

# Optimization of Nitrogen Dose under Different Irrigation Levels in Maize (*Zea mays* L.) during Post Monsoon Season at Rajendranagar, Hyderabad, India

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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, Rajendranagar, Hyderabad, India during post monsoon season of 2019-20 with an objective to optimize the nitrogen dose under varied degrees of water stress environment. The experiment was laid out in split plot design replicated thrice with three irrigation scheduling (60%DASM, 40%DASM and 20%DASM) as main plots and three nitrogen levels (90, 180 and 240 kg of nitrogen ha<sup>-1</sup>) as sub plots. The results indicated that, at 20% DASM, with increasing nitrogen dose from 90 to 180 and further 240 kg ha<sup>-1</sup>, the plant height and biomass increased significantly. Whereas a significant response in terms of the LAI, number of grains row<sup>-1</sup>, grain and stover yields and nitrogen uptake by plant was observed up to 180 kg N ha<sup>-1</sup>. Under deficit soil moisture condition (60% DASM) the maximum plant height (141.5cm), LAI (2.93), biomass (222.3 g plant<sup>-1</sup>), number of grains row<sup>-1</sup> (35.3) test weight (24.1 g),

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grain yield ( $4930 \text{ kg ha}^{-1}$ ), stover yields ( $7996 \text{ kg ha}^{-1}$ ) and nitrogen uptake by plant was recorded with low nitrogen dose of  $90 \text{ kg N ha}^{-1}$  and all these parameters were decreased with increasing nitrogen dose. The concentration of nitrogen in leaf, stem and grain was more under deficit soil moisture condition (60% DASM) and was decreased with relieving plant water stress by scheduling irrigation at 40% DASM and 20% DASM. This investigation evidences the need of nitrogen optimization under varied degree of moisture availability. Under deficit irrigated situation, lower dose of nitrogen is sufficient for optimum yield. Whereas under sufficient water availability, the beneficial effect increased nitrogen levels can be exploited for higher grain yield in maize.

*Keywords: Maize; water and nitrogen stress; nitrogen uptake.*

## 1. INTRODUCTION

Maize is known for its high genetic potential for yield 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 ( $10.57 \text{ t ha}^{-1}$ ) which is double than the global average ( $4.92 \text{ t ha}^{-1}$ ). In India, maize is the third most important cereal crop after rice and wheat with an area of 9.2 million ha, with total production of 28.7 million tonnes and productivity of  $3115 \text{ kg ha}^{-1}$  in 2016-17 [2]. In Telangana state maize is cultivated in an area of 0.71 m ha with a production of 3.52 m t and a productivity of  $3057 \text{ kg ha}^{-1}$  in 2015-16 [3].

Maize is a water demanding crop. Water and nutrients are the two basic inputs. It can yield higher when nutrients and water are not limiting factors. Maize crop growth is affected by different stresses viz., deficit irrigation, 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, particularly one week before flowering to two weeks after flowering [4]. Further the water stress occurring at different crop developmental stages could potentially limit biomass accumulation and consequently reduce grain yield of the maize crop. Out of the three macro elements (NPK), application of nitrogen fertilizer brings out yield increment in maize [5].

Nitrogen is the yield-limiting factor in agricultural production systems, as it supplies adequate mineral nitrogen for normal growth of plants. Maize being important cereal requires huge quantities of nitrogen due to its high yield

potential. Time-specific nitrogen applications are aimed to provide maize with nutrients when needed, in other case its deficiency can cause inevitable yield-loss. The interactive effects of water and nitrogen shows impact on morphological, physiological and yield attributes of maize. The increase in irrigation level from 0.6 IW/CPE ratio to 1.2 IW/CPE coupled with increase in nitrogen level from  $75 \text{ kg ha}^{-1}$  to  $300 \text{ kg ha}^{-1}$  significantly increased the total dry matter per plant [6]. Similarly [7] stated that, owing to the increased frequency of irrigation 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. Whereas, when maize grown under conditions of limited water supply requires less nitrogen to achieve the maximum grain yield than that required with well water supply [8]. Indiscriminate use of nitrogen fertilizers without considering soil moisture conditions may not help in yield maximization in maize. Therefore optimization of nitrogen dose based on availability of soil moisture and crop response is need of hour. Hence this investigation was designed to study the yield response of maize crop under differential water and nitrogen levels to optimize the nitrogen use based on availability of water for irrigation in maize crop.

## 2. MATERIALS AND METHODS

The experiment was conducted in the research farm of Agro Climatic Research Centre, Agricultural Research Institute, P.J.T.S Agricultural University, Rajendranagar, Hyderabad situated at  $17^{\circ}32'N$  latitude,  $78^{\circ}39'E$  longitude and at an altitude of 542.3 m above MSL in the Southern Telangana Agro- Climatic Zone in Telangana State.

The soil is sandy loam in texture and neutral in reaction with a pH of 7.45. The soil was low in organic carbon (0.26%) and available nitrogen

(149 kg ha<sup>-1</sup>) and high in available phosphorus (35.0 kg ha<sup>-1</sup>) and potassium (394 kg ha<sup>-1</sup>). The experiment was laid out in split-plot design replicated thrice. The treatments comprised of three irrigation scheduling (60%DASM, 40%DASM and 20%DASM) assigned to main plots and three nitrogen levels (90, 180 and 240 kg of nitrogen ha<sup>-1</sup>) assigned to sub plots. The crop was sown on 16<sup>th</sup> October 2019 and harvested at harvesting maturity. The nitrogen fertilizer levels were applied in 3 equal splits each at basal (in the form of DAP & urea), 6 leaf stage (in the form urea) and silking stage (in the form of urea) of the crop. The recommended entire dose of phosphorus at 60 kg ha<sup>-1</sup>(P<sub>2</sub>O<sub>5</sub>) in the form of Diammonium Phosphate applied as basal and 50 kg potassium oxide (K<sub>2</sub>O) ha<sup>-1</sup> in the form of muriate of potash was applied in 2 equal splits each at basal and silking stage. The field was laid out in ridges and furrows at 60 cm apart. The ridge height was around 20 cm in North –South direction. The seeds were sown at 1/4<sup>th</sup> height from the ground towards eastern side of the ridge. The plant to plant spacing within the row was 20cm. All the treatments were uniformly irrigated initially up to 15 days after sowing to ensure the better establishment of the crop. The standard management practices as recommended by the P.J.T.S.A.U for the state of Telangana were followed. Plant height, Leaf area and biomass measured at physiological maturity stage, yield attributes (Number of grain rows ear<sup>-1</sup>, Number of grains row<sup>-1</sup>, Test weight), grain yield, stover yield and harvest index were recorded and statistically analyzed. Nitrogen partitioning in above ground parts (stem, leaf, grain) are analyzed and presented. The Nitrogen content in the plant was estimated by the Microkjeldah method (Piper, 1966) [9]. The statistical analysis was done in Microsoft excel by using analysis of variance method under split plot design.

### 3. RESULTS AND DISCUSSION

#### 3.1 Plant Height (cm)

The plant height of maize was influenced by irrigation scheduling and nitrogen levels (Table1). The crop grown under optimum soil moisture condition by scheduling irrigation at 20% DASM (Depletion of Available Soil Moisture) recorded taller plants (190.8cm) and it decreased with increasing water stress by scheduling irrigation at 40% DASM (170.6cm) and 60% DASM (134.6cm). Optimal moisture in root zone might have favored better uptake of

nutrients, photosynthesis rate, accumulation of biomass resulting in increase in plant height. These favorable effects were reduced with increasing the moistures stress by furthering irrigation interval scheduled at 40% DASM and 60% DASM. The increase in plant height with reduction in water stress was also reported by [10]. The crop nurtured with 180 kg N ha<sup>-1</sup> recorded significantly more taller plant height (166.3cm) when compared its preceding lower dose of 90 kg N ha<sup>-1</sup> (163.6), However, it was comparable with its succeeding higher dose of 240 kg N ha<sup>-1</sup> (166.1cm). Similar results were also reported by [11] and [12].

The interaction effect of irrigation scheduling and nitrogen levels on plant height was significant. At 20% DASM (I<sub>3</sub>), the plant height was increased significantly from 182.9 cm to 188.9 cm and further to 200.6 cm with increasing nitrogen dose from 90 kg N ha<sup>-1</sup> to 180 N ha<sup>-1</sup> and further to 240 kg N ha<sup>-1</sup>, respectively. In contrast to this, when crop subjected to severe water stress under 60% DASM) the plant height was decreased from 141.5 cm to 138.4 cm and further to 124.1cm with increasing nitrogen dose from 90 kg N ha<sup>-1</sup> to 180 N ha<sup>-1</sup> and further to 240 kg N ha<sup>-1</sup>, respectively. Among the different treatment combinations, the crop irrigation scheduled at 20% DASM in conjunction with 240 kg N ha<sup>-1</sup> recorded significantly more plant height of 200.6 cm. The crop response to added nitrogen depends on soil moisture status. Under adequate moisture supply situation, the plant height increased significantly with increasing nitrogen dose from 90 to 240 kg N ha<sup>-1</sup>. As degree of water stress increases the response to nitrogen at higher dose was nullified and negative impact was observed. These results are in line with the findings of [13] who reported that, under deficit irrigated condition the maize crop responded positively up 120 kg N ha<sup>-1</sup> and further increase in nitrogen dose from 120 kg to 160 kg, negative results were observed.

#### 3.2 Leaf Area Index (LAI)

The Leaf Area Index of maize was influenced by irrigation scheduling, nitrogen levels and their interaction effect (Table 1). The crop irrigation scheduled at 20% DASM registered significantly higher LAI (4.47) when compared to 40% DASM (3.78) and 60% DASM (2.83) treatments. Similar results were also reported by [14,15] and [16]. A significant increase in LAI of maize was recorded from 90 kg N ha<sup>-1</sup>(3.56) to 180 kg N ha<sup>-1</sup> (3.74). Further increase in nitrogen dose to 240 kg N ha<sup>-1</sup>

<sup>1</sup> the LAI (3.79) was not increased significantly. Differential response of maize crop in terms of LAI to incremental dose of N was reported by several researchers. A significant increase in LAI of maize up to 200% RDN and 225 kg N ha<sup>-1</sup> were reported by [17] and [18], respectively.

The interaction effect of water and nitrogen levels on LAI was significant. The crop irrigation scheduled at 20% DASM in conjunction with 240 kg N ha<sup>-1</sup> (4.62) or with 180 kg N ha<sup>-1</sup> (4.57) were found at par in terms of LAI and significantly superior over lower nitrogen dose of 90 kg N ha<sup>-1</sup>(4.23). Similar results were also observed at 40% DASM. In contrast to this, there was a reduction in LAI with increasing nitrogen dose from 90 kg N ha<sup>-1</sup> to 240 kg N ha<sup>-1</sup> was recorded with the crop irrigation scheduled at 60% DASM. Owing to increased frequency of irrigation, availability of adequate water throughout the growth period along with incremental dose of nitrogen application leading to increased nutrient uptake, higher photosynthetic rate and thereby the higher plant height, LAI and thus dry matter production [7]. The decrease in LAI with increase in N levels under moisture stress situation attributed to crop subjected to stress more early under high fertilized nitrogen situation when compared to lower dose. The reduction in LAI at higher N levels under drought stress situation was also reported by [19].

### 3.3 Biomass (g plant<sup>-1</sup>)

The plant biomass was influenced by irrigation scheduling and nitrogen levels (Table 1). The crop irrigation scheduled at 20% DASM accumulated more biomass (273.9gplant<sup>-1</sup>) and was decreased with increasing water stress by scheduling irrigation at 40% DASM (259.0 g plant<sup>-1</sup>) and 60% DASM (211.0 g plant<sup>-1</sup>). The total dry matter production under 20% DASM was higher by 6% and 30% over 40% DASM and 60% DASM, respectively at physiological maturity stage. This could be mainly attributed to increased plant height and higher leaf area maintained throughout the crop period. These results are in line with the findings of [20], [21] and [16]. The effect of nitrogen levels on biomass accumulation was significant. The crop supplied with 240 kg N ha<sup>-1</sup> accumulated significantly more biomass (249.8 g plant<sup>-1</sup>) when compared to its preceding lower dose of 90 kg (245.5 g plant<sup>-1</sup>) and 180 kg (248.6 g plant<sup>-1</sup>) N ha<sup>-1</sup>. The lower biomass 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 [22].

The interaction effect of irrigation scheduling and nitrogen levels on biomass accumulation was significant. A significant response in biomass accumulation was observed with every incremental in nitrogen dose from 90 kg N ha<sup>-1</sup> (263.1 g plant<sup>-1</sup>) to 180 kg N ha<sup>-1</sup> (274.01 g plant<sup>-1</sup>) and further increased to 240 kg N ha<sup>-1</sup> (284.81 g plant<sup>-1</sup>) under 20% DASM. Similar trend was also observed under 40% DASM. In contrast to this, when crop irrigation scheduled at 60% DASM in conjunction with 90 kg N ha<sup>-1</sup> the crop accumulated 222.3 g plant<sup>-1</sup>. However it was decreased significantly with increasing the nitrogen does from 180 kg N ha<sup>-1</sup> (211.9 g plant<sup>-1</sup>) to 240 kg N ha<sup>-1</sup> (198.6 g plant<sup>-1</sup>). Water and nitrogen inputs must closely matched for efficient utilization of each input. Under water stress treatment (I<sub>1</sub>), decrease in biomass accumulation with increasing nitrogen dose was observed throughout the crop growth period. This could be due to miss match between crop water need and supply from rhizosphere. Under deficit irrigation (60% DASM) the crop consumed more nitrogen initially in high N treated (240 kg N ha<sup>-1</sup>) 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 (90 kg N ha<sup>-1</sup>), the crop could stay green and healthy for longer period which might have allowed slow and steady accumulation of biomass and slower depletion of moisture from root zone. [23] 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. [24] reported that, at silking stage of the maize a positive response in terms of biomass accumulation was observed up to 160 kg N ha<sup>-1</sup> and further increase in nitrogen dose from 200 kg to 300 kg N ha<sup>-1</sup>, the biomass was decreased when crop irrigation scheduled at 75% DASM or grown under rainfed situation as compared to irrigation scheduling at 25% DASM. A reduction in total shoot drymatter from 8.6 Mg to 8.5 Mg with increasing nitrogen dose from 80 to 160 kg N ha<sup>-1</sup> was under drought stress in 1995 no mark able change in 1996 and 1997 experiments [25].

### 3.4 Yield Attributes

#### 3.4.1 Number of grain rows ear<sup>-1</sup>

The influence of irrigation scheduling and nitrogen levels on number of grain rows ear<sup>-1</sup> was presented in Table 2. The more number of grain rows ear<sup>-1</sup> (16.6) was recorded with irrigation scheduling at 20% DASM. However, it was comparable with 40% DASM (16.2) and significantly superior over 60% DASM (15.6). The more number of grain rows ear<sup>-1</sup> in optimum irrigation scheduled plot (20% DASM) might be due to favorable soil moisture conditions throughout the crop growth period which leads to more biomass accumulation, which in turn favored a better partitioning of assimilates from source to sink. Similar findings were also reported by [26]. The grain rows ear<sup>-1</sup> was not influenced significantly with nitrogen levels and their interaction with irrigation scheduling.

#### 3.4.2 Number of grains row<sup>-1</sup>

The influence of irrigation scheduling and nitrogen levels on number of grains row<sup>-1</sup> was presented in (Table 2). Significantly more number of grains row<sup>-1</sup> (37.6) was recorded with irrigation scheduled at 20% DASM, which was comparable with 40% DASM (36.0) but significantly superior over 60% DASM (32.6) treatment. The more number of grains in a row with crop irrigation scheduled at 20% DASM might be due to favourable soil moisture conditions in root zone before pollination and continuation of the same even post anthesis period which is crucial for deciding number of grains in a row. The reduced number of grains in a row with increasing interval between two successive irrigations (40% DASM and 60% DASM) might be due to failure of fertilization as a result of moisture stress the crop which was experienced during this sensitive stage. These results are in agreement with the findings of [26] who reported that applying irrigation at 25% DASM resulted in the highest number of grains/row/ear when compared to irrigation scheduled either at 75% DASM or grown under rainfed situation. The nitrogen levels did not exhibit any significant influence on grains row<sup>-1</sup>.

The interaction effect of irrigation scheduling and nitrogen levels on number of grains row<sup>-1</sup> was significant. With increasing dose of nitrogen from 90 kg N ha<sup>-1</sup> to 180 kg N ha<sup>-1</sup> and further to 240 kg N ha<sup>-1</sup>, the number of grains in a row was increased from 34.4 to 37.6 and further to 40.7,

respectively when crop irrigation scheduled at 20% DASM (I<sub>3</sub>). In contrast to this under deficit irrigation (60% DASM), with increasing dose of nitrogen from 90 kg N ha<sup>-1</sup> to 180 kg N ha<sup>-1</sup> and further to 240 kg N ha<sup>-1</sup>, the number of grains in a row was decreased from 35.3 to 33.5 and further to reduced to 29.1, respectively. Similar results were also reported by [25].

#### 3.4.3 100 seed weight (g)

The 100 seed weight of maize was influenced by irrigation scheduling (Table 2). The crop irrigation scheduled at 20% DASM recorded more 100 seed weight of 27.3 g which was on par with 40% DASM (25.6 g) and significantly superior over 60% DASM (23.2 g). The crop irrigated at 20% DASM facilitated with optimum soil moisture in root zone throughout the crop growth period, favoured partitioning of accumulated above ground biomass into grain. Sub optimal soil moisture as a result of furthering interval between two successive irrigations might have affected the translocation of biomass from shoot to grain portion. These results are in conformity with the findings of [27] and [28].

#### 3.4.4 Grain yield

The grain yield of maize was influenced by irrigation scheduling and nitrogen levels (Table 3). The crop irrigation scheduled at 20% DASM recorded higher grain yield (9080 kg ha<sup>-1</sup>) and was decreased as increasing moisture stress through increasing interval between two successive irrigations scheduled at 40% DASM (8105 kg ha<sup>-1</sup>) and 60% DASM (4609 kg ha<sup>-1</sup>). These results are in conformation with the findings of [26] who reported that, irrigation scheduling at 25% DASM (4.6 t/ha) resulted in 26.7% and 15.4%, higher grain yield over irrigation scheduling at 75% DASM and rainfed crop respectively. The grain yield of maize increased with increasing nitrogen levels from 90 kg N ha<sup>-1</sup> to 240 kg N ha<sup>-1</sup>. The crop nurtured with 240 kg N ha<sup>-1</sup> recorded more grain yield of 7647 kg ha<sup>-1</sup> which was on par with 180 kg N ha<sup>-1</sup> (7635 kg ha<sup>-1</sup>) and significantly superior over 90 kg N ha<sup>-1</sup> (6511 kg ha<sup>-1</sup>). Similar results were also reported by [29].

The interaction effect of irrigation scheduling and nitrogen levels on grain yield of maize was significant. At 20% DASM with increasing nitrogen dose from 90 kg N ha<sup>-1</sup> to 180 N ha<sup>-1</sup> and further to 240 kg N ha<sup>-1</sup>, the grain yield was increased significantly from 7044 kg ha<sup>-1</sup> to 9982

kg ha<sup>-1</sup> and further to 10214 kg ha<sup>-1</sup>, respectively. Similar trend was also observed at 40% DAMS. Efficient utilization of nitrogen is depends on moisture conditions in rhizosphere. Owing 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 there by the higher plant height, LAI, dry matter production and grain yield [7]. In contrast to this, when crop subjected to severe water stress by scheduling irrigation at 60% DAMS (I<sub>1</sub>) the grain yield was decreased from 4930 kg ha<sup>-1</sup> to 4593 kg ha<sup>-1</sup> and further to 4302 kg ha<sup>-1</sup> with increasing nitrogen dose from 90 kg N ha<sup>-1</sup> to 180 N ha<sup>-1</sup> and further to 240 kg N ha<sup>-1</sup>, respectively. The reduction in grain yield with increase in nitrogen dose under moisture stress condition might be due to miss match between crop water need and supply from rhizosphere reflected in terms of reduced plant height, LAI, biomass accumulation number of grains ear<sup>-1</sup> and thus grain yield. These results are in conformation with the finding of [13] who reported that, least reduction in grain yield of maize per 100 mm of deficit irrigation occurred at the zero N treatment and greatest reduction at 160 kg applied N. Moderate nitrogen supply increases plant resistance to drought stress, while high or low nitrogen concentrations increase the sensitivity of maize to drought stress [23].

### 3.4.5 Stover yield

The stover yield of maize influenced by irrigation scheduling and nitrogen levels (Table 3).The crop irrigation scheduled at 20% DAMS registered higher Stover yield (11493 kg ha<sup>-1</sup>) and was decreased as increasing interval between irrigations scheduled at 40% DAMS (9624 kg ha<sup>-1</sup>) and 60% DAMS (7381 kg ha<sup>-1</sup>).These results are in line with the findings of [27]. A significant improvement in stover yield from 8698 kg ha<sup>-1</sup> to 9776 kg ha<sup>-1</sup> and further to 10024 kg ha<sup>-1</sup> was recorded with increasing nitrogen dose from 90 kg N ha<sup>-1</sup> to 180 kg N ha<sup>-1</sup> and further to 240 kg N ha<sup>-1</sup>, respectively. The increase in dry matter accumulation with higher level of nitrogen was due to better crop growth, which also gave maximum plant height, LAI and ultimately produced more biological yield. The above result was in conformity with the findings of [30].

Among the different treatment combinations, the crop irrigation scheduled at 20% DAMS in

conjunction with 240 kg N ha<sup>-1</sup> (I<sub>3</sub>N<sub>3</sub>) recorded more stover yield (12611 kg ha<sup>-1</sup>). However, it was comparable with I<sub>3</sub>N<sub>2</sub> (12550 kg ha<sup>-1</sup>) and significantly superior over rest of the treatment combinations. The increase in stover yield might be due to combined effect of irrigation and nitrogen levels which increased the availability of nutrients. Similar results were obtained by [26].

### 3.5 Harvest Index

The harvest index (%) of maize was influenced by irrigation scheduling (Table 3). The crop irrigation scheduled at 40% DAMS recorded highest harvest index of 0.46 which was comparable with 40% DAMS (0.44) and significantly more over 60% DAMS (0.39). Similar results were obtained by [31]. The nitrogen levels and their interaction with irrigation scheduling were not significant on Harvest Index of maize.

### 3.6 Nitrogen Uptake (g plant<sup>-1</sup>)

The effect of irrigation scheduling and nitrogen levels on nitrogen uptake (g plant<sup>-1</sup>) of maize crop was presented in Table 4.The crop irrigation scheduled at 20% DAMS recorded more nitrogen uptake (277.3 g plant<sup>-1</sup>) by the plants and was decreased with increasing water stress when irrigation scheduled at 40% DAMS (229.6 g plant<sup>-1</sup>) and 60% DAMS (176.0 g plant<sup>-1</sup>). The higher irrigation level resulted in a significant increase in plant-nutrient uptake [32]. Among the nitrogen levels, the crop nurtured with 240 kg N ha<sup>-1</sup> recorded more nitrogen uptake of (238.1 g plant<sup>-1</sup>) however it was on par with 180 kg N ha<sup>-1</sup> (236.2 g plant<sup>-1</sup>) and significantly more over 90 kg N ha<sup>-1</sup> (208.5 g plant<sup>-1</sup>). Higher accumulation of nitrogen in above ground biomass with increasing nitrogen dose was also documented by [26] and [33].

The interaction effect of irrigation scheduling and nitrogen levels on N accumulation was significant. At 20% DAMS with increasing nitrogen dose from 90 kg N ha<sup>-1</sup> to 240 kg N ha<sup>-1</sup> the accumulated nitrogen in above ground biomass was increased from 238.3 g plant<sup>-1</sup> to 305.3 g plant<sup>-1</sup>, respectively. This trend was also observed under moderate water stress situation (40% DAMS). Whereas, under deficit irrigation (60% DAMS) conditions the crop accumulated more nitrogen at lower dose of 90 kg N ha<sup>-1</sup> (199.2 g plant<sup>-1</sup>) as compared to its successive higher levels of 180 kg N ha<sup>-1</sup> (199.2 g plant<sup>-1</sup>)

**Table 1. Mean plant height (cm), leaf area index and biomass (g plant<sup>-1</sup>) of maize at physiological maturity stage as influenced by irrigation scheduling and nitrogen levels**

Yield attributes Treatments	Plant height				Leaf Area Index (LAI)				Biomass (g plant <sup>-1</sup> )			
	60 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	Mean	60 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	Mean	60 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	Mean
60% DASM	141.5	138.4	124.1	134.6	2.93	2.84	2.73	2.83	222.3	211.9	198.6	211.0
40% DASM	166.5	171.7	173.7	170.6	3.52	3.82	4.01	3.78	251.0	260.0	266.0	259.0
20% DASM	182.9	188.9	200.6	190.8	4.23	4.57	4.62	4.47	263.1	274.0	284.8	273.9
Mean	163.6	166.3	166.1	165.4	3.56	3.74	3.79		245.5	248.6	249.8	
	S.Em±		CD (P=0.05)		S.Em±		CD (P=0.05)		S.Em±		CD (P=0.05)	
Main (I)	1.4		5.5		0.06		0.25		0.41		1.62	
Sub (N)	0.7		2.1		0.05		0.15		0.28		0.85	
Sub (N)at same main(I)	1.2		3.6		0.08		0.26		0.48		1.47	
Main (I) at same or different sub (N)	1.7		6.2		0.09		0.33		0.57		2.01	

Note: DASM (Depletion of Available Soil Moisture)

**Table 2. Yield attributes of maize as influenced by irrigation scheduling and nitrogen levels**

Yield attributes Treatments	Number of grain rows ear <sup>-1</sup>				Number of grains row <sup>-1</sup>				Test weight (g)			
	60 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	Mean	60 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	Mean	60 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	Mean
60% DASM	15.6	15.4	15.8	15.6	35.3	33.5	29.1	32.6	24.1	23.3	22.1	23.2
40% DASM	16.1	16.6	16.0	16.2	33.9	35.5	38.7	36.0	25.1	24.6	27.1	25.6
20% DASM	16.5	16.5	16.8	16.6	34.4	37.6	40.7	37.6	26.2	27.2	28.4	27.3
Mean	16.1	16.2	16.2	16.1	34.5	35.5	36.2	35.4	25.1	25.0	25.8	25.4
	S.Em±		CD (P=0.05)		S.Em±		CD (P=0.05)		S.Em±		CD (P=0.05)	
Main (I)	0.1		0.5		0.70		2.74		0.42		1.67	
Sub (N)	0.2		NS		0.78		NS		0.47		NS	
Sub (N)at same main(I)	0.3		NS		1.36		4.18		0.81		NS	
Main (I) at same or different sub(N)	0.3		NS		1.31		4.35		0.79		NS	

Note: DASM (Depletion of Available Soil Moisture)

**Table 3. Grain yield, Stover yield and Harvest Index of maize as influenced by irrigation scheduling and nitrogen levels**

Yield attributes Treatments	Grain yield (kg ha <sup>-1</sup> )				Stover yield (kg ha <sup>-1</sup> )				Harvest Index			
	60 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	Mean	60 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	Mean	60 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	Mean
60% DASM	4930	4593	4302	4609	7996	6897	7250	7381	0.38	0.40	0.38	0.39
40% DASM	7560	8330	8425	8105	8781	9880	10210	9624	0.46	0.46	0.45	0.46
20% DASM	7044	9982	10214	9080	9317	12550	12611	11493	0.43	0.44	0.45	0.44
Mean	6511	7635	7647	7265	8698	9776	10024	9499	0.43	0.43	0.43	0.43
	S.Em <sub>+</sub>		CD (P=0.05)		S.Em <sub>+</sub>		CD (P=0.05)		S.Em <sub>+</sub>		CD (P=0.05)	
Main (I)	234		920		399		1566		0.01		0.03	
Sub (N)	110		338		295		910		0.01		NS	
Sub (N)at same main(I)	190		586		511		1576		0.01		NS	
Main (I) at same or different sub (N)	281		1031		577		2012		0.01		NS	

Note: DASM (Depletion of Available Soil Moisture)

**Table 4. Nitrogen uptake (g plant<sup>-1</sup>) by maize at physiological maturity stage as influenced by irrigation scheduling and nitrogen levels**

Treatments	Nitrogen uptake			
	60 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	Mean
60% DASM	199.2	183.6	145.1	176.0
40% DASM	188.1	236.6	264.0	229.6
20% DASM	238.3	288.3	305.3	277.3
Mean	208.5	236.2	238.1	
	S.Em <sub>+</sub>		CD (P=0.05)	
Main (I)	4.3		17.3	
Sub (N)	2.7		8.5	
Sub (N)at same main (I)	7.4		17.2	
Main (I) at same or different sub (N)	5.8		20.9	

Note: DASM (Depletion of Available Soil Moisture)



**Table 5. Nitrogen partitioning in different parts of above ground biomass of maize as influenced by irrigation scheduling and nitrogen levels at physiological maturity**

Treatments	Yield attributes											
	Stem nitrogen (%)				Leaf nitrogen (%)				Grain nitrogen (%)			
	60 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	Mean	60 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	Mean	60 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	Mean
60% DASM	0.73	0.88	0.92	0.84	0.67	0.78	0.88	0.78	1.40	1.65	1.68	1.58
40% DASM	0.49	0.62	0.68	0.60	0.49	0.63	0.86	0.66	1.23	1.53	1.68	1.48
20% DASM	0.56	0.61	0.66	0.61	0.51	0.61	0.75	0.62	1.26	1.45	1.49	1.40
Mean	0.59	0.70	0.75	0.68	0.55	0.67	0.83	0.69	1.29	1.54	1.61	1.48
	S.Em±		CD (P=0.05)		S.Em±		CD (P=0.05)		S.Em±		CD (P=0.05)	
Main (I)	0.03		0.11		0.04		NS		0.02		0.11	
Sub (N)	0.03		0.10		0.02		0.07		0.020		0.06	
Sub (N)at same main(I)	0.06		NS		0.04		NS		0.03		NS	
Main (I) at same or different sub (N)	0.05		NS		0.05		NS		0.04		NS	

Note: DASM (Depletion of Available Soil Moisture)

and 240 kg N ha<sup>-1</sup>(145.1 g plant<sup>-1</sup>). [34] 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 increasing nitrogen dose from N<sub>1</sub> to N<sub>3</sub> levels. Several researchers have reported that, the maize crop responds positively to increased nitrogen levels [6] and [35].

### 3.7 Nitrogen Partitioning (%) in above Ground Plant Parts at Harvest

The effect of irrigation scheduling and nitrogen levels on nitrogen concentration in above ground plant parts (stem, leaf and grain) were analyzed at harvest and presented in Table 5. The crop grown under severe water stress treatment scheduled at 60% DASM recorded 0.84%, 0.78 % and 1.58% nitrogen in stem, leaf and grain, respectively which was decreased with increasing frequency between two successive irrigations scheduled at 40% DASM and 20% DASM. The increase in biomass with increasing frequency between two successive irrigations resulted in dilution effect of mineral N concentration in different plant parts. Increased biomass accumulation is accompanied by decreased shoot mineral concentration, has been defined as a dilution effect (Jarrell and Beverly1981). The optimum plant N% decreased unmistakably according to the increase in crop biomass [36]. The influence of nitrogen levels on concentration of nitrogen (%) in different plant parts was significant. The nitrogen concentration in stem, leaf and grain increased with increasing nitrogen dose. The crop nurtured with 240 kg N ha<sup>-1</sup> recorded more N concentration (%) in stem (0.75%), leaf (0.83%) and grain (1.61%) and were decreased with reducing nitrogen dose from 180 kg N ha<sup>-1</sup> to 90 kg N ha<sup>-1</sup> in stem, leaf and grain. The enhanced N accumulation with increased nitrogen dose was reported by [37] and [38]. The interaction effect of irrigation scheduling and nitrogen levels on nitrogen partitioning was not significant.

## 4. CONCLUSION

Water and nitrogen are the key elements in deciding growth and yield of maize. The present investigation conferred the options and decisions

to be taken based on availability of water and optimization of nitrogen fertilizers. The maize crop can yield higher when nutrients and water are not limiting factors. Under optimum soil moisture conditions, the beneficial effects of incremental nitrogen dose can be harnessed for higher gain yield. The response of crop to incremental nitrogen dose differed with degree of moisture stress. Under deficit irrigation, the maize crop responds only at lower levels of nitrogen. Therefore, nitrogen dose can be optimized based on availability of water for irrigation.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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