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Grain Yield, Growth and Yield Components of Maize as Influenced by Irrigation Intervals and Irrigation Levels

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Irrigation intervals influence the soil moisture, plant stress where irrigation levels determine water availability based on environmental demand with their combined management was crucial for optimizing maize growth and yield under varying irrigation conditions. Maize responds differently to

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varying irrigation intervals and levels influencing the growth and yield of a crop. A field experiment was laid out in a randomized complete block design with factorial concept comprised of eight treatments with two irrigation intervals (irrigation at five days and ten days) and four irrigation levels (1.0, 0.8, 0.6 and 0.4 CPE) were evaluated at Centre for climate resilient agriculture, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences (KSNUAHS), Shivamogga, during summer season of 2023. Irrigation at five-day intervals with 1.0 CPE significantly improved grain yield (9835 kg ha^{-1}), straw yield (15016 kg ha^{-1}), harvest index (0.40), grain yield per plant (181.53 g), test weight (26.51 g), grains per cob (587.33), plant height (196.25 cm), number of leaves (10.63) and stem girth (7.46 cm).The plant height, number of leaves, number of grains per cob and test weight exhibited strong positive correlation with grain yield emphasizing their role in enhancing maize productivity under varying irrigation levels. The optimal irrigation strategies for maize, emphasizing the effects of different irrigation intervals and levels on growth and yield. It provides practical insights for sustainable water management and maximizing productivity particularly under resource constraints.

Keywords: Correlation; grain yield; irrigation intervals; irrigation levels.

1. INTRODUCTION

"Maize (*Zea mays* L.) is an important cereal crop predominantly used as feed for animals. It is also an important food crop and used as a major feedstock for biofuels production particularly bioethanol" (Erenstein et al., 2022). "Globally, 206.3 million ha is under maize cultivation, yielding 780 million tons with 3150 kg ha^{-1} of productivity. In India, maize is being grown over an area of 9.86 million ha with a production of 31.51 million tons and productivity of 3195 kg ha^{-1}. Being one of the largest producer, Karnataka accounts for almost 16 per cent of total maize produced in India (5.18 million tons) grown over an area of 1.68 million ha with a productivity of 3092 kg ha^{-1}" (Anon., 2023).

"Water scarcity is an increasingly important issue in many parts of the world. Climate change predictions of increase in temperature and decrease in rainfall, water will become even scarcer. Proper irrigation management is crucial for maintaining optimal plant water status, which directly influences vital physiological processes such as cell elongation, cell division, cell wall synthesis and photosynthesis. Efficient irrigation scheduling is essential for conserving water resources and achieving optimal crop production. With increasing pressure to enhance the agricultural production, developing high-yield, water-efficient irrigation strategies is pivotal for sustainable agricultural development" (Zhang et al., 2019).

The growth and yield components of maize are highly sensitive to irrigation intervals and levels. Irrigation intervals determine the frequency of water application, influencing soil moisture, root zone aeration and nutrient solubility. Shorter intervals helps to maintain consistent soil moisture, reducing stress during critical growth stages, longer intervals may expose the crop to water deficits, affecting physiological efficiency (Markovic et al., 2017). Scheduling irrigation based on cumulative pan evaporation is a practical approach that incorporates climatic factors, ensuring better water management and improving productivity.

The concept of cumulative pan evaporation was considered in the study, where irrigation scheduling was determined by the daily recorded cumulative pan evaporation. This approach has proven to be a reliable, economical and practical method for scheduling irrigation by incorporating climatic factors into the decision making process (Verma et al., 2023). Maize can be cultivated in all seasons, but summer maize productivity is particularly affected by irrigation. Hence there is a need to develop proper irrigation schedules to realize higher productivity. The current investigation addresses and optimizes the irrigation schedule for summer maize. The optimal irrigation ensures that the crop receives adequate water to sustain growth without wastage or environmental degradation.

2. MATERIALS AND METHODS

Experimental site: The experiment was conducted at the Centre for climate resilient agriculture, KSNUAHS during summer season of 2023, located at 13º 58' to 14º ' North latitude and 75º 42' East longitude and at an altitude of 650 m above the mean sea level. The research area comes under the Southern Transition Zone of Karnataka (Zone VII). The soil was slightly acidic in reaction (pH – 6.6), low in soluble salts (0.32 dS m^{-1}) and was low in organic carbon (0.45 g kg^{-1}). Among major nutrients, it was medium in available nitrogen (245.19 kg ha^{-1}), medium in available P_2O_5 (24.5 kg ha^{-1}) and high in available K_2O (179.00 kg ha^{-1}). The mean weekly values of important weather parameters recorded during the crop season are depicted in Fig. 1.

Experimental details: The experiment was laid out in a factorial randomized complete block design with three replications. Two irrigation intervals (irrigation at five days and ten days) and four irrigation levels (1.0, 0.8, 0.6 and 0.4 CPE) were used in the experiment. The maize crop was planted at the spacing of 45cm × 30 cm. The net plot size was 3.6 m × 4.2 m used for the cultivation. The land was ploughed by tractor drawn mould board plough followed by harrowing to bring the soil to a fine tilth. Sowing was done by hand dibbling with one seeds at each hill. Fertilizer was applied according to the treatments. Half of nitrogen, entire dose of phosphorous and potassium in the form of urea, diammonium phosphate (DAP) and murate of potash (MOP), respectively were band placed as per the treatments. Fertilizer was applied 4-5 cm deep and 5 cm away from the seed as basal dose. Remaining half dose of nitrogen in the form of urea was top dressed in two equal splits at 25 and 45 days after sowing in the ring formed 5 cm away from the plant. Thinning and gap filling was done at 10 days after sowing of maize to maintain optimum plant population. Earthing up was done by using a spade at 45 days after sowing after the final top dressing. Irrigations were given as per the treatments. The first irrigation was applied just after sowing for uniform germination and second irrigation was applied after one week of sowing to ensure better germination and crop establishment. Thereafter, the irrigation treatments were imposed. The cumulative pan evaporation values from standard USWB class ‘A’ pan evaporimeter was used for scheduling of irrigation. Daily pan evaporation and rainfall data from sowing till physiological maturity was collected from the meteorological observatory located at Centre for climate resilient agriculture, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences (KSNUAHS), Shivamogga. Irrigations were applied to individual plots based on cumulative pan evaporation values recorded at fixed time interval. Amount of irrigation water applied to be calculated based on CPE (1.0, 0.8, 0.6 and 0.4) values. During the cropping season, if any rainfall was received, it was subtracted from the cumulative pan evaporation and the irrigation amount was adjusted accordingly based on the remaining cumulative pan evaporation. Irrigation buffer channels were maintained surrounding to all the bunded experimental plots to avoid seepage of applied water from one plot to other.

Data collection: From the net plot, three plants were selected and tagged randomly for recording the growth and yield parameters.

Growth parameters:

Plant height (cm): The plant height was measured from the base of the plant to youngest fully opened top leaf up to the stage of tasseling. After tasseling, plant height was measured from the base of the plant to collar of the flag leaf. The average height of three plants was considered and expressed in centimeters.

Number of leaves per plant: Number of fully opened photosynthetically active leaves from ground to the tip of the plant is recorded from three plants in each plot and expressed as number per plant.

Stem girth: Stem girth was recorded at harvest from three plants/plot. It was measured at the last but one internode from the ground.

Yield parameters:

Number of grains per cob: The number of grains on each cob was estimated by multiplying the number of grain rows by the number of grains per row with an average taken from five labeled plants.

Test weight (g): The 100 grains from completely dried five cobs were obtained after harvest, weighed and the average weight was expressed in grams.

Grain yield per plant (g $plant^{-1}$): The grain yield of the cobs obtained from five labeled plants of maize was noted and the average was worked out as grain yield per plant and expressed in grams per plant.

Grain yield (kg ha^{-1}): The grain obtained from each net plot and also from the five sample cobs was sundried, cleaned thoroughly and the total weight was recorded and expressed in kg ha^{-1}.

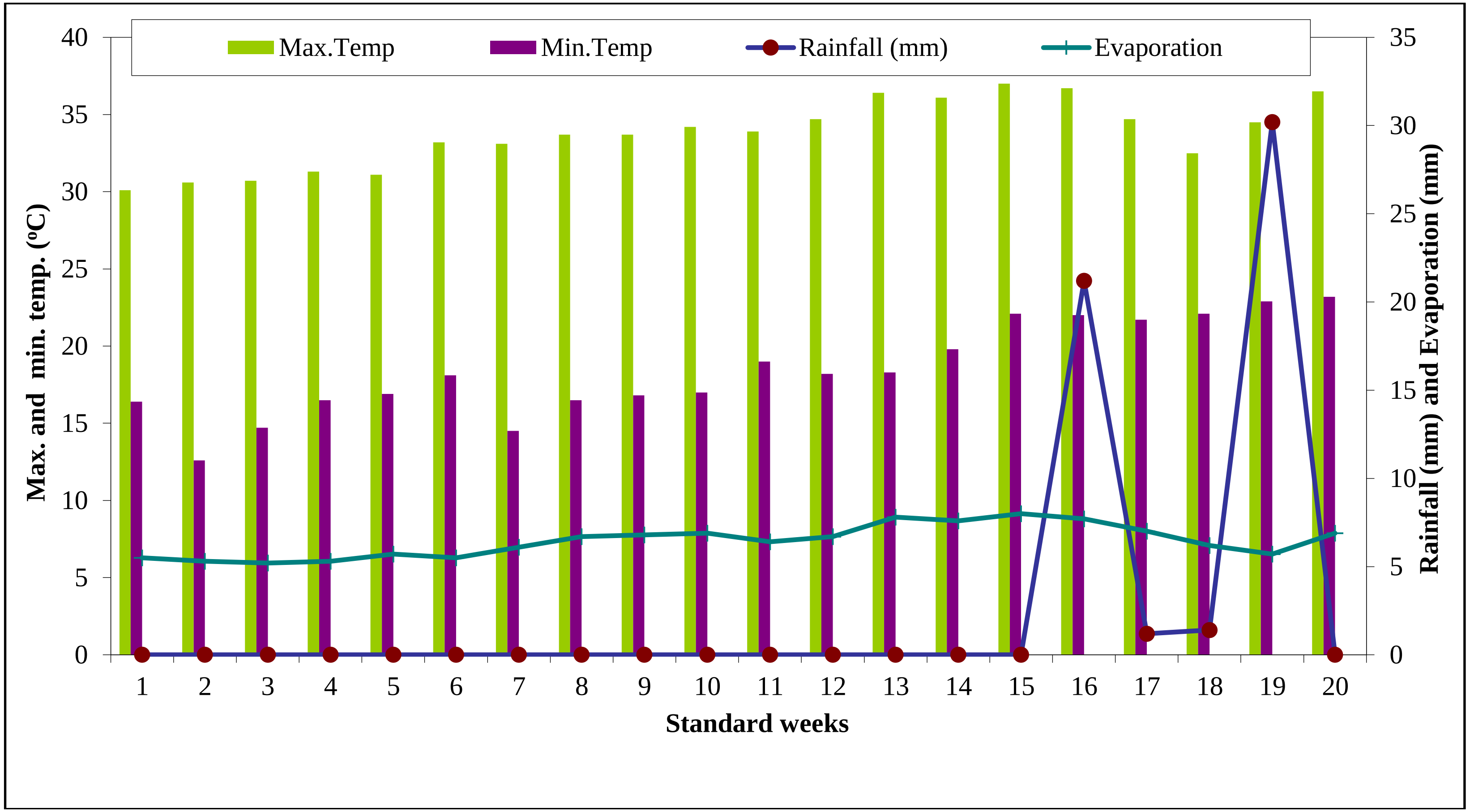

Fig. 1. The weekly actual weather data prevailed during the crop growing period (2023) at experimental site of ZAHRS, Navile, KSNUAHS, Shivamogga

Straw yield (kg ha^{-1}): Straw left over after cob separation was cut at ground level, sun dried, weighed and expressed in kg ha^{-1}.

Harvest index: The harvest index is defined as the ratio of economic yield to total biological yield (Donald, 1962) and expressed in percentage. The harvest index of maize was worked out as indicated below.

$$\text{Harvest index} = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})}$$

Statistical analysis: The data collected from the experiment at harvest were subjected to statistical analysis by adopting Fischer's method of analysis of variance technique as outlined by Gomez and Gomez (1984). Summary tables for treatment effect have been prepared and furnished with standard error of means (S.Em±) and critical difference (C.D.) at 5 per cent level of probability (p=0.05) has also been given where the treatment differences were significant.

Correlation between growth an yield parameters with the grain yield of Maize: Simple correlation between growth parameters *i.e*. plant height, number of leaves, stem girth and yield parameters *i.e*. number of grains per cob, test weight, grain yield per plant and grain yield on the development of maize was estimated to know the correlation between these growth and yield parameters and grain yield. The statistical analysis tool, the R studio was used for correlation coefficient (r) calculation. The significance (probability) of the correlation coefficient was determined from the t-statistic.

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

The data on growth components *viz*., plant height, number of leaves per plant and stem girth were significantly influenced by irrigation intervals and irrigation levels on maize are presented in Table 1. Irrigation at five-day intervals (M_1) recorded significantly higher plant height (161.11 cm), number of leaves per plant (9.95) and stem girth (6.97 cm) at harvest compared to irrigation at ten days interval. A significant decrease in plant height was observed with an increase in the irrigation interval. Increased growth parameters with more frequent irrigations have been reported by Wang et al. (2017), Amin et al. (2015), Huang et al. (2022) and Anjum et al. (2014), whereas, prolonged intervals between irrigations result in water stress, hindering the leaf expansion, photosynthesis and stem girth (Azarpanah et al., 2013; Mubeen et al., 2013; Baloch et al., 2014; Ezz and Haffez, 2019).

Scheduling irrigation at higher CPE significantly increased all the growth parameters. Irrigation application at 1.0 CPE recorded the higher plant height (160.81 cm), number of leaves per plant (10.48) and stem girth (6.92 cm) compared to other irrigation levels (Table 1). Higher irrigation level at 1.0 CPE provided sufficient soil moisture enhancing nutrient absorption and promoting growth. The similar findings were reported by Nagarajan (2019), Ramachandiran et al. (2016) and Parthasarathi et al. (2013). The lower plant height (111.31 cm), number of leaves per plant (9.12) and stem girth (6.03 cm) was recorded with the application of irrigation at 0.4 CPE. The findings suggest that insufficient water availability could not support the optimal cell division and elongation necessary for growth and development of the crop Roja et al., (2020), Rajasekhar et al., (2019), Rasool et al., (2020) and Rathod et al., (2023).

Irrigation at five days interval with 1.00 CPE recorded significantly higher plant height (196.25 cm), number of leaves (10.63) and stem girth (7.46 cm) at harvest compared to other interactions (Table 1). This optimal combination of sufficient water and frequent irrigation ensures consistent hydration and nutrient supply supporting higher growth. Application of irrigation at ten days interval with 0.4 CPE recorded significantly lower plant height (91.45 cm), number of leaves (8.80) and stem girth (5.49 cm). The combined stress of low water and infrequent irrigation limits cell division and elongation leading to stunted growth.

3.2 Yield and Yield Parameters

Application of irrigation at each five days interval recorded significantly higher grain yield (6929 kg ha^{1}), straw yield (10620 kg ha^{-1}), harvest index (0.39), grain yield per plant (160.88 g plant^{-1}), test weight (24.95 g plant^{-1}) and number of grains per cob (507.08) was presented in Table 2. The increase in yield parameters of maize with shorter irrigation interval due to better growth of crop, efficient dry matter partitioning and translocation in to the sink under no moisture stress as a result of continuous moisture supply in the root zone. Similar findings were reported by Halim et al., 2014 and Adamu et al., 2014. The increase in grain yield of maize at five days irrigation interval was about 12.83 % over irrigation at ten days interval.

Table 1. Growth parameters of maize as influenced by irrigation intervals and levels at harvest

Treatments	Plant height (cm)	Number of leaves	Stem girth (cm)
Irrigation intervals (M)			
M_1: 5 days interval	161.11	9.95	6.97
M_2: 10 days interval	109.84	9.67	5.95
S.Em±	0.64	0.07	0.03
C.D. (p=0.05)	3.90	0.44	0.21
Irrigation levels (I)			
I_1: 1.00 CPE	160.81	10.48	6.92
I_2: 0.8 CPE	147.25	9.88	6.63
I_3: 0.6 CPE	122.52	9.75	6.26
I_4: 0.4 CPE	111.31	9.12	6.03
S.Em±	2.24	0.05	0.05
C.D. (p=0.05)	6.91	0.15	0.15
Interactions (M×I)			
M_1I_1	196.25	10.63	7.46
M_1I_2	173.44	9.97	7.01
M_1I_3	143.57	9.77	6.86
M_1I_4	131.17	9.43	6.57
M_2I_1	125.37	10.33	6.39
M_2I_2	121.07	9.80	6.26
M_2I_3	101.47	9.73	5.65
M_2I_4	91.45	8.80	5.49
S.Em±	3.17	0.07	0.07
C.D. (p=0.05)	9.77	0.21	0.21

Table 2. Yield and yield parameters of maize as influenced by irrigation intervals and levels

Treatments	No of grains per cob	Test weight (g plant^{-1})	Grain yield per plant (g plant^{-1})	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
Irrigation intervals (M)						
M_1: 5 days interval	507.08	24.95	160.88	6929	10620	0.39
M_2: 10 days interval	390.43	23.87	102.08	6141	10049	0.38
S.Em±	2.08	0.05	3.51	32.10	26.32	0.002
C.D. (p=0.05)	12.68	0.27	21.35	195.35	160.17	0.01
Irrigation levels (I)						
I_1: 1.00 CPE	534.80	25.56	159.60	9305	14369	0.39
I_2: 0.8 CPE	485.00	24.44	136.03	7435	11781	0.39
I_3: 0.6 CPE	418.27	24.20	124.13	5570	8810	0.39
I_4: 0.4 CPE	356.97	23.44	106.17	3830	6378	0.37
S.Em±	2.21	0.15	2.57	36.65	167.80	0.003
C.D. (p=0.05)	6.80	0.47	7.91	112.92	517.04	0.009
Interactions (M×I)						
M_1I_1	587.33	26.51	181.53	9835	15016	0.40
M_1I_2	541.13	24.93	164.73	7860	11688	0.40
M_1I_3	483.53	24.47	160.07	5900	9230	0.39
M_1I_4	416.33	23.90	137.20	4120	6547	0.39
M_2I_1	482.27	24.62	137.67	8775	13722	0.39
M_2I_2	428.87	23.96	107.33	7010	11875	0.37
M_2I_3	353.00	23.94	88.20	5240	8391	0.38
M_2I_4	297.60	22.98	75.13	3540	6209	0.36
S.Em±	3.12	0.22	3.63	51.83	237.31	0.004
C.D. (p=0.05)	9.61	0.66	11.19	159.69	731.21	0.012

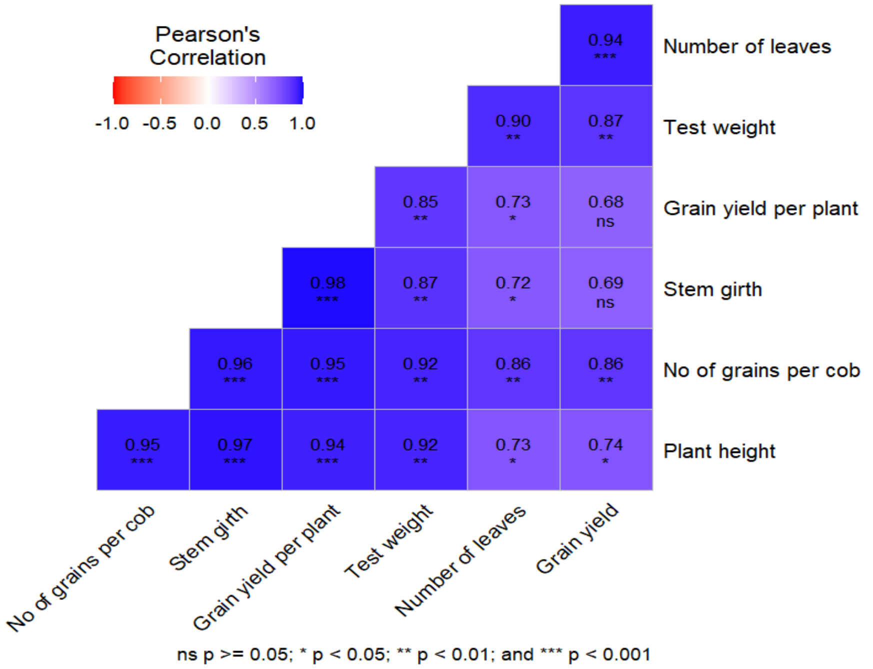

Fig. 2. Relationship between growth and yield parameters of maize as influenced by irrigation intervals and levels

The irrigation levels differed significantly with respect of yield and yield parameters. Irrigation at 1.0 CPE recorded higher grain yield (9305 kg ha^{-1}), straw yield (14369 kg ha^{-1}), harvest index (0.39), grain yield per plant (159.60 g plant^{-1}), test weight (25.56 g plant^{-1}) and number of grains per cob (534.80) was presented in Table 2. The lower irrigation level of 0.4 CPE recorded significantly lower grain yield (3830 kg ha^{-1}), straw yield (6378 kg ha^{-1}) and harvest index (0.37). The per cent increase in number of grains per cob, test weight and grain yield per plant was 49.82, 9.04 and 50.32 per cent over irrigation at 0.4 CPE. Alemi (1981) reported that the water stress in maize reduced test weight by 8 % as compared to non-stress conditions. The lower grain yield and yield parameters due to water shortage in maize was also reported by Adamu et al. (2014), Aulakh et al. (2012).

Interaction effect of irrigation interval and irrigation levels had a significant influence on yield and yield parameters of maize (Table 2). Irrigation at five days interval with 1.0 CPE recorded the higher grain yield (9835 kg ha^{-1}), straw yield (15016 kg ha^{-1}), harvest index (0.40), grain yield per plant (181.53 g plant^{-1}), test weight (26.51 g plant^{-1}) and number of grains per cob (587.33). However irrigation at ten days interval with 0.4 CPE recorded the lower grain yield (3540 kg ha^{-1}), straw yield (6209 kg ha^{-1}), harvest index (0.36), grain yield per plant (75.13 g plant^{-1}), test weight (22.98 g plant^{-1}) and number of grains per cob (297.60). The water stress reduced the plant growth and inhibited the pollination leading to fewer grains per cob and lower overall yield (Rani et al., 2017 and Pallavi et al., 2021).

3.3 Correlation between Growth and Yield Characters with Grain Yield in Maize

The Fig. 2 illustrates Pearson's correlation between various growth and yield parameters of maize as influenced by irrigation intervals and irrigation levels. The grain yield in maize is strongly and positively influenced by growth and yield traits, particularly number of grains per cob (r = 0.86), test weight (r = 0.87), number of leaves (r = 0.94) and plant height (r = 0.74) all of which exhibit significant relationships indicate that enhancing these parameters through improved irrigation management and agronomic practices can significantly boost maize productivity.

4. CONCLUSION

The maize growth and yield are significantly influenced by irrigation intervals and levels.

Maize, a globally important cereal crop, requires efficient irrigation strategies to optimize its growth and yield, particularly under resource constrained conditions. The study aimed to evaluate the impact of irrigation intervals and levels on the growth and yield components of maize. Irrigation at five day intervals with 1.0 CPE recorded the highest yield and growth parameters, including plant height, stem girth and number of leaves. The findings highlights the importance of frequent irrigation and optimal water application for maximizing maize productivity.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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