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Response of summer fodder maize (*Zea mays* L.) to irrigation scheduling based on IW/CPE ratio and levels of nitrogen

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Abstract
Maize (*Zea mays* L.) is one of the most important fodder crop species and is grown throughout a wide range of climates. India relies on mixed farming, combining crops and livestock. Livestock, contributing 7% to the national GDP, serves as a crucial livelihood for 70% of the rural population. However, the livestock sector faces challenges such as a deficit in green fodder, dry crop residues, and concentrate feeds. Maize, a significant cereal crop globally, plays a vital role in livestock productivity in India. Deficit irrigation scheduling on the other hand is the practice of irrigating crops below the full water requirement. The effects of water stress on crop growth and fodder yield will depend on the timing and magnitude of water stress as well as crop type, since different crops have different levels of tolerance to water stress. For many field crops the most critical period of water stress is during the transition from vegetative to reproductive growth or from flowering to fruit setting. Nitrogen fertilizer played important role in improving soil fertility and increase in crop productivity. A study has been conducted during summer season of 2021 at Junagadh (21.50 N latitude and 70.50 E longitude) of Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh under typically subtropical climatic conditions to know the best irrigation scheduling and optimum nitrogen level for summer fodder maize. The treatment combinations include three irrigation levels (I_1, I_2 and I_3 at 0.6, 0.8 and 1.0 IW/CPE respectively) and four nitrogen levels (N_1, N_2, N_3 and N_4 at 60, 80, 100 and 120 kg N/ha). The treatments were laid out using Split plot Design and replicated four times with 12 treatment combinations. The variety taken for the experiment was African tall and sown on the spacing of 30cm×10cm. Irrespective of nitrogen levels, I_3 significantly produced highest green as well as dry fodder yield (336.46 q/ha and 91.73 q/ha) and on the other hand, N_4 produced highest green as well as dry fodder yield (372.82 q/ha and 99.09 q/ha) which is statistical differ from other levels. Crude protein and Crude fiber content (7.21 and 32.75%) were found highest in I_3. Benefit cost ratio (2.29) was calculated highest in irrigation at IW/CPE is 1.0 with application of 120 kg nitrogen.

Keywords: Summer fodder maize (*Zea mays* L.), scheduling based, IW/CPE ratio

Introduction

The agricultural production system in India relies on mixed farming, combining crops and livestock. Livestock, contributing 7% to the national GDP, serves as a crucial livelihood for 70% of the rural population. However, the livestock sector faces challenges such as a deficit in green fodder, dry crop residues, and concentrate feeds. Maize, a significant cereal crop globally, plays a vital role in livestock productivity in India due to its succulence and palatability. Livestock population is around 500 million and is expected to grow at the rate of 1.23% in the coming years. The milk production in India was 94.5 million tonnes, the highest in the world (Chaudhary *et al.*, 2012) [5].

The current deficit in fodder production is attributed to inadequate cultivation of fodder crops, exacerbating during summer months. Maize stands out as a versatile and adaptable crop, offering high-quality fodder and the option for silage. Its cultivation spans 115 million hectares globally, with India accounting for 9.4 million hectares in 2014. Maize fodder has low protein content but it is relished by the animals due to being succulent and palatable (Ali *et al.*, 2004) [2]. States like Andhra Pradesh and Gujarat lead in productivity. Maize serves various purposes, including direct human consumption, animal feed, and industrial applications. It provides raw materials for starch, alcohol, and other industries, containing 10% protein and significant amounts of Vitamins A and E. Maize's role in livestock nutrition is crucial, offering a balance between biomass production and nutritional quality. In the world, maize is cultivated in about 115 million hectares with the production of about 290 million tonnes of grains, whereas in India, this crop was sown in about 9.4 million hectares during 2014 (Anon., 2014) [3].

Water availability emerges as a critical factor in maize cultivation, influencing growth, yield, and nutrient efficiency. Irrigation scheduling, considering the Irrigation Water to Crop Evapotranspiration ratio, proves essential for optimal water use. Furthermore, nitrogen fertilizer plays a key role in maize growth, impacting not only yield but also protein content.

The interactive effects of water and fertilizer, especially nitrogen and phosphorus, are crucial for maize forage quality and yield. Proper nutrient management, including splitting nitrogen application to different growth stages, can enhance yield and quality. African tall maize varieties are noted for their suitability as forage, but research on water and fertilizer requirements, particularly in summer and scarcity zones, is limited. In conclusion, addressing the challenges in fodder production for livestock, particularly in the context of water scarcity, requires a comprehensive approach integrating maize cultivation, proper irrigation scheduling, and optimized nutrient management.

Materials and Methods

A field trail was conducted during summer season of 2021 at, Junagadh (21.50 N latitude and 70.50 E longitude) of Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh under typically subtropical climatic conditions to know the best irrigation scheduling and optimum nitrogen level for summer maize. Three irrigation regimes was laid out in main plot and four levels of nitrogen in sub plots, 12 treatment combinations were replicated with four times. The spacing of fodder maize crop was 30×10 cm and variety taken from the experiment was Fodder maize, African tall. The treatment combinations include three irrigation levels (I_1, I_2 and I_3 at 0.6, 0.8 and 1.0 IW/CPE respectively) and four nitrogen levels (N_1, N_2, N_3 and N_4 at 60, 80, 100 and 120 kg N/ha). The treatments were laid out using Split plot Design and replicated four times with 12 treatment combinations. The biometric (plant height, number of leaves, length of internodes, stem thickness, leaf stem ratio and dry matter) and yield and yield attributes from each treatment were taken and tabulated after statistical test.

Soil data

Data from soil and plant were taken periodically. The soil type of experimental field was sandy loam in texture with pH of 8.27 and EC was 0.43 dSm^{-1}. The available soil N was 269.14 kg/ha which is low, P_2O_5 was 27.71 kg/ha which is medium and K_2O was 214.57 kg/ha which is medium in range (Table 1).

Meteorological parameters

The maximum temperature during cropping season was ranged between 35.20 to 40.87 °C whereas minimum temperature ranged from 17.19 to 25.53 °C. While, the minimum and maximum relative humidity ranged between 58 to 85% (RH I) and 12 to 30% (RH II). Bright sunshine hours, wind velocity and daily evaporation were 7.53 to 10.27 hrs/day, 4.14 to 7.41 km/hr and 7.04 to 9.30 mm/day, respectively. (Table 2).

Table 1: Physio-chemical properties of the experimental site

Particular	Value at 0-30 cm depth	Method followed
A. Mechanical Composition		
1. Sand %	22.56	
2. Silt %	13.71	International Pipette method (Piper, 1950) [10]
3. Clay %	63.73	
4. Texture class	Clayey	
B. Chemical Composition		
1. Soil pH (1:2.5)	8.27	pH meter (Richards, 1954) [12]
2. Electrical conductivity (dS /m) at 25 ^{0}C (1:2.5)	0.43	EC meter (Jackson, 1974) [6]
3. Organic Carbon (%)	0.98	Walkley and Black's method (Jackson, 1974) [6]
4. Available N (kg /ha)	269.14	Alkaline KMnO4 method (Subbaiah and Asija, 1956) [14]
5. Available P_2O_5 (kg /ha)	27.71	Olsen's method (Olsen *et. al.*, 1954)
6. Available K_2O (kg /ha)	214.57	Flame photometric method (Jackson, 1974) [6]
C. Soil moisture constants		
Field capacity (%)	29.90	Field method (Piper, 1950) [10] Sunflower method (Piper, 1950) [10] Clod method (Page *et al*., 1986)
Permanent wilting point (%)	13.16	
Bulk density (mg/m^3)	1.36	

Table 2: Mean weekly weather data during summer 2021

Std. Week	Temperature (°C)		Relative humidity (%)			Bright sunshine	Rainfall (mm/day)	Wind velocity	Eva. (mm/day)
No.	Max.	Min.	I	II	Avg.	(hr./day)		(km/h)	
February-2021									
08	34.6	16.8	63	23	43	10.20	0.00	3.70	6.30
09	35.20	17.19	60	18	39	10.27	0.00	5.23	7.04
March-2021									
10	37.56	17.59	79	16	48	9.83	0.00	4.14	7.57
11	37.50	20.27	59	14	37	10.10	0.0	4.76	7.73
12	37.43	20.96	60	17	38	9.53	0.00	4.91	8.19
13	40.06	20.70	58	19	39	9.96	0.00	5.14	8.99
April-2021									
14	40.11	21.83	85	17	51	9.87	0.00	5.24	8.54

15	40.87	22.57	61	12	36	9.50	0.00	5.87	9.26
16	39.33	23.34	79	19	49	9.14	9.60	5.50	7.64
17	40.13	25.53	72	22	47	7.53	0.00	5.34	7.96
May-2021									
18	40.27	25.16	69	23	46	8.83	1.70	5.51	8.43
19	39.87	25.41	76	30	53	10.16	0.00	7.41	9.30
20	36.30	25.80	79	45	62	3.40	47.80	8.80	7.20
21	38.10	26.40	78	42	60	9.20	3.60	8.80	8.50

* As these are taken at the time of I observation (in morning hours) and at the time of II observation (in the evening hours), hence written as RH I and RH II.

Results and Discussion

Effect on plant parameters

In all occasions, (30, 45, 60 DAS and Harvest) I_3 produced highest plant height (68.86, 109.77, 139.99 and 158.90 cm respectively) followed by I_2 (66.87, 106.11, 133.45 and 147.84 cm respectively) and the same trend was observed in case of number of leaves per plant at 30, 45, 60 DAS and at harvest.In case of nitrogen levels plant height (30, 45, 60 DAS and Harvest) and number of leaves per plant (30, 45, 60 DAS and Harvest) were found statistically highest in N_4 followed by N_3 level and in case of number of leaves per plant at 30 DAS N_2 also at par with N_3 and N_4. Lowest plant height in all occasions found with treatments I_1 and N_1 levels. The increase in plant height in response to more number of irrigations was also reported by Adamu *et al.*, (2014) [1].

Effect on yield and yield attributes

Significanly higher length of internodes, stem thickness and leaf:stem ratio at harvest were recorded with I_3 (13.72 cm, 5.76 cm and 0.73, respectively) due to more no of irrigations followed by I_2 (12.79 cm, 5.46 cm, and 0.69 respectively). Lowest length of internodes, stem thickness and leaf:stem ratio were recorded in I_1 (10.92 cm, 4.56 cm and 0.41). It may be due to water stress. Days to 50% flowering gave no significant results. Maximum green and dry fodder yield were observed in I_3 (336.46 q/ha and 91.73 q/ha respectively) followed by I_2 Lowest yield had been seen in I_1 (283.00 q/ha and 79.10 q/ha respectively). Crude protein and crude fiber were recorded significantly highest with I_3 followed by $I_{2.}$

In case of nitrogen levels all parameters like length of internodes, stem thickness, leaf:stem ratio, green as well as dry fooder yields, crude protein and crude fibre were recorded significantly higher values with N_4 followed by N_3. Higher yield at increased levels of nitrogen might be owing to better nutrient uptake leading to greater drymatter production and higher photosynthetic rate and increased translocation of photosynthates from source to sink. Similar results were reported by Aulakh *et al.*, (2013) [6] and Mahesh *et al.*, (2016) [8] (Table 4).

Interaction effect of irrigation and nitrogen levels found significant in case of green and dry fooder yield. I_3N_4 gave significantly higher green as well as dry fodder yield and followed by I_3N_3 and I_2N_4 in case of green fodder yield and I_2N_4, I_3N_3 and I_2N_3 in case of dry fooder yield. This was ascribed due to cumulative significant interaction of irrigation scheduling and nitrogen in respect of improvement in yield attributes *viz.*, green fodder yield and dry fodder yield. These findings are in conformity with those reported by Shah *et al.* (2011) [13], Reza and Ramezani (2012) [11] and Kiran *et al.* (2013) [7].

Economics of crop

Highest gross return (Rs/ha 80,258/-) and net return (Rs/ha 45210/-) obtained in I_3N_4 whereas least gross return and net return calculated in I_1N_1 (Rs/ha 82068/- and Rs/ha 52368/- respectively) (Table 6). Benefit cost ratio (2.29) was calculated highest in irrigation at IW/CPE is 1.0 with application of 120 kg N/ha. Irrigation of IW/CPE at 1.0 saves water without any significant reduction of green as well as dry fodder yield. Application of 120 kg N/ha produced highest fodder yield.

Table 3: Plant height and number of leaves per plant as influenced by various levels of irrigation schedules based on IW/CPE ratio and levels of nitrogen

	Plant height (cm)				Number of leaves per plant			
Treatments	**At 30 DAS**	**At 45 DAS**	**At 60 DAS**	**At harvest**	**At 30 DAS**	**At 45 DAS**	**At 60 DAS**	**At harvest**
(A) Irrigation schedules (I)								
I1: 0.6 IW/CPE ratio	61.10	99.02	122.45	141.17	6.60	7.09	13.22	13.05
I2: 0.8 IW/CPE ratio	66.87	106.11	133.45	147.84	7.67	9.44	14.83	13.91
I3: 1.0 IW/CPE ratio	68.86	109.77	139.99	158.90	8.22	10.29	15.57	14.98
S.Em.±	1.51	2.41	3.04	3.52	0.17	0.25	0.41	0.41
C.D. at 5%	5.22	8.32	10.51	12.18	0.60	0.86	1.43	1.40
C.V. %	9.19	9.17	9.20	9.43	9.31	11.25	11.37	11.61
(B) Fertilizer (F)								
N1: 60 kg N/ha	60.98	94.78	117.06	136.77	6.60	7.60	12.61	11.67
N2: 80 kg N/ha	64.63	98.98	126.08	145.63	7.10	8.55	14.07	13.44
N3: 100 kg N/ha	66.41	109.84	138.11	152.78	7.95	9.47	15.36	14.98
N4: 120 kg N/ha	70.41	116.26	146.60	162.03	8.33	9.99	16.12	15.83
S.Em.±	1.67	2.65	2.93	3.19	0.15	0.18	0.27	0.30
C.D. at 5%	4.85	7.70	8.51	9.25	0.43	0.53	0.78	0.86
C.V. %	8.82	8.76	7.70	7.40	6.92	7.17	6.39	7.34
(C) Interaction (I x F)								
S.Em.±	2.89	4.60	5.08	5.52	0.26	0.32	0.46	0.51
C.D. at 5%	NS	NS	14.74	16.03	NS	NS	NS	NS

Table 4: Yield and yield attributing characters as influenced by various levels of irrigation schedules based on IW/CPE ratio and levels of nitrogen

Treatments	Days to 50% flowering	Length of internodes (cm)	Stem thickness (cm)	Leaf: stem ratio at harvest	Green fodder yield (q/ha)	Dry fodder yield (q/ha)	Crude protein content (%)	Crude fiber content (%)
(A) Irrigation schedules (I)								
I1: 0.6 IW/CPE ratio	45.62	10.92	4.56	0.41	283.00	79.10	6.49	26.28
I2: 0.8 IW/CPE ratio	46.42	12.79	5.46	0.69	315.61	84.02	6.82	30.44
I3: 1.0 IW/CPE ratio	47.02	13.72	5.76	0.73	336.46	91.73	7.21	32.75
S.Em.±	0.97	0.29	0.15	0.02	7.04	2.23	0.16	0.68
C.D. at 5%	NS	0.99	0.51	0.06	24.37	7.72	0.55	2.34
C.V. %	8.41	9.15	11.31	10.94	9.04	10.51	9.25	9.05
(B) Fertilizer (F)								
N1: 60 kg N/ha	46.81	10.00	4.31	0.52	236.59	68.68	6.57	24.22
N2: 80 kg N/ha	46.35	11.82	4.90	0.60	279.68	77.41	6.72	29.16
N3: 100 kg N/ha	46.21	13.68	5.75	0.64	357.68	94.61	6.93	32.11
N4: 120 kg N/ha	46.03	14.40	6.08	0.68	372.82	99.09	7.14	33.93
S.Em.±	0.78	0.26	0.12	0.02	6.48	1.78	0.14	0.63
C.D. at 5%	NS	0.74	0.35	0.04	18.80	5.17	0.40	1.83
C.V. %	5.81	7.12	7.98	8.77	7.20	7.04	7.06	7.32
(C) Interaction (I x F)								
S.Em.±	1.35	0.44	0.21	0.03	11.22	3.09	0.24	1.09
C.D. at 5%	NS	NS	NS	NS	32.56	8.96	NS	NS

Table 5: Interaction effect of irrigation schedules based on IW/CPE ratio and levels of nitrogen on plant height, green and dry fooder yield

Plant height at 60 DAS				Plant height at harvest		
	I1	I2	I3	I1	I2	I3
N1	114.70	114.76	121.72	122.71	141.70	145.91
N2	115.24	126.27	136.73	144.22	146.19	146.49
N3	116.20	145.39	150.75	148.86	149.97	159.51
N4	143.65	147.40	150.77	148.88	153.51	183.19
S.Em. ±		5.08			5.52	
C.D. at 5%		14.74			16.03	

Green fodder yield (q/ha)				Dry fodder yield (q/ha)		
	I1	I2	I3	I1	I2	I3
N1	183.93	250.72	275.11	61.32	61.83	82.90
N2	274.33	279.65	285.06	70.47	78.68	83.10
N3	331.81	356.85	384.38	91.37	93.76	98.68
N4	341.96	375.21	401.29	93.23	101.81	102.23
S.Em. ±		11.22			3.09	
C.D. at 5%		32.56			8.96	

Table 6: Economics of different treatment combinations of irrigation scheduling and nitrogen levels

Treatment combinations	Green fodder yield (kg/ha)	Gross realization (₹/ha)	Cost of Cultivation (₹/ha)	Net realization (₹/ha)	B: C ratio
I1N1 I1N2 I1N3 I1N4 I2N1 I2N2 I2N3 I2N4 I3N1 I3N2 I3N3 I3N4	18393	36786	32116	4670	1.15
	27433	54865	32527	22338	1.69
	33181	66361	32708	33653	2.03
	34196	68391	33005	35387	2.07
	25072	50144	31455	18689	1.59
	27965	55931	33208	22723	1.68
	35685	71370	33389	37981	2.14
	37521	75043	33686	41357	2.23
	27511	55021	34159	20862	1.61
	28506	57013	32817	24196	1.74
	38438	76875	34751	42124	2.21
	40129	80258	35048	45210	2.29

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