A Study on Sensor Based Irrigation and Nitrogen Management in Maize Zea Mays L

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Abstract:

Maize is widely called as the "Queen of Cereals" owing to its great producing capacity among the cereal crop. The ever-increasing demand combined with the ever-increasing expenses of water and energy has made it imperative to create new technologies for the appropriately managing of water resources. The conventional method of farming is no longer viable because of the increasing shortage of water; as a result, it is no longer possible to satisfy the needs of ever-increasing populations. During the Kharif-2019 growing season, the field experiment entitled "Sensor and SMI based irrigation management in Maize *[Zea mays (L.)]* to enhance growth, yield, and water use efficiency" was carried out at the 'L' Block, ZARS, University of Agricultural Sciences, GKVK, Bangalore 560065. The experiment included seven different treatments: T1 was surface irrigation, T2 was drip irrigation at three-day intervals, T3 was green soil moisture indicator (GSMI) based drip irrigation, T4 was yellow soil moisture indicator based drip irrigation (YSMI), T5 was sensor based drip irrigation at 25% depletion of available soil moisture (DASM), T6 was sensor based drip irrigation at 50% DASM, and T7 was sensor based drip irrigation at 75% DASM. These were arranged in RCBD, and three copies were made of them. According to the findings, sensor-based drip irrigation with a concentration of 25% DASM resulted in considerably better growth metrics, kernel yield, and Stover yield. However, GSMI-based drip irrigation reported a yield that was on par with that of conventional irrigation. Additionally, greater water usage efficiency was obtained with the same treatment. In contrast, surface irrigation resulted in a grain yield of 6551 kilogrammes per hectare, a stover yield of 8007 kilogrammes per hectare, and a water usage efficiency of 131.8 kilogrammes per cubic metre per hectare.

Keywords: *Maize Zea Mays L, Sensor Based Irrigation, Nitrogen Management*

Tob Regul Sci. ™ 2021;7(5): 2310-2318
DOI: https://doi.org/10.52783/trs.v7i5.1337

Introduction:

By delivering up-to-the-minute information on a crop's water and fertiliser requirements, sensor-based irrigation and nitrogen management systems strive to improve the efficiency of water and nutrient delivery during crop production. These systems make use of a wide variety of sensors to monitor environmental conditions and the state of crops. Some examples of these sensors are weather stations, crop canopy sensors, and soil moisture sensors. After collecting this information, the next step is to utilise it to make educated judgements on the timing of irrigation and the distribution of nitrogen fertiliser.

In maize production, some of the benefits of sensor-based irrigation and nitrogen control include the following:

Improved Water Use Efficiency: By continuously monitoring soil moisture levels, farmers can avoid over- or under-irrigation, ensuring that water is applied when and where it is needed. This leads to improved water use efficiency and can help conserve water resources.

Enhanced Nitrogen Use Efficiency: Sensors can provide information about crop nutrient status and nitrogen availability in the soil. This enables farmers to adjust nitrogen fertilizer applications based on real-time needs, reducing the risk of over-application and minimizing nitrogen losses through leaching or volatilization.

Increased Yield and Quality: Optimizing irrigation and nitrogen management can positively impact maize yield and quality. Providing adequate water and nutrients at critical growth stages promotes optimal plant development, leading to improved yield and grain quality attributes.

Environmental Sustainability: Sensor-based systems allow for precise and targeted irrigation and nutrient application, minimizing environmental impacts associated with excessive water use and nitrogen runoff. This contributes to more sustainable agricultural practices.

Studies on sensor-based irrigation and nitrogen management in maize have demonstrated promising results. Researchers have investigated the use of different sensor technologies, such as soil moisture sensors, plant-based sensors, and spectral sensors, to guide irrigation and nitrogen management decisions. These studies have shown potential for water and nitrogen savings while maintaining or even improving crop productivity.

Review of Literature

Kuncham and Rao (2014) studied soil matric potential data and reported that the soil moisture tension acquired from gypsum block sensor and tensiometer were the same up to -70 k Pa, but that the values obtained from the tensiometer were not accurate. They came to the conclusion that the resistance block sensor is the sole method that can provide accurate and trustworthy readings in dry conditions. The potential may be measured over a broader range (0 to -200 k Pa) using a resistance block sensor, which was affordable to purchase.

In their study, Mittelbach et al. (2012) revealed that the root means square difference (RMSD) of volumetric water content (VWC) for the least effort sensors was significantly different from the TDR estimates, which were up to 0.3 m3 in volume, with the maximum value in near surface layers. The relative standard deviation, or RMSD, for the VWC anomalies is smaller than that for the absolute estimates of the manufacturer. They proceeded under the assumption that none of the evaluated sensors had a degree of execution that was predicted with the specific producer specifics when the situations under consideration were taken into account.

According to Mohamed et al. (2011)'s findings, the watermark produced much greater tension readings than the tensiometers did. In contrast to tensiometers, watermark provided an estimate of the material's water content that was both similar and much drier. However, the general direction of the curves representing the soil water tension that were produced by each treatment was the same. It was determined that the linear relationships of the Soil Wet Content (SMC) acquired from all of the gravimetric measurements and sensors produced the most accurate results. Correlation coefficients (R2) range from 0.96 to 0.98 for tensiometers and from 0.91 to 0.95 for watermarks, respectively. The results of the applied math studies suggest that a quality difference exists between the gravimetric technique and the sensors used to measure the amount of water in the soil.

Instead of using resistance to estimate moisture content, Juang and Radharamanan (2010) created a low-cost soil moisture monitoring system that uses gypsum blocks for spray irrigation systems. This system uses a peripheral interface controller (PIC) with a transmitter as the sensing unit. It concludes that this method of getting moisture content is a reliable one after measuring the time constant of increasing capacitance.

Material and Methods:

During the Kharif-2019 growing season, a field experiment with the working title "Sensor and SMI based irrigation management in Maize *[Zea mays (L.)]* to enhance growth, yield, and water use efficiency" was carried out at the M-block, Agroforestry unit, ZARS, GKVK in Bengaluru. The experimental location is located in the Eastern Dry Zone (Zone-5) of Karnataka, which can be found at an elevation of 930 metres above mean sea level (MSL). The coordinates for this area are 12 degrees 51 minutes north latitude and 77 degrees 35 minutes east longitude. T1 was surface irrigation, T2 was drip irrigation at three-day intervals, T3 was green soil moisture indicator (GSMI) based drip irrigation, T4 was yellow soil moisture indicator (YSMI) based drip irrigation, T5 was sensor based drip irrigation at 25% depletion of available soil moisture (DASM), T6 was sensor based drip irrigation at 50% DASM, and T7 was sensor based drip irrigation at 75% DASM. These seven treatments were laid out in a randomised

Five plants are selected at random from each treatment in order to record the observations on the characteristics of the plant, such as its height, number of leaves, leaf area, dry matter production, yield parameters, and so on. The height of the plant was measured from the soil level up to the fully expanded top leaf, and the results were averaged out to get the plant's height in centimetres. The average values of completely opened green leaves were recorded for five different plants that were chosen at random. The leaf area of the chosen plants was measured using a leaf area metre (Model Li-300 from Licor Co Nebraska), and the results were represented in centimetres squared per plant. It was found that the plant's leaves, stem, and roots all accumulated dry materials in significant amounts. Five plants were chosen at random from each treatment, then uprooted without injuring the roots to a depth of 15 centimetres, and portions such as leaf, stem, and root were oven dried at temperatures between 65 and 70 degrees Celsius. These specimens were weighed, and the results were recorded as grammes (g) plant-1. These data were used in the process of calculating the overall dry weight of each plant. The length of the cobs taken from five different plants was measured, and the average of those measurements was used to determine the length of the cobs in centimetres. A random count of kernels taken from the net plot was performed, and the total weight of 100 kernels was used to represent the test weight in grammes. The kernel that was harvested from the net plot was dried and then given a weight. The weight of the grain taken from the net plot was used to calculate the grain yield per hectare, which was then stated in kilogrammes per hectare. After being exposed to the light for eight to ten days, the plant dry matter from the net plot was measured. The yield of the stove was calculated and given in kilogrammes per hectare.

The water usage efficiency (WUE) was calculated by subtracting the quantity of water used from the yield of maize (Viets, 1972). The results were reported as a number of kilogrammes per square metre per hectare.

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

For the remaining treatments, the percentage of water that might have been conserved compared to surface irrigation was computed. The statistical analysis of the data that was gathered from the experimental plots was carried out by adhering to the technique that was outlined in Gomez and Gomez (1984). P = 0.05 was used as the threshold of significance for both the 'F' and 't' tests. Calculations of critical differences were performed whenever the 'F' test produced significant results.

Results and Discussion

The examination of growth shed light on the influence that sensor-based irrigation levels had on all of the growth-attributing characteristics. At harvest, sensor-based drip watering at 25% DASM resulted in higher plants (203.4 centimetres), a greater total number of leaves (13.3), a larger leaf area (9083 centimetres squared plant^{-1}), and a greater accumulation of dry matter (479.5 grammes plant^{-1}). According to Gordin et al. 2019, irrigation scheduling that was based on soil sensors (including a soil moisture sensor and tensiometer) resulted in increased leaf area as well as accumulations of fresh and dry biomass. It was largely due to irrigating the crop at the appropriate time, which resulted in the constant availability of essential moisture in the root zone. This could have assisted in better nutrient absorption, which resulted in more cell division and elongation. The major reason for this was that irrigating the crop at the required time. On the other hand, the stress brought on by surface watering has resulted in a 9.2 percent reduction in plant height. Both Durga et al. (2018) and Kumar et al. (2018) came to the same conclusions on the findings.

When it comes to determining whether or not maize has the capacity to provide an economic yield, irrigation plays a decisive and essential role. Moisture stress has a significant impact not only on the development of maize but also on characteristics such as the length of the cob, the number of kernels per pod, and the weight of 100 kernels. In the current research, sensor-based drip irrigation at 25% DASM produced longer cobs (19.0 centimetres), heavier 100-kernel weight (30.5 grammes), heavier kernel weight (192.1 g cob^{-1}), and heavier overall cob weight (245.6 grammes). In sensor-based drip irrigation at 25% DASM, both kernel yield (10679 kg ha^{-1}) and Stover yield (12273 kg ha^{-1}) were shown to be significantly higher. The generation of longer cobs, more kernels per row, and a greater test weight were the factors that contributed to the increased kernel yield achieved with sensor-based drip irrigation at 25% DASM (Table 2). The presence of adequate moisture in the soil led to an increase in these yield parameters, which also favoured photosynthetic production and the transfer of photosynthates to the sink, which led to an improvement in 100-seed weight. Because the appropriate amount of moisture was not always available, the crop was subjected to stress in the area close to the root zone. This resulted in significantly decreased grain production from surface irrigation. Khanna et al. (2018) and Lathashree (2019) came to quite similar conclusions in their research.

Due to sensor-based irrigation control, a fluctuation in total water use (ha-cm) was detected, which is shown in Table 3. The most water was used for surface irrigation of maize (49.7 ha-cm), which was 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), and sensor-based drip irrigation at 25% DASM. Surface irrigation of maize used the most water.

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) are the three methods of drip irrigation that were used.

In terms of water use efficiency, the treatments varied considerably with regard to sensor-based irrigation management (Table 3). The sensor-based drip irrigation at 25% DASM was found to have the highest WUE (219.2 kg ha-cm^{-1}), followed by the Green SMI-based drip irrigation (214.4 kg ha-cm^{-1}) and the drip irrigation at three days' interval (202.2 kg ha-cm^{-1}). On the other hand, we found that the treatment that received surface irrigation had a lower WUE (131.8 kg ha-cm^{-1}) (Table 3). A greater yield was the direct consequence of more effective water usage by the plants, which was made possible by the drip irrigation system's ability to minimise water loss and increase water retention by the plants. According to Shah and Das (2012), the use of drip irrigation had a beneficial impact that aided in keeping steady soil moisture potential. The decreased water usage efficiency of surface irrigation was linked to increased evaporation loss of soil moisture as a result of a larger exposed wetting surface following irrigation. This was caused by the irrigation process. Researchers Bharathi et al. (2007), Sui (2017), and Lathashree (2019) all came to comparable conclusions in their studies.

Table 1: Sensor based irrigation Influence of maize on growth parameters

	Treatment	T_1 : Surface irrigation	T_2 : Drip irrigation at 3 days interval	T_3 : Green SMI based drip irrigation	T_4 : Yellow SMI based drip irrigation	T_5 : Sensor based drip irrigation at 25% DASM	T_6 : Sensor based drip irrigation at 50% DASM	T_7 : Sensor based drip irrigation at 75% DASM	F – test	S.Em.±	CD (p=0.05 or 0.01)
Plant height	(cm) at harvest	184.6	194.1	200	194.7	203.4	195.6	187.3	**	2.19	6.76
Number of leaves at harvest		9.67	12	12.6	11.3	13.3	12.3	10.3	**	0.57	1.74
Leaf area(cm^2 $plant^{-1}$) at harvest		7390	8052	9013	8598	9083	8375	7550	**	162	501
Dry matter production (g	$plant^{-1}$) at harvest	350.3	416	436	365.7	479.5	432.6	354.4	**	15.1	46.5

Table 2: Sensor based irrigation Influence of maize on yield parameters

	Treatment	T_1 : Surfac	T_2 : Drip	T_3 : Green	T_4 : Yello	T_5 : Sensor	T_6 : Sensor	T_7 : Sensor	F –	S.Em.±	CD (p=0.

		e irrigation	irrigation at 3 days interval	SMI based drip irrigation	w SMI based drip irrigation	based drip irrigation at 25% DASM	based drip irrigation at 50% DASM	based drip irrigation at 75% DASM	test		05 or 0.01)
Cob length (cm)		15.6	17.3	18.1	16.1	19	17.5	15.8	*	0.62	1.9
100	kernel weight (g)	27.7	28	30.3	27.8	30.5	28.6	27.3	*	0.23	0.71
	Kernel yield (kg ha^{-1})	6551	8331	10441	7548	10676	8436	6555	**	421	1299
Stover yield (kg ha^{-1})		8007	9485	11975	9145	12273	9690	8033	*	810	2498

Table 3: Sensor based irrigation in maize of Total water used, Water Use Efficiency (WUE), Water saved

	Treatment	T_1 : Surface irrigation	T_2 : Drip irrigation at 3 days interval	T_3 : Green SMI based drip irrigation	T_4 : Yellow SMI based drip irrigation	T_5 : Sensor based drip irrigation at 25% DASM	T_6 : Sensor based drip irrigation at 50% DASM	T_7 : Sensor based drip irrigation at 75% DASM
Total water used	Effective Rainfall	21.7	21.7	21.7	21.7	21.7	21.7	21.7
	Irrigated	28	19.5	27	19.5	27	19.5	15
	Total	49.7	41.2	48.7	41.2	48.7	41.2	36.7

(ha-cm)								
Water use efficiency (kg ha-cm^{-1})		131.8	202.2	214.4	183.2	219.2	204.7	178.6
Water saved (%)		-	30.4	3.6	30.4	3.6	30.4	46.4

Conclusion

Changing the frequency of the irrigation led to an increase in crop yield as well as the generation of agricultural biomass. In maize, sensor-based drip irrigation applied at a rate of 25% DASM resulted in increased growth parameters, yield attributing parameters, yield, and water use efficiency.

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