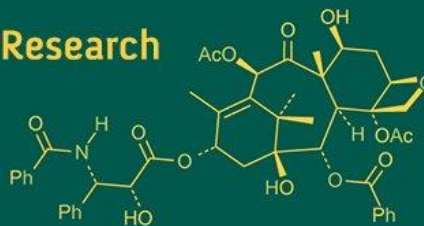


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Response of Rabi maize to different irrigation schedules and plant densities for growth and yield characters

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Abstract

The study investigated the response of *Rabi* maize (*Zea mays* L.) to different irrigation schedules and plant densities under late *Rabi* conditions at the Research Farm of Sardar Patel University, Madhya Pradesh, India. A split-plot design with three replications was employed, featuring four irrigation schedules based on IW/CPE ratios (1.2, 1.0, 0.8, and 0.6) as main plots and three planting densities (66,666, 83,333, and 111,111 plants ha⁻¹) as sub-plots. Results indicated that irrigation at a 1.2 IW/CPE ratio significantly enhanced plant height, dry matter accumulation, cob length, kernel yield (6,806.7 kg ha⁻¹), and stover yield (10,004.3 kg ha⁻¹), outperforming lower irrigation regimes. Higher planting density (111,111 plants ha⁻¹) also improved grain and stover yields, demonstrating the dominance of plant population in yield determination. However, no significant interaction effects between irrigation and planting density were observed. The study concludes that an irrigation schedule of 1.2 IW/CPE combined with higher plant density optimizes maize productivity under *Rabi* conditions, offering a sustainable approach to water and resource management.

Keywords: *Rabi* maize, irrigation scheduling, IW/CPE ratio, plant density, and yield attributes

Introduction

Maize (*Zea mays* L.), commonly known as corn, stands as one of the most significant cereal crops globally and is often referred to as the "queen of cereals" due to its exceptional genetic yield potential and wide adaptability. Its unique C4 photosynthetic pathway offers higher photosynthetic efficiency and better water and nitrogen use efficiency than many other cereals (Ranum *et al.*, 2014) [14]. In India, maize has gained increasing importance in recent decades owing to its diverse utility as food, feed, fodder, and a key raw material in industrial processing sectors, including starch, ethanol, and biofuels (Khan *et al.*, 2008) [9].

Rabi maize cultivation, especially under irrigated conditions, has witnessed considerable expansion due to the increasing demand for maize-based products and the availability of improved hybrids that perform well in cooler climates. The success of *rabi* maize, however, largely depends on the availability and scheduling of irrigation. Unlike *kharif* maize, which benefits from monsoonal rains, *rabi* maize is completely dependent on supplementary irrigation. This makes efficient water management a vital aspect for achieving optimal crop growth and yield.

Water stress at critical growth stages, particularly during tasseling, silking, and grain filling, can significantly impair physiological processes, kernel development, and final yield (Zaidi *et al.*, 2015) [17]. On the other hand, over-irrigation not only leads to water wastage but can also cause nutrient leaching and increased disease incidence. Therefore, applying the right amount of water at the right time using scientifically developed irrigation schedules becomes essential to optimize both water use and crop performance.

Among various irrigation scheduling methods, climatological approaches based on the IW/CPE (Irrigation Water/Cumulative Pan Evaporation) ratio have been found effective in maximizing water-use efficiency and yield (Prihar & Sandhu, 1987) [13]. These methods align irrigation with the actual evapotranspiration needs of the crop and local weather conditions, thus providing a scientific basis for sustainable water management.

The present investigation was undertaken to evaluate the response of *rabi* maize to different irrigation schedules based on IW/CPE ratios with the objective of identifying the most

suitable irrigation regime for improving growth

attributes, yield components, and overall productivity under late *rabi* conditions.

Materials and Methods

The field experiment was conducted during the *Rabi* season of 2024-25 at the Research Farm of the Department of Agronomy, Sardar Patel University, Balaghat, Madhya Pradesh (Lat. 21.8°N, Long. 80.2°E, Alt. 288 m above mean sea level). The region experiences a tropical wet and dry (savanna) climate. The experimental site was characterized by sandy loam soil, nearly uniform topography, and moderate internal drainage.

The experiment was laid out in a split-plot design with three replications. The main plot treatments consisted of four irrigation schedules based on IW/CPE ratios:

Main plots: Irrigation schedules

M₁: 1W/CPE ratio of 1.2

M₂: IW/CPE ratio of 1.0

M₃: IW/CPE ratio of 0.8

M₄: IW/CPE ratio of 0.6

Sub plots: Planting densities

S₁: 75 cm x 20 cm (66,666 plants ha⁻¹)

S₂: 60 cm x 20 cm (83,333 plants ha⁻¹)

S₃: 45 cm x 20 cm (1,11,111 plants ha⁻¹)

Observations Recorded

Five plants were tagged in each net plot area for recording observations that did not involve destructive sampling. All the observations were recorded on these plants at 30, 60, 90 DAS and at harvest. Five plants in the second row from the border row in each plot were cut at each time for recording dry matter accumulation.

Pre-Harvest Observations

- Plant Height
- Drymatter Accumulation
- Days to 50 percent Tasseling
- Days to 50 percent Silking
- Number of Cobs Plant⁻¹

Post-Harvest Observations

- Cob Length
- Number of Kernel Rows Cob⁻¹
- Number of Kernels Cob⁻¹
- Cob Weight
- Test Weight (100-kernel weight)
- Kernel and Stover Yield
- Harvest Index
- Shelling Percentage

The data recorded on various parameters of crop was subjected to statistical scrutiny by the method of analysis of variance outlined by Panse and Sukhatme (1985). Statistical significance was tested by 'F' value at 5 percent level of probability. Wherever the 'F' value found significant, critical difference (CD) was worked out at 5 percent level of probability.

Results and Discussion

Plant height of maize increased progressively with crop age, significantly influenced by irrigation schedules and planting densities but not by their interaction. Irrigation at 1.2

IW/CPE ratios resulted in the tallest plants, comparable to 1.0 IW/CPE but significantly superior to 0.8 and 0.6 ratios. Higher moisture availability under 1.2 IW/CPE likely enhanced cell elongation and nutrient uptake, aligning with findings by Hussain *et al.* (2001)^[8] and Shivakumar *et al.* (2011)^[16]. Among planting densities, 45 cm x 20 cm (S₃) produced taller plants at harvest, attributed to reduced interplant competition and better resource utilization, consistent with observations by Gozubenli *et al.* (2003). Dry matter accumulation was highest under 1.2 IW/CPE, significantly surpassing lower irrigation regimes. This trend reflects improved photosynthetic activity and nutrient mobility under adequate moisture, as noted by Reddy *et al.* (2012)^[15]. Similarly, higher planting densities (S₃) yielded greater dry matter due to increased plant numbers per unit area, corroborating Hugar and Halikatti (2015)^[7]. CGR peaked at 1.2 IW/CPE during 30-60 DAS, with similar results for 1.0 IW/CPE. Higher planting densities (S₃) also enhanced CGR, likely due to efficient light interception and resource use, as reported by Prasanna *et al.* (2019)^[12]. Irrigation at 1.2 IW/CPE accelerated tasseling and silking (60.3 and 67.5 days, respectively), while 0.6 IW/CPE delayed these stages due to moisture stress, supporting Adamu *et al.* (2014)^[1]. Lower planting densities (S₁) promoted earlier flowering, whereas higher densities (S₃) delayed it, reflecting resource competition (Arvadiya *et al.*, 2012)^[2]. For cob length and weight, 1.2 IW/CPE produced the longest and heaviest cobs, statistically similar to 1.0 IW/CPE. Lower densities (S₁) outperformed higher densities (S₃), likely due to reduced competition for nutrients and light (Muniswamy *et al.*, 2007)^[10]. For kernel rows and kernels per cob, 1.2 IW/CPE and S₁ spacing maximized these traits, with water stress under 0.6 IW/CPE and high-density crowding (S₃) negatively impacting kernel development (Bharathi *et al.*, 2007)^[3]. Kernel yield was highest under 1.2 IW/CPE (43.8% more than 0.6 IW/CPE) and S₃ density (25.1% higher than S₁), demonstrating the dominance of plant population in yield determination (Borras *et al.*, 2003)^[4]. Stover yield followed trends similar to kernel yield, with 1.2 IW/CPE and S₃ yielding the most biomass, as observed by Dutta *et al.* (2016)^[5]. Harvest index remained unaffected by treatments, indicating stable partitioning efficiency.

Table 1: Plant height (cm) of maize as influenced by irrigation schedules and planting densities

Treatments	30 DAS	60 DAS	90 DAS	At Harvest
Irrigation schedules				
M ₁ -1.2 IW/CPE	74.0	175.2	224.7	227.5
M ₂ -1.0 IW/CPE	67.1	168.8	218.5	221.9
M ₃ -0.8 IW/CPE	59.4	122.7	194.3	197.8
M ₄ -0.6 IW/CPE	59.3	114.7	171.9	174.5
SEm±	2.65	4.01	3.42	4.13
CD (p = 0.05)	9.1	13.8	11.8	14.2
CV (%)	12.2	8.2	5.0	6.0
Planting densities				
S ₁ -75 cm x 20 cm	65.9	141.2	197.0	200.8
S ₂ -60 cm x 20 cm	65.4	144.7	200.9	203.0
S ₃ -45 cm x 20 cm	63.6	149.9	209.2	212.2
SEm±	1.14	2.15	3.20	2.97

CD ($p = 0.05$)	NS	6.4	9.6	8.8
CV (%)	6.0	5.1	5.4	5.0
Interaction (M x S)	NS	NS	NS	NS
Interaction (S x M)	NS	NS	NS	NS

Table 2: Dry matter accumulation (kg ha^{-1}) of maize as influenced by irrigation schedules and planting densities

Treatments	30 DAS	60 DAS	90 DAS	At harvest
Irrigation schedules				
M ₁ -1.2 IW/CPE	992.4	4092.7	10453.4	16998.7
M ₂ -1.0 IW/CPE	943.7	3809.1	9966.2	14868.1
M ₃ -0.8 IW/CPE	780.9	3596.0	9132.5	11961.6
M ₄ -0.6 IW/CPE	675.0	3146.0	8195.1	9760.6
SE $\pm$	26.87	93.73	206.17	356.81
CD ($p = 0.05$)	92.9	324.3	713.4	1234.7
CV (%)	9.5	7.6	6.5	7.9
Planting densities				
S ₁ -75 cm x 20 cm	737.9	3399.4	8342.2	11921.0
S ₂ -60 cm x 20 cm	798.2	3559.8	9165.3	12942.0
S ₃ -45 cm x 20 cm	1007.9	4023.6	10792.1	15328.9
SE $\pm$	22.28	58.86	122.26	219.96
CD ($p = 0.05$)	66.8	176.4	366.5	659.4
CV (%)	9.1	5.5	4.9	5.6
Interaction (M x S)	NS	NS	NS	NS
Interaction (S x M)	NS	NS	NS	NS

Table 3: Crop growth rate ($\text{g m}^{-2} \text{ day}^{-1}$) of maize as influenced by irrigation schedules and planting densities

Treatments	30-60 DAS	60-90 DAS	90-Harvest
Irrigation schedules			
M ₁ -1.2 IW/CPE	10.3	21.2	32.8
M ₂ -1.0 IW/CPE	9.6	20.5	24.5
M ₃ -0.8 IW/CPE	9.4	18.5	14.3
M ₄ -0.6 IW/CPE	8.2	16.8	8.0
SE $\pm$	0.30	0.70	0.83
CD ($p = 0.05$)	1.1	2.4	2.9
CV (%)	9.5	11	12.6
Planting densities			
S ₁ -75 cm x 20 cm	8.9	16.5	17.9
S ₂ -60 cm x 20 cm	9.2	18.7	18.6
S ₃ -45 cm x 20 cm	10.1	22.6	22.5
SE $\pm$	0.22	0.47	1.07
CD ($p = 0.05$)	0.6	1.4	3.2
CV (%)	8.2	8.5	18.6
Interaction (M x S)	NS	NS	NS
Interaction (S x M)	NS	NS	NS

Table 4: Days to 50 percent tasseling and silking of maize as influenced by irrigation schedules and planting densities

Treatments	50% Tasseling	50% Silking
Irrigation schedules		
M ₁ -1.2 IW/CPE	58.1	65.5
M ₂ -1.0 IW/CPE	60.1	67.2
M ₃ -0.8 IW/CPE	61.9	69.0
M ₄ -0.6 IW/CPE	63.7	70.9
SE $\pm$	0.34	0.37
CD ($p = 0.05$)	1.1	1.2
CV (%)	1.6	1.6
Planting densities		
S ₁ -75 cm x 20 cm	60.3	67.5
S ₂ -60 cm x 20 cm	61.1	68.2
S ₃ -45 cm x 20 cm	61.5	68.7
SE $\pm$	0.32	0.29
CD ($p = 0.05$)	0.9	0.8
CV (%)	1.8	1.4
Interaction (M x S)	NS	NS
Interaction (S x M)	NS	NS

Table 5: Yield attributing characters of maize as influenced by irrigation schedules and planting densities

Treatments	Cobs per plant	Cob length (cm)	Number of kernel rows per cob
Irrigation schedules			
M ₁ -1.2 IW/CPE	1.09	16.8	16.8
M ₂ -1.0 IW/CPE	1.05	16.4	15.9
M ₃ -0.8 IW/CPE	1.00	12.7	15.1
M ₄ -0.6 IW/CPE	1.00	10.7	15.0
SEm±	0.02	0.32	0.35
CD (p = 0.05)	NS	1.1	1.2
CV (%)	5.8	6.8	6.6
Planting densities			
S ₁ -75 cm x 20 cm	1.0	14.9	16.0
S ₂ -60 cm x 20 cm	1.0	14.1	15.8
S ₃ -45 cm x 20 cm	1.0	13.3	15.4
SEm±	0.02	0.21	0.16
CD (p = 0.05)	NS	0.6	0.4
CV (%)	5.9	5.0	3.5
Interaction (M x S)	NS	NS	NS
Interaction (S x M)	NS	NS	NS

Table 6: Cob weight (g), kernels per cob, test weight (g) and shelling percentage (%) of maize as influenced by irrigation schedules and planting densities

Treatments	Cob Weight (g)	Number of kernels per cob	Shelling percentage (%)
Irrigation schedules			
M ₁ -1.2 IW/CPE	125.2	487.3	75.1
M ₂ -1.0 IW/CPE	122.3	434.6	74.1
M ₃ -0.8 IW/CPE	103.5	395.3	72.0
M ₄ -0.6 IW/CPE	85.0	291.0	66.7
SEm±	2.54	17.74	1.24
CD (p = 0.05)	8.7	61.4	4.3
CV (%)	6.9	13.2	5.1
Planting densities			
S ₁ -75 cm x 20 cm	114.3	425.4	74.7
S ₂ -60 cm x 20 cm	109.5	402.4	71.5
S ₃ -45 cm x 20 cm	103.2	378.2	69.7
SEm±	1.58	5.87	1.06
CD (p = 0.05)	4.7	17.6	3.1
CV (%)	5.0	5.0	5.1
Interaction (M x S)	NS	NS	NS
Interaction (S x M)	NS	NS	NS

Table 7: Test weight (g) of maize as influenced by irrigation schedules and planting densities

Treatments	Main Plots Vs Sub Plots			
	S1 75 cm x 20 cm	S2 60 cm x 20 cm	S3 45 cm x 20 cm	Mean
M ₁ -1.2 IW/CPE	28.30	26.87	25.57	26.91
M ₂ -1.0 IW/CPE	27.63	26.43	23.93	26.00
M ₃ -0.8 IW/CPE	26.33	25.73	24.67	25.58
M ₄ -0.6 IW/CPE	24.53	23.43	22.63	23.53
Mean	26.70	25.62	24.20	
	SEm ±	CD	CV	
MAIN PLOT	0.53	1.85	6.29	
SUB PLOT	0.42	1.25	5.68	
Interaction				
M X S	0.84	NS		
S X M	0.87	NS		

Table 8: Number of kernel rows cob⁻¹ of maize as influenced by irrigation schedules and planting densities

Treatments	Main Plots Vs Sub Plots			
	S1 75 cm x 20 cm	S2 60 cm x 20 cm	S3 45 cm x 20 cm	Mean

M ₁ -1.2 IW/CPE	17.10	17.00	16.47	16.86
M ₂ -1.0 IW/CPE	16.50	15.57	15.53	15.87
M ₃ -0.8 IW/CPE	16.17	15.37	14.53	15.36
M ₄ -0.6 IW/CPE	15.53	15.10	14.57	15.07
Mean	16.33	15.76	15.28	
	SEm ±	CD	CV	
MAIN PLOT	0.31	1.06	5.83	
SUB PLOT	0.23	0.68	5.00	
Interaction				
M X S	0.46	NS		
S X M	0.48	NS		

Table 9: Kernel yield (kg ha⁻¹) of maize as influenced by irrigation schedules and planting densities

Treatments	Main Plots Vs Sub Plots			Mean
	S1 75 cm x 20 cm	S2 60 cm x 20 cm	S3 45 cm x 20 cm	
M ₁ -1.2 IW/CPE	6045.67	6824.33	7550.33	6806.78
M ₂ -1.0 IW/CPE	5790.67	6117.00	7143.67	6350.44
M ₃ -0.8 IW/CPE	4703.33	5681.00	6437.00	5607.11
M ₄ -0.6 IW/CPE	3666.00	3645.00	4158.00	3823.00
Mean	5051.42	5566.83	6322.25	
	SEm ±	CD	CV	
MAIN PLOT	149.73	518.15	7.95	
SUB PLOT	101.22	303.47	6.21	
Interaction				
M X S	202.44	NS		
S X M	223.02	NS		

Table 10: Stover yield (kg ha⁻¹) and harvest index (%) of maize as influenced by irrigation schedules and planting densities

Treatments	Kernel yield (kg ha ⁻¹)	Stover yield (kg ha ⁻¹)	Harvest index (%)
Irrigation schedules			
M ₁ -1.2 IW/CPE	6806.7	10004.3	40.5
M ₂ -1.0 IW/CPE	6350.4	8822.7	41.8
M ₃ -0.8 IW/CPE	5607.1	7648.7	42.1
M ₄ -0.6 IW/CPE	3823.0	5817.7	39.9
SEm±	149.73	250.10	1.10
CD (p = 0.05)	518.1	865.4	NS
CV (%)	7.9	9.2	8.0
Planting densities			
S ₁ -75 cm x 20 cm	5051.4	7298.0	41.1
S ₂ -60 cm x 20 cm	5566.8	8020.5	40.8
S ₃ -45 cm x 20 cm	6322.2	8901.6	41.4
SEm±	101.22	136.30	0.69
CD (p = 0.05)	303.4	408.6	NS
CV (%)	6.2	5.8	5.8
Interaction (M x S)	NS	NS	NS
Interaction (S x M)	NS	NS	NS

Conclusion

Irrigation scheduled at a 1.2 IW/CPE ratio resulted in significantly higher growth and yield-attributing parameters in maize, leading to a marked increase in both kernel and stover yields, closely followed by the 1.0 IW/CPE ratio. Higher plant density (1,11,111 plants ha⁻¹) resulted in increased grain and stover yields in maize. The interaction between irrigation scheduling and planting densities did not significantly affect growth parameters, yield attributes, or overall yield.

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