : Yellow SMI based drip irrigation	21.7	19.5	41.2	183.2	30.4
T_5 : Sensor based drip irrigation at 25% DASM	21.7	27.0	48.7	219.2	3.6
T_6 : Sensor based drip irrigation at 50% DASM	21.7	19.5	41.2	204.7	30.4
T_7 : Sensor based drip irrigation at 75% DASM	21.7	15.0	36.7	178.6	46.4

The variation in total water usage (ha-cm) was observed due to sensor based irrigation management (Table 3). Surface irrigation of maize used maximum water (49.7 ha-cm) followed by sensor based drip irrigation at 25 % DASM (48.7 ha-cm), GSMI based drip irrigation (48.7 ha-cm), drip irrigation at three days interval (41.2 ha-cm), sensor based irrigation at 50 % DASM (41.2 ha-cm), YSMI based drip irrigation (41.2 ha-cm) and sensor based drip irrigation at 75% DASM (36.7 ha-cm).

The treatments also differed significantly for WUE with sensor based irrigation management (Table 3). Significantly higher WUE (219.2 kg ha-cm^{-1}) was recorded in sensor based drip irrigation at 25% DASM, followed by Green SMI based drip irrigation (214.4 kg ha-cm^{-1}) and drip irrigation at three days' interval (202.2 kg ha-cm^{-1}). Whereas, lower WUE was observed in the treatment receiving surface irrigation (131.8 kg ha-cm^{-1}) (Table 3). Higher water use efficiency with the drip irrigation system was due to reduced water loss and efficient water use by the plants, resulting in a higher yield. The favorable effect of drip irrigation helped in maintaining constant soil moisture potential (Shah and Das, 2012). The lower water use efficiency of surface irrigation was attributed to more evaporation loss of soil moisture due to a more exposed wetting surface upon irrigation. Similar findings were reported by Bharathi *et al*. (2007), Sui (2017); Lathashree (2019).

CONCLUSION

Altering the irrigation frequency resulted in increased productivity and crop biomass production. Sensor based drip irrigation at 25% DASM recorded higher growth parameters, yield attributing parameters, yield and WUE of maize.

FUTURE SCOPE

Combined use of sensors for nutrient and irrigation management in maize needs attention.

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Conflict of Interest. None.

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