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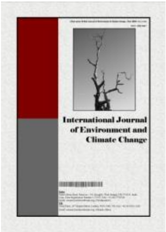

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Dry Matter Production and Nitrogen Uptake as Influenced by Irrigation and Nitrogen Levels in Maize

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Authors' contributions

This work was carried out in collaboration among all authors. Author BS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author BBN mentored and monitored the work. Authors AB, MUD and TLN managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted at Agro Climate Research Center, Agricultural Research Institute, P.J.T.S Agricultural University, Rajendranagar, Hyderabad, India during *rabi* 2019-20. The field experiment was laid out in a split plot design with three replications. The treatments comprising of three irrigation scheduling based on (Depletion of Available Soil Moisture) at 60% DASM, 40% DASM and 20% DASM as main plots and three nitrogen levels viz., 90, 180 and 240 kg N ha^{-1} as sub-plots. The experiment was laid out in split plot design. The results indicated that, among the different treatment combinations, the crop irrigation scheduled at 20 % DASM in conjunction with 240 kg N ha^{-1} accumulated significantly more dry matter of 34.2 g, 149.2 g, 233.7 g and 284.8 g plant^{-1}, at 6th leaf, silking, dough and physiological maturity stages, respectively. The nitrogen uptake was found to be more when the crop was irrigated at 20 % DASM in conjunction with 240 kg N ha^{-1} (67.1 g, 231.8 g, 294.7 g and 305.3 g plant^{-1}) at 6th leaf, silking, dough and physiological maturity stages, respectively.

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1. INTRODUCTION

Maize, a miracle crop, queen of cereals is known for the highest genetic yield potential among cereals. It is grown over a wide range of climatic conditions in semi-arid and sub tropics of Indian subcontinent. Worldwide production [1] was about 1.09 BMT. United States of America is the largest producer of maize contributes more than 35.87 % of the world maize harvest. The USA has the highest productivity (10.57 t ha^{-1}) which is double than the global average (4.92 t ha^{-1}). In India, maize is the third most important cereal crop after rice and wheat with an area of 9.2 m ha, production of 28.7 million tonnes and productivity of 3115 kg ha^{-1} in 2016-17 [2]. In Telangana maize is cultivated in an area of 0.71 m ha with a production of 3.52 m t and a productivity of 3057 kg ha^{-1} in 2015-16 [3]. Projected demand for maize production by 2050 in India is around 121MT, is 4 to 5 times of current production. India contributes merely 2.5 % in world maize production.

Agriculture sector is most affected by the onset of drought as it is highly reliable on the weather, climate, soil moisture etc. According to [4] drought may be broadly defined as a long-term average condition of the balance between precipitation and evapotranspiration in a particular area, which also depends on the timely onset of monsoon. Agricultural drought is nothing but the decline in the productivity of crops due to irregularities in rainfall in terms of its onset, distribution and withdrawal, extreme weather events like heavy rains, prolonged dry spell, heat and cold waves, floods etc. Drought is unpredictable as it can occur at any stage of the crop. Maize is a water demanding crop. It can yield higher when nutrients and water are not limiting factors. Maize crop growth is affected by different stresses viz., deficit irrigation, water, pest, weed, nutrients, etc., which reduce the productivity. Among the various inputs, water and nutrients are considered as the two key inputs making maximum contribution to maize productivity.

However, maize is very sensitive to water and other environmental stresses in the period one week before flowering to two weeks after flowering [5]. Further the water stress occurring at different crop developmental stages could potentially limit biomass accumulation and consequently reduce grain yield of the maize crop. [6] reported that, out of the three macro elements (NPK), application of nitrogen fertilizer brings out the higher yield increase in maize. Traditionally, maize has been widely cultivated as a rainfed crop during *kharif* season in the country. But recent studies have shown that it can also be successfully grown during *rabi* season in many parts of the country. The yield level of maize during *rabi* season is considerably higher than that of *kharif* due to its higher water and fertilizer use efficiencies [7]. Maize responds well to the management practices like irrigation and nitrogen [8]. To maximize the water and N use efficiencies, losses of water and nitrogen need to be minimized.

Depletion of available soil moisture (DASM) can be the sound basis of deciding time and amount of irrigation, but gravimetric measurements of soil-moisture contents required for this method are cumbersome. The soil profile moisture sensors can be used to make it more feasible. However, Nitrogen and Irrigation (DASM based) interaction effects on maize have not been studied adequately in India. Hence, the current field investigation was carried out to study the effect of variable irrigation rates and N-rates on dry-matter and nutrient uptake in maize hybrid Cargil 900M.

2. MATERIALS AND METHODS

Experiment was conducted during *rabi* 2019 at Agro Climate Research Centre, A.R.I., Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad. The site of experiment is located at N17°32", E78°39" and 542.3 MSL in the Southern Telangana Agro-Climatic Zone in Telangana State which falls under semi-arid tropics (SAT).

Cargil 900M is a modified single cross hybrid, suitable for irrigated conditions and was used for the present study. The experiment consisted of 27 combinations of 3 irrigation schedules (I_1: irrigated at 60 %Depletion of Available Soil Moisture, I_2: irrigated at 40 %DASM and I_3: irrigated at 20 %DASM) as main plots and Nitrogen levels (N_1: 90 kg N ha^{-1}, N_2: 180 kg N ha^{-1} and N_3: 240 kg N ha^{-1}) as sub plots. To determine dry matter production, two successive plants from the sampling row were cut close to the ground level at six leaf stage, silking, dough and physiological maturity. The plants were shade dried and then oven dried at 70°C till

constant weight is obtained. Nitrogen in the form of urea was applied as per treatments. Nitrogen content in the plant sample was estimated by the Micro kjeldahl method [9], From the results of the chemical analysis, nitrogen uptake was calculated using following formulae. The observed data on crops were subjected to analysis of variance (ANOVA) procedures as outlined for split plot design [10] to find out the treatment
difference. Wherever the treatment difference was found significant, the critical differences were worked out at 5 per cent probability level. When the treatment difference was non-significant is denoted as NS.

$$\text{N Uptake (kg ha}^{-1}\text{)} = \frac{\text{N concentration (\%)} \times \text{Dry matter production (kg ha}^{-1}\text{)}}{100}$$

3. RESULTS AND DISCUSSION

The effect of irrigation scheduling and nitrogen levels on dry matter accumulation were statistically analyzed and presented in table 1.

3.1 Dry Matter Accumulation

3.1.1 Irrigation scheduling

The total dry matter accumulation was influenced by irrigation scheduling at all crop phenological stages. The crop irrigation scheduled at 20% DASM (I_3) accumulated significantly higher dry matter with values of 31.1 g, 140.8 g, 226.3 g and 273.9 g plant^{-1} when compared to irrigation scheduled at 40% DASM (I_2) and 60 % DASM (I_1) at 6thleaf, silking, dough and physiological maturity stages, respectively. The dry matter recorded under I_1 (60 % DASM) remained significantly inferior to I_2 (40 % DASM) and I_3 (20 % DASM) throughout the crop growth stages.

Optimal moisture in root zone favored better uptake of nutrients, maintained good relative leaf water content, stomatal conductance, and better photosynthesis rate which favour better accumulation biomass Dry matter accumulation of maize tended to increase progressively with advance in the age of the crop. These favorable effects were reduced with increase in the moistures stress by furthering irrigation interval through scheduling at 40 % DASM and 60 % DASM. The total dry matter production of I_3 was higher by 6 % and 30 % over I_2 and I_1, respectively at physiological maturity stage. This could be mainly attributed to increased plant height and higher leaf area maintained throughout the crop period. These findings were in agreement with [11], [12] and [13].

3.1.2 Nitrogen levels

The effect of nitrogen dose on dry matter accumulation was significant at all crop stages. The crop supplied with 240 kg N ha^{-1} (N_3) accumulated significantly more dry matter at 6th leaf (33.2 g plant^{-1}), silking (133.6 g plant^{-1}) and physiological maturity stages (249.8 g plant^{-1}) when compared to its preceding lower dose of 90 kg (N_1) and 180 kg (N_2) N ha^{-1}. However, it was comparable with N_2 at dough stage of the crop growth. The dry matter accumulation of 26.8 g and 245.5 g plant^{-1} at lower dose of 90 kg N ha^{-1} (N_1) remained significantly inferior to N_2 (180 kg N ha^{-1}) and N_3 (240 kg N ha^{-1}) levels at 6th leaf and physiological maturity stages, respectively. However, it was comparable with N_2 and remained significantly inferior to N_3 at silking and dough stages of the crop growth. Similarly, [14] conducted experiment with four rates of nitrogen; N_1 (150 kg ha^{-1}), N_2 (200 kg ha^{-1}), N_3 (250 kg ha^{-1}) and N_4 (300 kg ha^{-1}) The maximum Total Dry Matter (1595 g m^{-2}) at final harvest was accumulated by N_4 (300 kg N ha^{-1}), followed by N_3 (250 kg N ha^{-1}) which gave 1542 g m^{-2}. The minimum value (1403 g m^{-2}) of TDM was noticed by N_1 (150 kg N ha^{-1}).

The lower dry matter accumulation at lower doses of nitrogen could be due to deficiency of N, which is the building block of protein, a constituent of chlorophyll, which is essential for carbohydrate formation that finally led to slower dynamics of dry matter accumulation [15].

3.1.3 Interaction effect

The interaction effect of irrigation scheduling and nitrogen levels on dry matter accumulation was significant throughout the crop growth stages. A significant response in biomass accumulation was observed with incremental dose of nitrogen from 90 kg N ha^{-1} to 180 kg N ha^{-1} and further to 240 kg N ha^{-1} irrespective of irrigation scheduling at 6th leaf stage and either at 20 % DASM (I_2) or 40 % DASM (I_3) at rest of the crop growth phases. In contrast to this, when crop irrigation scheduled at 60 % DASM in conjunction with 90 kg N ha^{-1} (I_1N_1) accumulated significantly more biomass of 125.1 g, 187.9 g and 222.3 g plant^{-1} and was decreased significantly with increase in the nitrogen does from 180 kg N ha^{-1} (I_1N_2) to

240 kg N ha^{-1} (I_1N_3) at silking, dough and physiological maturity stages, respectively. Among the different treatment combinations, the crop irrigation scheduled at 20 % DASM in conjunction with 240 kg N ha^{-1} (I_3N_3) accumulated significantly more biomass of 34.2 g, 149.2 g, 233.7 g and 284.8 g $plant^{-1}$, at 6^{th} leaf, silking, dough and physiological maturity stages, respectively.

Water and nitrogen inputs must closely matched for efficient utilization of each input. Under water stress treatment (I_1), decrease in biomass accumulation with increase in nitrogen dose was observed at silking, dough and physiological maturity stages. This could be due to mismatch between crop water need and supply from rhizosphere. Under I_1 scheduling, crop consumed more nitrogen initially in high N treated (I_1N_2 & I_1N_3) plots as a result of plentiful availability of water initially and luxuriant amount of nitrogen, put forth rapid biomass accumulation. As days progress, rapid depletion of soil moisture due to enhanced demand for water by the shoot led to early exhibition of wilting symptom by the crop which affected progress in biomass accumulation. Whereas in low nitrogen treated plots (I_1N_1), crop could stay green and healthy for longer period which might have allowed slow and steady accumulation of biomass as a result of slower depletion of moisture from root zone. [16] reported that, moderate nitrogen supply increases plant resistance to drought stress, while high or low nitrogen concentrations increase the sensitivity of maize to drought stress. [17] reported that, at silking stage of the maize a positive response in terms of biomass accumulation was observed up to 160 kg N ha^{-1} and further increase in nitrogen dose from 200 kg to 300 kg N ha^{-1}, the biomass was decreased when crop irrigation scheduled at 75 % DASM or grown under rainfed situation as compared to irrigation scheduling at 25 % DASM. [18] observed reduction in total shoot dry matter from 8.6 Mg to 8.5 Mg with increasing nitrogen dose from 80 to 160 kg N ha^{-1} was under drought stress during 1995 no markable change during 1996 and 1997 experiments.

The increase in dry matter accumulation with increase in nitrogen dose from 90 to 240 kg N ha^{-1} was recorded under crop irrigation scheduled at either 40 % or 20 % DASM at silking, dough and physiological maturity stages. This could be due to optimal moisture availability in rhizosphere which enable the plant to extract nitrogen from soil to meet the demand in the shoot portion. [19] observed that, owing to the increased frequency of irrigation and availability of adequate water throughout the growth period along with a higher dose of nitrogen application leading to increased nutrient uptake, higher photosynthetic rate and thereby the higher plant height, LAI and dry matter production.

3.2 Nitrogen Uptake (g $Plant^{-1}$)

The nitrogen uptake (g $plant^{-1}$) of maize crop was analyzed statistically and presented in table 2.

3.2.1 Irrigation scheduling

The influence of irrigation scheduling on nitrogen uptake was found significant at silking, dough and physiological maturity stages. Irrigation scheduled at 20 % DASM (I_3) recorded significantly higher nitrogen uptake of 205.9 g $plant^{-1}$, 265.6 g $plant^{-1}$ and 277.3 g $plant^{-1}$ at silking, dough and physiological maturity stages, respectively and was significantly superior over irrigation scheduled at 40 % DASM (I_2) and 60 % DASM (I_1). There was a significant reduction in uptake of nitrogen with increasing water stress through furthering interval between two successive irrigations from I_2 to I_1 level was observed at silking, dough and physiological maturity stages of the crop.

The higher accumulation of nitrogen content in above ground biomass under optimal irrigation scheduling (I_3) might be due to presence optimum soil moisture contentment throughout the crop growth period. These results are in accordance with the findings of [20] who reported that nutrient uptake in grain as well as stover were significantly greater under well- watered conditions (irrigation at 25 % DASM) compared to water-stressed conditions, similarly [21] also reported that higher irrigation level resulted in a significant increase in plant-nutrient uptake.

3.2.2 Nitrogen levels

Nitrogen uptake by plant was influenced by nitrogen levels applied to the crop. The crop nurtured with N_3 (240 kg N ha^{-1}) recorded higher nitrogen uptake of 63.2g $plant^{-1}$, 194.1 g $plant^{-1}$,235.9 g $plant^{-1}$ and 238.1 g $plant^{-1}$at six leaf, silking, dough and physiological maturity stages, respectively and which was significantly more over N_2 & N_1 levels from 6leaf to dough stage and on par with N_2at physiological maturity stage. The crop nurtured with lower dose of nitrogen (N_1) remained significantly inferior to N_2 and N_3 in terms of N uptake throughout the crop growth period.

Table 1. Drymatter accumulation (g plant^{-1}) of maize at different growth stages as influenced by irrigation scheduling and nitrogen levels

Crop stage	6th Leaf stage				Silking stage				Dough stage				Physiological maturity stage			
Treatments	**N_1**	**N_2**	**N_3**	**Mean**	**N_1**	**N_2**	**N_3**	**Mean**	**N_1**	**N_2**	**N_3**	**Mean**	**N_1**	**N_2**	**N_3**	**Mean**
I_1	25.4	27.9	32.1	28.5	125.1	118.0	113.2	118.8	187.9	184.0	169.9	180.6	222.3	211.9	198.6	211.0
I_2	27.2	30.1	33.5	30.2	130.7	132.4	138.4	133.8	205.7	211.4	218.8	212.0	251.0	260.0	266.0	259.0
I_3	27.8	31.3	34.2	31.1	133.8	139.3	149.2	140.8	219.7	225.3	233.7	226.3	263.1	274.0	284.8	273.9
Mean	26.8	29.8	33.2		129.9	129.9	133.6		204.4	206.9	207.5		245.5	248.6	249.8	
	S.Em$\pm$		CD (P=0.05)		S.Em$\pm$		CD (P=0.05)		S.Em$\pm$		CD (P=0.05)		S.Em$\pm$		CD (P=0.05)	
Main (I)	0.05		0.21		0.37		1.44		0.55		2.16		0.41		1.62	
Sub (N)	0.08		0.25		0.09		0.29		0.40		1.24		0.28		0.85	
Sub (N)at same main (I)	0.14		0.43		0.16		0.51		0.70		2.15		0.48		1.47	
Main (I) at same or different sub (N)	0.13		0.41		0.39		1.50		0.79		2.77		0.57		2.01	

Note: I_1: 60 % DASM; I_2:40 % DASM; I_3:20 % DASM; N_1: 90 kg N ha^{-1}; N_2: 180 kg N ha^{-1}; N_3: 240 kg N ha^{-1}; [DASM (Depletion of Available Soil Moisture)]

Table 2. Nitrogen uptake (g plant^{-1}) by maize during different phases as influenced by irrigation scheduling and nitrogen levels

Crop stage	6th Leaf stage				Silking stage				Dough stage				Physiological maturity stage			
Treatments	**N1**	**N2**	**N3**	**Mean**	**N1**	**N2**	**N3**	**Mean**	**N1**	**N2**	**N3**	**Mean**	**N1**	**N2**	**N3**	**Mean**
I1	53.6	45.5	57.5	52.2	170.5	157.4	145.3	157.7	188.6	177.0	154.2	173.3	199.2	183.6	145.1	176.0
I2	48.0	52.8	64.9	55.2	175.1	191.8	205.3	190.7	201.0	240.9	258.9	233.6	188.1	236.6	264.0	229.6
I3	54.5	61.0	67.1	60.9	175.3	210.5	231.8	205.9	243.0	259.2	294.7	265.6	238.3	288.3	305.3	277.3
Mean	52.0	53.1	63.2		173.6	186.5	194.1		210.9	225.7	235.9		208.5	236.2	238.1	
	S.Em+		CD (P=0.05)		S.Em+		CD (P=0.05)		S.Em+		CD (P=0.05)		S.Em+		CD (P=0.05)	
Main (I)	2.1		NS		2.9		11.9		2.7		10.9		4.3		17.3	
Sub (N)	2.3		7.1		1.5		4.6		2.3		7.1		2.7		8.5	
Sub (N)at same main (I)	3.6		NS		5.1		9.5		4.7		13.8		7.4		17.2	
Main (I) at same or different sub (N)	3.8		NS		3.6		13.4		4.2		14.7		5.8		20.9	

Note: I_1: 60 % DASM; I_2:40 % DASM; I_3:20 % DASM; N_1: 90 kg N ha^{-1}; N_2: 180 kg N ha^{-1}; N_3: 240 kg N ha^{-1}; [DASM (Depletion of Available Soil Moisture)]

Maize is more responsive and luxuriant consumer of nitrogen fertilizers among the cereal crops. Higher accumulation of nitrogen in above ground biomass with increasing nitrogen dose was well documented by several researchers ([20], [22] and [23]).

3.2.3 Interaction effect

The nitrogen uptake was significantly influenced by interaction of irrigation scheduling and nitrogen levels at silking, dough and physiological maturity stages. A significant response in nitrogen uptake was observed with incremental dose of nitrogen from 90 to 180 and further to 240 kg N ha^{-1} irrespective of irrigation scheduling at 6^{th} leaf stage and either at 20 % DASM (I_2) or 40 % DASM (I_3) at rest of the crop growth phases. In contrast to this, when crop irrigation was scheduled at 60 % DASM in conjunction with 90 kg N ha^{-1} (I_1N_1) accumulated significantly more nitrogen of 170.5 g, 188.6 g and 199.2 g $plant^{-1}$ and was decreased significantly with increase in the nitrogen dose from 180 kg N ha^{-1} (I_1N_2) to 240 kg N ha^{-1} (I_1N_3) at silking, dough and physiological maturity stages, respectively. Among the different treatment combinations, the crop irrigation scheduled at 20 % DASM in conjunction with 240 kg N ha^{-1}(I_3N_3) accumulated significantly more nitrogen of 67.1 g, 231.8 g, 294.7 g and 305.3 g $plant^{-1}$, at 6^{th} leaf, silking, dough and physiological maturity stages, respectively.

Under water stress conditions the crop accumulated more nitrogen at lower dose (I_1N_1) as compared to its successive higher levels (I_1N_2 & I_1N_3). Under deficit irrigation the crop nurture with higher N was exhibited moisture stress more early (I_1N_2 & I_1N_3) than low N fertilized plot (I_1N_1). Whereas the crop nurture with low N (I_1N_1) maintained healthy leaves more days and thus might have accumulated higher N in shoot portion as compared high N applied treatments. [24] ascertained that under deficit soil moisture in response to low N supply; maize develops a greater root-to-shoot ratio and undergoes a slower rate of phenological development, with a greater proportion of root biomass enhancing the absorption capacity of N. Under mild stress and optimum soil moisture situation, the crop responded positively in terms of accumulation of nitrogen in above ground biomass with increase in nitrogen dose from N_1 to N_3 levels. Similarly, [25] have reported that, the maize crop responds positively to increased nitrogen levels.

4. CONCLUSIONS

A significant response in dry matter accumulation was observed with incremental dose of nitrogen from 90 to 240 kg N ha^{-1} at 20 % DASM (I_3) or 40 % DASM (I_2). Whereas under 60 % DASM (I_1), the dry matter accumulation was decreased with increase in nitrogen dose at silking, dough and physiological maturity stages. A significant response in nitrogen uptake was observed with incremental dose of nitrogen from 90 to to 240 kg N ha^{-1} in conjunction either with 20 % DASM (I_2) or 40 % DASM (I_3). In contrast to this, when crop irrigation scheduled at 60% DASM in conjunction with 90 kg N ha^{-1} (I_1N_1) accumulated significantly more nitrogen of 170.5g, 188.6 g and 199.2 g $plant^{-1}$ and was decreased significantly with increasing the nitrogen dose from 180 kg N ha^{-1} (I_1N_2) to 240 kg N ha^{-1} (I_1N_3) at silking, dough and physiological maturity stages, respectively.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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