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Response of Maize (*Zea mays* L.) to Precision Water and Nitrogen Management

REKHA M. GONAL[1], H. M. JAYADEVA[2], S. B. YOGANANDA[3], S. KAMALA BAI[4] AND A. SATHISH[5],
[1& 2] Department of Agronomy, [3] Department of Agronomy, College of Agriculture, V.C. Farm, Mandya
[4] AICRP on Weed Management, [5]Department of SS & AC, CoA, UAS, GKVK, Bengaluru
e-Mail : rekhagonal07@gmail.com

ABSTRACT

A field experiment was conducted at College of Agriculture, V.C. Farm, Mandya during summer 2020, *Rabi* 2020 and summer 2021 to study the response of maize to precision water and nitrogen management. The experiment was laid out in strip block design with 21 treatments. Among different levels of irrigations, IW:CPE ratio of 1.0 (I_3) recorded significantly higher kernel and stover yield (100.85 and 138.08 q ha^{-1}, respectively) in pooled analysis. Green seeker based N at NDVI 0.8 (N_6) recorded significantly higher kernel and stover yield (104.56 and 144.73 q ha^{-1}, respectively). In the interaction, irrigation at IW : CPE ratio 1.0 and Green seeker based N at NDVI 0.8 (I_3N_3) resulted in significantly higher kernel and stover yield in pooled analysis (114.88 and 166.67 q ha^{-1}, respectively). It was on par with I_3N_4 *i.e.,* scheduling of drip irrigation at IW : CPE ratio of 1.0 and SPAD based N at threshold 50 (113.18 and 163.95 q ha^{-1}, respectively). Similar trend was observed in all the seasons.

Keywords : Maize, Irrigation, Nitrogen, Green seeker, SPAD, LCC

GLOBALLY Maize (*Zea mays* L.) is one of the important cereal crop after wheat and rice. It has got wider adaptability to different climatic conditions and can be grown throughout the year. Due to higher yield potential, it's called the 'Queen of cereals' and 'King of fodder'. Used as a staple food for human consumption, livestock and poultry feed and in many industries as a raw material. In India, about 35 per cent of the produce is used for human consumption, 25 per cent in poultry and cattle feed, 15 per cent in food processing industries. It is cultivated in an area of 9.56 million hectare in India, with a production of 28.76 million tonnes and productivity of 3006 kg ha^{-1}. Karnataka alone contributes 14.88 per cent of the total maize production with an area of 1.42 million hectare and production of 4.4 million tonnes (Anonymous, 2021). However, the productivity of maize in India is very low (2689 kg ha^{-1}), when compared to the world (5500 kg ha^{-1}), which indicates a large gap between potential productivity and actual productivity.

Tremendous opportunity exists to improve the productivity and profitability of maize production through precise application of crop inputs such as water and nitrogen. Appropriate method and scheduling of irrigation leads to efficient use of nutrients which in turn increases the yield and net returns. Compensating the evapotranspiration losses is one of the practical approaches to schedule irrigation. Daily irrigation in drip method is practically possible and desirable, providing ideal soil moisture condition which may not be possible under surface irrigation due to higher application losses, labour drudgery, insufficient water to spread over the entire field *etc*.

Proper assessment of the limiting conditions for maize production and productivity is difficult as it is grown in a wide range of climatic conditions, but nutrient management is one of the most important factors limiting maize production (Jat *et al.,* 2013). Precise and responsive N fertilizer management in Maize is compelling for both economic and environmental reasons. Nitrogen is regarded as the most primary nutrient required by the maize plant for its timely and proper growth and development (Maitra *et al*., 2019). Precision management tools are technology related and are built with accurate, intelligent, smart sensing and diagnosing and management abilities which can be very fruitful for managing the nutrient loss status in maize crop.

Leaf colour chart (LCC) is a handy and precise nutrient management tool containing different shades of green color which can be useful in comparing with the leaf color and applying the required amount of fertilizer. SPAD chlorophyll meter is an innovative tool which provides a quick and on field reading of the chlorophyll content of any leaf in a plant. The estimation of the nutrient requirement of maize crop at its various growth stages helps in providing the required dosage of nitrogen to the crop thereby reducing the nitrogen losses in maize cultivation. Green Seeker uses certain artificial intelligence loaded crop sensors. Normalized Difference Vegetative Index (NDVI) readings can note the effects of balanced fertilizer applications.

Estimation of the nutrient requirement of maize crop at various growth stages helps in providing the required dosage of nitrogen thereby reducing the nitrogen losses in maize cultivation. Considering the benefits of these tools and irrigation, the study was conducted to ascertain the effect of precision water and nitrogen management on growth and yield of maize.

Material and Methods

Field experiments were conducted at College of Agriculture, V.C. Farm, Mandya. The site falls under Southern Dry Zone of Karnataka (Agro climatic zone-6). Situated at latitude of 12º 56' North, longitude of 76º 81' East and an altitude of 695 m above mean sea level. The present investigation was carried out to study the influence of precision water and nitrogen management on maize during summer 2020, *rabi* 2020 and summer 2021. The experiment was laid out in strip block design with 21 treatments and replicated thrice. Treatments included main factor: irrigation levels I_1: IW:CPE ratio of 0.6, I_2: IW:CPE ratio of 0.8 and I_3: IW:CPE ratio of 1.0 and sub factor: nutrient management, N_1: LCC based N at threshold 4, N_1: LCC based N at threshold 6, N_3: SPAD based N at threshold 40, N_4: SPAD based N at threshold 50, N_5: Green Seeker based N at NDVI 0.6, N_6: Green Seeker based N at NDVI 0.8 and N_7: 100 per cent RDF. Surface irrigation with recommended RDF was included as control. Recommended dose of fertilizer applied was 150 : 75 : 40 kg NPK ha^{-1}, 10 t FYM ha^{-1}. Gross plot size: 6.0 m × 3.6 m (21.60 m^2), net plot size: 4.2 m × 2.7 m (11.34 m^2). Sowing was done on 24.03.2020 (summer 2020), 12.09.2020 (*rabi* 2020) and 11.02.2021 (summer 2021).

Land was prepared by ploughing with disc plough followed by passing cultivator twice, harrowed and levelled to get required seed bed. Drip system including pump, filter units, main line and sub lines were installed. Inline laterals of 16 mm size within lines spaced at 45 cm apart with 4 lph capacities were laid out at a distance of 60 cm apart and thereby lateral spacing of 60 cm was fixed. There were 10 maize rows at a distance of 60 cm apart in each treatment. Seeds of maize hybrid 30B07 were dibbled (two seeds per hole) at 30 cm interval in the furrows spaced at 60 cm apart. Recommended dose of FYM (10 t ha^{-1}) was applied to all the treatments mixed into the soil 15 days prior to sowing. 50 per cent of recommended N and full dose of P_2O_5 and K_2O were applied as basal dose. Remaining 50 per cent N was applied as guided by LCC, SPAD and Green Seeker readings for different treatments at 15, 30, 45, 60 and 75 days after sowing. Irrigation was scheduled based on the IW:CPE ratio fixed at three irrigation levels, by recording daily pan evaporation. Whenever the pan evaporation reached the pre determined level, irrigation was scheduled accordingly.

Five plants were selected at random and tagged in the net plot. These plants were used for recording various biometric observations. Observations on growth parameters were recorded at 30, 60, 90 days after sowing (DAS) and at harvest. Data related to yield was recorded at the time of harvest. The experimental data collected were subjected to Fisher's method of 'Analysis of variance' (ANOVA). Pooled analysis and analysis of year wise data was performed as per the procedure outlined by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Plant Height (cm)

Plant height varied among different levels of irrigation and nutrient management in pooled analysis (Table 1). Among the different irrigation levels, IW:CPE ratio of 1.0 (I_3) recorded significantly higher plant height at 30, 60, 90 DAS and at harvest (46.95, 142.94, 190.94 and 195.32 cm, respectively). Green Seeker based N at NDVI 0.8 (N_6) recorded significantly higher plant height (49.34, 147.56, 196.78 and 201.64 cm, respectively) among different nitrogen management strategies. In pooled analysis of interaction effect, I_3N_6 (irrigation at IW:CPE ratio of 1.0 and Green Seeker based N at NDVI 0.8) resulted in significantly higher plant at 30, 60, 90 DAS and at harvest (53.67, 154.85, 206.99 and 211.19 cm, respectively). It was on par with treatment receiving irrigation at IW:CPE ratio of 1.0 and SPAD based N at threshold 50 *i.e.,* I_3N_4 (52.85, 152.97, 205.84 and 209.69 cm, respectively). Significantly lower plant height was recorded in I_1N_1 *i.e.,* irrigation at IW:CPE ratio of 0.6 and LCC based N at threshold 4 (28.87, 121.2, 164.44 and 167.69 cm, respectively). Similar trend was observed in all the three seasons. The increased plant height is mainly attributed to the better availability of moisture in the crop root zone throughout the growing period and split application of nitrogen based on NDVI readings which resulted in better uptake and reduction in nitrogen losses. This is in conformity with Prakasha and Mudalagiriyappa (2018) in maize and Yadav *et al.* (2012) in sugarcane.

TABLE 1

Plant height of maize as influenced by precision water and nitrogen management (pooled data of 3 seasons)

Treatments	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	At harvest
Irrigation levels (I)				
I_1	37.79	130.65	174.58	177.93
I_2	42.68	136.24	181.91	186.35
I_3	46.95	142.94	190.94	195.32
F test	*	*	*	*
S. Em ±	0.16	0.28	0.27	0.45
C.D. (p=0.05)	0.62	1.11	1.06	1.75
Nitrogen management (N)				
N_1	34.66	126.30	169.45	172.72
N_2	43.78	137.92	183.90	188.05
N_3	36.98	130.38	173.83	176.86
N_4	46.56	142.88	191.01	195.22
N_5	41.45	132.94	177.94	182.34
N_6	49.34	147.56	196.78	201.64
N_7	44.54	138.29	184.42	188.93
F test	*	*	*	*
S. Em ±	0.22	0.94	0.85	0.97
C.D. (p=0.05)	0.67	2.88	2.62	2.99
Interaction (I × N)				
I_1N_1	28.87	121.29	164.44	167.69
I_1N_2	39.79	130.99	174.81	178.19
I_1N_3	30.73	127.21	169.62	171.61
I_1N_4	41.57	135.11	180.08	183.89
I_1N_5	38.78	129.06	172.14	175.63
I_1N_6	44.28	138.45	184.25	188.98
I_1N_7	40.49	132.42	176.73	179.53
I_2N_1	35.81	127.47	170.06	173.30
I_2N_2	43.13	136.01	181.24	185.81
I_2N_3	37.60	128.32	171.17	174.25
I_2N_4	45.25	140.56	187.11	192.09
I_2N_5	40.91	130.84	176.53	181.35
I_2N_6	50.08	149.37	199.11	204.74
I_2N_7	46.01	141.13	188.13	192.93
I_3N_1	39.30	130.14	173.85	177.18
I_3N_2	48.41	146.76	195.64	200.13
I_3N_3	42.60	135.61	180.70	184.71
I_3N_4	52.85	152.97	205.84	209.69
I_3N_5	44.65	138.93	185.16	190.03
I_3N_6	53.67	154.85	206.99	211.19
I_3N_7	47.13	141.33	188.40	194.33
F test	*	*	*	*
S. Em ±	0.28	0.78	0.84	1.11
C.D. (p=0.05)	0.91	2.38	2.54	3.42
Control	42.47	136.61	182.47	186.54

Leaf Area (cm² plant⁻¹)

Pooled analysis (Table 2) showed that among the three levels of irrigation, IW:CPE ratio of 1.0 (I_3) recorded significantly higher leaf area at 30, 60, 90 DAS and at harvest (1546, 4764, 11300 and 9628 cm^2 $plant^{-1}$, respectively). Significantly higher leaf area was recorded in Green Seeker based N at NDVI 0.8 (N_6) among the precision nitrogen management practices

TABLE 2

Leaf area of maize as influenced by precision water and nitrogen management (pooled data of 3 seasons)

Treatments	Leaf area (cm² plant-1)			
	30 DAS	60 DAS	90 DAS	At harvest
I_1	1364	4109	9557	8151
I_2	1445	4353	10134	8643
I_3	1546	4764	11300	9628
F test	*	*	*	*
S. Em ±	5.47	26.55	43.46	36.89
C.D. (p=0.05)	21.49	104.26	170.63	144.87
Nutrient management (N)				
N_1	1330	4004	9314	7944
N_2	1472	4438	10328	8808
N_3	1354	4079	9491	8091
N_4	1533	4732	11267	9597
N_5	1396	4206	9786	8346
N_6	1600	4942	11745	10009
N_7	1478	4459	10384	8856
F test	*	*	*	*
S. Em ±	8.97	45.77	70.73	60.47
C.D. (p=0.05)	27.64	141.03	217.95	186.33
Interaction (I×N)				
I_1N_1	1284	3868	8996	7672
I_1N_2	1380	4156	9667	8245
I_1N_3	1294	3896	9062	7728
I_1N_4	1424	4288	9974	8506
I_1N_5	1335	4021	9353	7977
I_1N_6	1445	4352	10122	8633
I_1N_7	1389	4182	9727	8296
I_2N_1	1329	4002	9308	7938
I_2N_2	1440	4337	10087	8603
I_2N_3	1332	4011	9330	7957

Treatments	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	At harvest
I_2N_4	1474	4448	10360	8836
I_2N_5	1399	4214	9803	8361
I_2N_6	1635	4907	11455	9769
I_2N_7	1509	4552	10598	9039
I_3N_1	1376	4144	9639	8221
I_3N_2	1597	4822	11229	9577
I_3N_3	1438	4329	10081	8588
I_3N_4	1701	5460	13467	11450
I_3N_5	1453	4383	10203	8702
I_3N_6	1721	5569	13657	11625
I_3N_7	1536	4644	10826	9233
F test	*	*	*	*
S. Em ±	6.08	35.77	67.69	56.79
C.D. (p=0.05)	22.72	124.26	225.69	189.92
Control	1452	4409	10331	8807

(1600, 4942, 11745 and 10009 cm^2 $plant^{-1}$, respectively). Interaction of I_3N_6 *i.e.,* scheduling of drip irrigation at IW:CPE ratio of 1.0 and Green Seeker based N at NDVI 0.8 resulted in significantly higher leaf area at 30, 60, 90 DAS and at harvest (1721, 5569, 13657 and 11625 cm^2 $plant^{-1}$, respectively), which was on par with I_3N_4 *i.e.,* irrigation at IW:CPE ratio of 1.0 and N application based on SPAD at threshold 50 (1701, 5460, 13467 and 11450 cm^2 $plant^{-1}$, respectively). Drip irrigation scheduling at IW:CPE ratio of 0.6 and LCC based N at threshold 4 (I_1N_1) recorded significantly lower leaf area at all the growth stages (1284, 3868, 8996 and 7672 cm^2 $plant^{-1}$, respectively). In the three seasons, similar trend was observed. Scheduling of drip irrigation at IW:CPE ratio of 1.00 resulted in better availability of water and in turn better nutrient uptake and translocation, maintenance of turgidity of the cells and more number of leaves per plant. Split application of nitrogen based on Green Seeker NDVI values resulted in balance between supply and demand of the crop, leading to faster cell division and cell enlargement. Development of efficient photosynthetic system enables higher light interception by the plant which leads to development of more number leaves in turn higher leaf area. The results are in conformity with the findings of Shruthi and Sheshadri (2017) and Hanumanthappa *et al.* (2015).

Total Dry Matter Accumulation (g plant^{-1})

Irrigation at IW:CPE ratio of 1.0 (I_3) recorded significantly higher total dry matter in pooled data (Table 3) at 30, 60, 90 DAS and at harvest (10.48, 101.95, 233.82 and 277.00 g plant^{-1}, respectively) among the three levels. Among the precision nitrogen management practices, Green Seeker

TABLE 3

Total dry matter accumulation of maize as influenced by precision water and nitrogen management (pooled data of 3 seasons)

Treatments	Total dry matter accumulation (g plant-1)			
	30 DAS	60 DAS	90 DAS	At harvest
Irrigation levels (I)				
I_1	9.58	93.81	215.85	254.34
I_2	9.89	97.05	223.91	263.59
I_3	10.48	101.95	233.82	277.00
F test	*	*	*	*
S.Em.±	0.03	0.18	0.62	0.21
C.D. (p=0.05)	0.11	0.70	2.44	0.81
Nutrient management (N)				
N_1	9.28	90.06	210.76	248.18
N_2	10.01	98.50	225.62	265.64
N_3	9.52	92.87	214.11	252.16
N_4	10.48	102.16	233.72	277.49
N_5	9.85	96.98	222.25	262.02
N_6	10.67	103.92	238.53	282.39
N_7	10.06	98.71	226.69	266.95
F test	*	*	*	*
S.Em.±	0.05	0.39	1.04	0.34
C.D. (p=0.05)	0.14	1.20	3.21	1.04
Interaction (I×N)				
I_1N_1	8.86	84.43	201.96	237.60
I_1N_2	9.74	96.11	219.03	258.18
I_1N_3	9.15	88.49	203.96	240.62
I_1N_4	9.87	97.81	222.11	261.75

Treatments	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	At harvest
I_1N_5	9.68	94.88	217.12	256.26
I_1N_6	9.97	98.40	225.45	265.39
I_1N_7	9.79	96.56	221.30	260.55
I_2N_1	9.27	90.16	210.92	248.26
I_2N_2	9.93	98.30	225.07	264.99
I_2N_3	9.51	92.21	214.45	252.20
I_2N_4	10.08	99.05	228.45	268.83
I_2N_5	9.82	97.37	222.48	262.48
I_2N_6	10.42	102.98	237.14	279.08
I_2N_7	10.16	99.27	228.86	269.28
I_3N_1	9.71	95.60	219.39	258.70
I_3N_2	10.36	101.10	232.76	273.76
I_3N_3	9.90	97.92	223.93	263.65
I_3N_4	11.47	109.62	250.62	301.87
I_3N_5	10.05	98.68	227.16	267.31
I_3N_6	11.63	110.39	253.01	302.69
I_3N_7	10.23	100.32	229.90	271.04
F test	NS	*	*	*
S.Em.±	0.06	0.22	0.69	0.46
C.D. (p=0.05)	0.20	0.79	2.58	1.43
Control	9.98	97.6	224.53	264.98

based N at NDVI 0.8 (N_6) recorded significantly higher total dry matter (10.67, 103.92, 238.53 and 282.39 g plant^{-1}, respectively). Interaction between scheduling of drip irrigation at IW:CPE ratio of 1.0 and nitrogen application through Green Seeker based N at NDVI 0.8 (I_3N_3) recorded significantly higher total dry matter accumulation at 30, 60, 90 DAS and at harvest (11.63, 110.39, 253.01 and 302.69 g plant^{-1}, respectively). Drip irrigation scheduling at IW:CPE ratio of 1.0 and SPAD based N at threshold 50 (I_3N_4) was on par with this treatment (11.47, 109.62, 250.62 and 301.87 g plant^{-1}, respectively). Significantly lower total dry matter accumulation was recorded in I_1N_1 *i.e.*, irrigation scheduling at IW:CPE ratio of 0.6 and LCC based N at threshold 4 (8.86, 84.43, 201.96 and 237.60 g plant^{-1}, respectively). Similar trend was recorded in all the three seasons. Adequate supply of moisture and nitrogen at all the stages of crop growth was responsible for rapid growth in leaves, stem and cobs. Maintaining soil moisture around field capacity throughout the crop growth period was achieved by irrigation scheduled at IW:CPE ratio of 1.0. The improved dry matter production and partitioning resulted in better source to sink ratio. Availability of nitrogen for longer time due to more splits and lower leaching losses resulted in production of taller plants, more number of leaves and larger leaf area, increased photosynthetic activities lead to enhanced dry matter accumulation. Similar results were reported by Rajiv (2012) in maize and Prabhudeva and Nagaraju (2017) in rice.

Kernel and Stover Yield (q ha^{-1})

Kernel and stover yield in the pooled analysis (Table 4) showed that irrigation at IW:CPE ratio of 1.0 recorded significantly higher kernel and stover yield (100.85 and 138.08 q ha^{-1}, respectively) among the three levels. Nitrogen management through Green Seeker based N at NDVI 0.8 recorded significantly higher kernel and stover yield among the different practices (104.56 and 144.73 q ha^{-1}, respectively). Interaction effect of drip irrigation scheduled at IW:CPE ratio of 1.0 and Green Seeker based N at NDVI 0.8 (I_3N_6) was significantly higher with respect to kernel and stover yield (114.88 and 166.67 q ha^{-1}, respectively). This was on par with treatment I_3N_4 *i.e.,* irrigation scheduled at IW:CPE ratio of 1.0 and SPAD based N at threshold 50 (113.18 and 163.95 q ha^{-1}, respectively). Interaction between irrigation at IW:CPE ratio of 0.6 and LCC based N at threshold 4 (I_1N_1) recorded significantly lower kernel and

TABLE 4

Kernel and stover yield of maize as influenced by precision water and nitrogen management (pooled data of 3 seasons)

Treatment	Kernel yield (q ha^{-1})	Stover yield (q ha^{-1})
Irrigation levels (I)		
I_1	85.75	111.97
I_2	93.42	123.33
I_3	100.85	138.08
F test	*	*
S.Em.±	0.29	0.49
C.D. (p=0.05)	1.16	1.94
Nutrient management (N)		
N_1	79.88	102.82
N_2	94.63	125.30
N_3	87.17	112.64
N_4	100.44	138.18
N_5	90.89	119.77
N_6	104.56	144.73
N_7	95.78	127.77
F test	*	*
S.Em.±	0.52	0.87
C.D. (p=0.05)	1.60	2.67
Interaction (I×N)		
I_1N_1	68.05	86.89
I_1N_2	87.91	114.60
I_1N_3	83.13	106.38
I_1N_4	90.67	120.69
I_1N_5	86.34	111.54
I_1N_6	95.39	126.74
I_1N_7	88.77	116.94
I_2N_1	84.80	108.11
I_2N_2	93.39	123.36
I_2N_3	85.97	110.19
I_2N_4	97.48	129.88
I_2N_5	90.03	119.34
I_2N_6	103.43	140.78
I_2N_7	98.82	131.63
I_3N_1	86.78	113.47
I_3N_2	102.59	137.96
I_3N_3	92.42	121.34
I_3N_4	113.18	163.95
I_3N_5	96.31	128.44
I_3N_6	114.88	166.67
I_3N_7	99.76	134.73
F test	*	*
S.Em.±	0.54	0.86
C.D. (p=0.05)	1.73	2.79
Control	93.34	124.46

stover yield (68.05 and 86.89 q ha^{-1}, respectively). The same trend was followed in the three seasons. The higher kernel and stover yield could be attributed to improved growth and yield parameters, due to maintenance of optimum soil moisture condition throughout the crop growth period. In general, drip irrigation method has higher application efficiency and supplies water to root zone with a lower discharge rate not more than infiltration rate of soil (Ramah *et al.,* 2011). Drip irrigation and split application of nitrogen coinciding with the actual needs of crop, better translocation of photosynthates from source to sink, higher growth and yield attributing characters might have helped to realize maximum yield. Similar results were reported by Mallikarjuna Swamy (2015) in maize and Shivananda Goudra (2018) in rice.

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