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Effect of irrigation scheduling based on depletion of available soil moisture and nitrogen levels on biomass partitioning and nitrogen concentration in maize (*Zea mays* L.)

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Abstract

Maize (*Zea mays* L.), known as the “queen of cereals,” possesses high yield potential and plays a vital role in global as well as Indian agriculture. However, its productivity in India remains relatively low due to limitations in water and nutrient management. Efficient irrigation scheduling and nitrogen management are therefore essential for improving crop productivity and resource-use efficiency under variable climatic conditions. The present study was conducted to evaluate the influence of irrigation scheduling based on depletion of available soil moisture (DASM) and nitrogen levels on biomass partitioning and nitrogen concentration in above-ground plant parts of maize at harvest. The experiment comprised three irrigation schedules, namely irrigation at 60% DASM (I_1), 40% DASM (I_2), and 20% DASM (I_3), along with three nitrogen levels of 90, 180, and 240 kg N ha⁻¹. The results indicated that irrigation scheduling significantly influenced biomass accumulation in the cob, with increased intervals between irrigations resulting in reduced biomass translocation to the cob. However, the percentage distribution of biomass among plant parts did not vary markedly across irrigation treatments. Nitrogen levels did not show a conspicuous effect on biomass partitioning in terms of both absolute values and percentage distribution. Irrigation scheduling significantly affected nitrogen concentration in plant parts, where higher irrigation intervals recorded comparatively greater nitrogen concentration in stem and grain due to the dilution effect associated with increased biomass under frequent irrigation. Nitrogen concentration in stem, leaf, and grain increased significantly with increasing nitrogen levels, with the highest concentration recorded under 240 kg N ha⁻¹. The interaction between irrigation scheduling and nitrogen levels was found to be non-significant for nitrogen concentration in different plant parts. Overall, the study highlights that irrigation scheduling and nitrogen management influence nitrogen concentration and biomass accumulation in maize, although their combined effect on biomass partitioning and nitrogen concentration was not significant. These findings emphasize the importance of balanced water and nitrogen management strategies for improving maize productivity under varying moisture conditions.

Keywords: Irrigation scheduling, productivity, biomass partitioning, depletion of available soil moisture

Introduction

Maize (*Zea mays* L.), popularly known as the “queen of cereals,” is endowed with the highest genetic yield potential among cereal crops and occupies a prominent position in global and Indian agriculture. It is cultivated across diverse agro-climatic regions, ranging from semiarid tropics to subtropical environments. Globally, maize production exceeds 1.2 billion tonnes, with the United States and China contributing a major share. In India, maize production has increased significantly in recent years, reaching about 43–50 million tonnes during 2024–26; however, productivity (3.4–3.7 t ha⁻¹) remains lower than the global average, indicating a substantial scope for improvement through efficient resource management (OECD, 2025) [18].

In India, maize ranks third after rice and wheat in area and production; however, its average productivity remains comparatively low, highlighting the need for improved management strategies (FAO, 2023) [6]. With the projected maize demand in India expected to reach nearly 121

million tonnes by 2050, enhancing productivity and resource-use efficiency has become imperative ([OECD-FAO Agricultural Outlook, 2021](#))^[17].

Indian agriculture is predominantly monsoon-dependent, and maize cultivation is frequently exposed to climatic variability such as erratic rainfall, delayed onset or early withdrawal of monsoon, prolonged dry spells, and extreme weather events (IPCC, 2021). Water stress, particularly during critical growth stages from one week before flowering to two weeks after flowering, severely affects maize growth, biomass accumulation, and yield formation. Above-ground biomass production is a key indicator of crop performance, as it reflects the efficiency of radiation interception, photosynthesis, and assimilate translocation ([Monteith, 1977](#))^[16]. Moisture stress at different phenological stages can significantly reduce dry matter accumulation and alter biomass partitioning, ultimately leading to yield penalties ([Lobell et al., 2014](#))^[14].

Among the essential nutrients, nitrogen is the most critical and yield-limiting factor in maize production due to its fundamental role in photosynthesis, protein synthesis, and enzymatic activity. Maize, being an exhaustive crop with high nutrient demand, requires adequate and timely nitrogen supply to sustain vigorous growth and optimal biomass production. Nitrogen deficiency results in reduced leaf area development and poor assimilate translocation, whereas excessive or inefficient nitrogen application lowers nitrogen use efficiency and poses environmental concerns ([Ladha et al., 2005](#))^[13]. Moreover, soil moisture availability strongly governs nitrogen mineralization, mobility, and uptake, thereby influencing nitrogen partitioning within the plant.

Understanding the combined effects of DASM-based irrigation scheduling and nitrogen levels on biomass production and nitrogen partitioning is therefore essential for developing efficient water–nitrogen management strategies aimed at sustaining maize productivity under variable climatic conditions.

2. Materials and methods:

2.1 Experimental site and weather conditions

The experiment was conducted during the *rabi* 2019 season at the Agro Climate Research Centre, Agricultural Research Institute, Rajendranagar, Hyderabad, India (17°32' N, 78°39' E; 542 m above mean sea level). The region falls under a semi-arid tropical climate. During the crop growth period, the mean temperature ranged from 16.7°C to 29.3°C, with relative humidity varying between 54% and 91%. A total rainfall of 78.8 mm was received.

2.2 Soil characteristics

The soil of the experimental field was sandy loam in texture. Soil samples collected from 0–45 cm depth were analyzed using standard procedures. The soil had moderate fertility, and the total available soil moisture in the root zone was estimated to be 68.94 mm based on field capacity and permanent wilting point.

2.3 Experimental design and treatments

The experiment was laid out in a split-plot design with three replications. Irrigation scheduling was assigned to main plots, and nitrogen levels to sub-plots.

Irrigation treatments (based on depletion of available soil moisture, DASM):

- I₁: 60% DASM (higher moisture stress)
- I₂: 40% DASM (moderate moisture stress)
- I₃: 20% DASM (near-optimum moisture)

Nitrogen levels:

N₁: 90 kg N ha⁻¹

N₂: 180 kg N ha⁻¹

N₃: 240 kg N ha⁻¹

Irrigation was applied at a depth of 50 mm as per treatment schedule. The lay-out, size of the plot, sampling technique and the units of measurements were followed as suggested by Gomez (1972) to maintain international standards.

2.4 Crop management practices

Maize hybrid Cargill 900M was sown at a spacing of 60 cm × 20 cm using a seed rate of 12 kg ha⁻¹. Farmyard manure @ 10 t ha⁻¹ was applied before sowing. A uniform dose of 60 kg P₂O₅ ha⁻¹ and 50 kg K₂O ha⁻¹ was applied to all treatments. Nitrogen was applied as per treatments in three equal splits at basal, six-leaf stage, and silking stage. All other agronomic practices were carried out uniformly for all plots.

2.5 Biomass partitioning

At harvest, plants were separated into stem, leaf, and cob, and dried in an oven at 70°C until constant weight. Biomass partitioning was expressed as dry matter accumulation (g plant⁻¹) and percentage distribution among plant parts.

2.6 Nitrogen concentration analysis

Dried plant samples were ground and analyzed for nitrogen content using the Micro-Kjeldahl method ([Piper, 1966](#))^[19]. Nitrogen concentration was expressed as percentage (%) in stem, leaf, and grain.

2.7 Statistical analysis

Data were analyzed using analysis of variance (ANOVA) for a split-plot design. Treatment differences were tested at the 5% level of significance ([Gomez and Gomez, 1984](#))^[7].

3. Results and Discussions:

3.1 Biomass partitioning at harvest

Translocation of dry matter which has accumulated in stem and leaves into cob measured at harvest was influenced by irrigation scheduling and nitrogen levels was summarized in g plant⁻¹ and percentage were depicted in Fig. 1 & 2, respectively.

3.1.1 Irrigation scheduling

The effect of irrigation scheduling on biomass partitioning clearly indicated that, with increasing interval between two successive irrigations, the amount of biomass accumulation into the cob was decreased. However, there was no markable difference in per cent partitioning of biomass between the irrigation scheduling (Fig. 2). Similar findings have been reported in maize, where drought stress reduced dry matter accumulation in reproductive organs, while having comparatively lesser influence on the overall partitioning pattern. ([Cai et al., 2022](#), [Loescher et al., 2017](#))^[2]. Furthermore, higher soil moisture availability has been associated with increased dry matter accumulation in maize, whereas moisture stress leads to a decline in biomass production ([Divya Singh et al., 2025](#))^[4].

3.1.2 Nitrogen levels

The effect of nitrogen levels on biomass partitioning was not conspicuous either in terms of absolute values (g plant⁻¹) or in percentage distribution, indicating that nitrogen primarily influenced total biomass rather than its proportional allocation among plant parts, as also reported in earlier studies ([Yue et al., 2021](#))^[20]. Similarly, studies in maize indicate that nitrogen mainly affects biomass accumulation and nitrogen redistribution, with limited influence on dry matter partitioning patterns ([Fan et al., 2023](#))^[5].

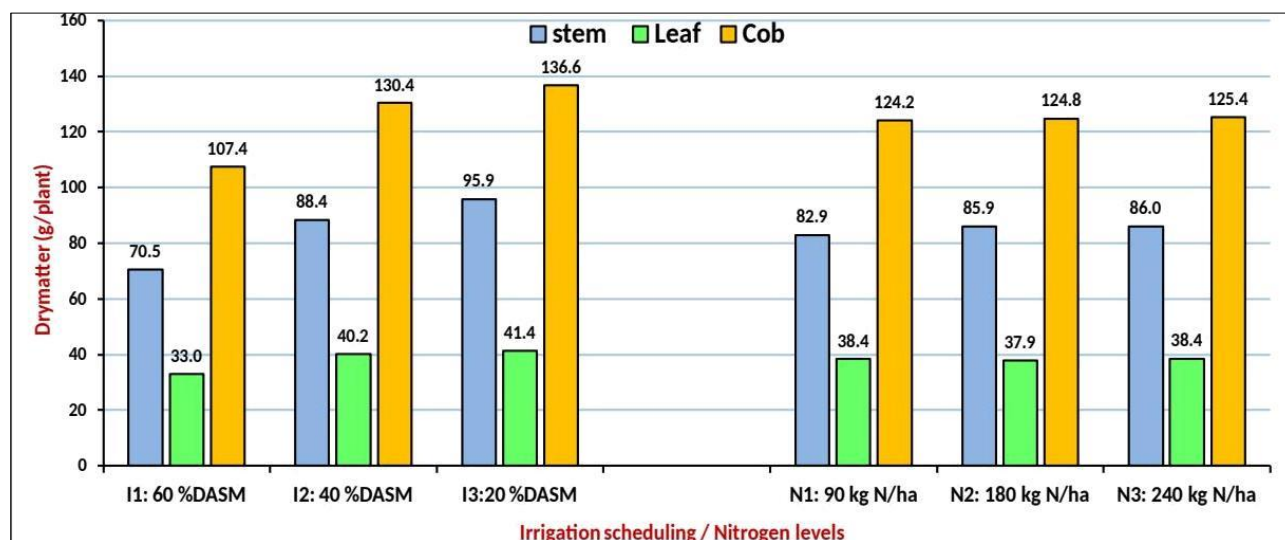


Fig 1: Biomass partitioning (g plant⁻¹) at harvest in maize as influenced by irrigation scheduling and nitrogen levels.

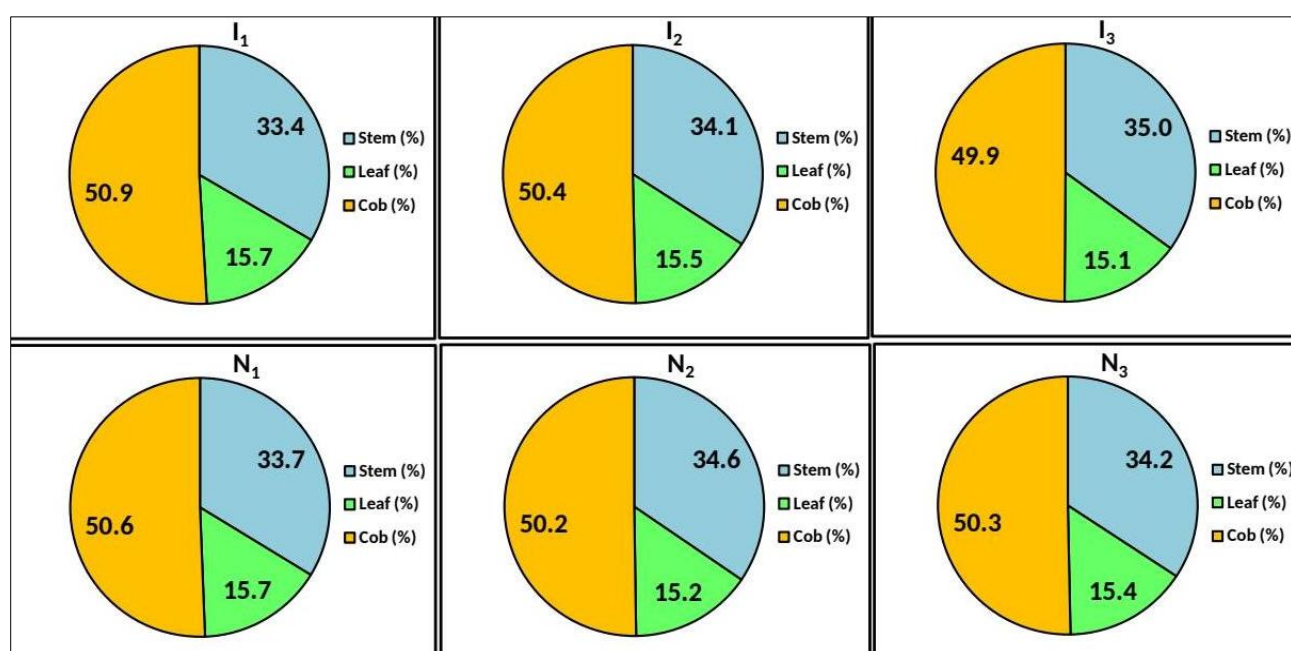


Fig 2: Biomass partitioning (%) at harvest in maize as influenced by irrigation scheduling and nitrogen levels.

3.2 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 1.

3.2.1. Irrigation scheduling

The effect of irrigation scheduling on concentration of nitrogen (%) in different plant parts was significant. The concentration of N in leaf and grain were decreased with increase in frequency between two successive irrigations from I₁ to I₃. The crop irrigation scheduled at 60 % DASM (I₁) recorded 0.67 % and 1.58 % N, in stem and grain, respectively which was comparable with I₂ and significantly more over I₃ treatment. The influence of irrigation scheduling on N concentration in leaf was not significant. The increase in biomass with increase in frequency between two successive irrigations resulted in dilution effect of mineral N concentration in different plant parts. Increased dry-weight accumulation is accompanied by decreased shoot mineral concentration, has been defined as a dilution effect (Jarrell and

Beverly1981) [12]. The lower concentration of N in frequently irrigated treatment (I₃) when compared to increased irrigation interval treatment (I₁) evidences the dilution effect of mineral nitrogen.

Greenwood *et al* (1990) [9] have shown that the optimum plant N % decreased unmistakably according to the increase in crop biomass. Optimal environmental conditions often will be accompanied by decreases in plant mineral concentrations (Davis, 2009) [3].

3.2.2 Nitrogen levels

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 increase in nitrogen dose. The crop nurtured with 240 kg ΔNha⁻¹ (N₃) recorded more N concentration (%) in stem (0.75 %) and grain (1.61 %) which was comparable with N₂ in stem (0.70 %) and grain (1.54) and significantly more over N₁ in stem (0.59 %) and grain (1.29 %). The crop nurtured with 240 kg N ha⁻¹ (N₃) recorded more N

concentration (%) in leaf (0.83 %) and significantly superior over Nu₂ and N₁.

The enhanced N accumulation with increased nitrogen dose was reported by several researchers ([Hassanein et al., 2007](#), [Amin et al., 2011](#))^[10].

Table 1: Nitrogen partitioning in different parts of above ground biomass of maize as influenced by irrigation scheduling and nitrogen levels at physiological maturity stage.

Plant parts	Stem (%)				Leaf N (%)				Grain (%)			
Treatments	N1	N2	N3	Mean	N1	N2	N3	Mean	N1	N2	N3	Mean
I ₁	0.73	0.88	0.92	0.84	0.67	0.78	0.88	0.78	1.40	1.65	1.68	1.58
I ₂	0.49	0.62	0.68	0.60	0.49	0.63	0.86	0.66	1.23	1.53	1.68	1.48
I ₃	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: I₁: 60 % DASM; I₂: 40 % DASM; I₃: 20 % DASM; N₁: 90 kg N ha⁻¹; N₂: 180 kg N ha⁻¹; N₃: 240 kg N ha⁻¹; [DASM (Depletion of Available Soil Moisture)]

Conclusions

The present investigation demonstrated that irrigation scheduling based on depletion of available soil moisture (DASM) plays a crucial role in regulating biomass production and nitrogen dynamics in maize. Irrigation at 20% DASM ensured better soil moisture availability, which significantly enhanced dry matter accumulation and its translocation to the cob, whereas moisture stress under 60% DASM reduced biomass production. However, irrigation scheduling did not markedly influence the proportional distribution of biomass among plant components, indicating that moisture stress primarily affects total biomass rather than its partitioning pattern.

Nitrogen levels had no significant effect on biomass partitioning but significantly influenced nitrogen concentration in different plant parts. Higher nitrogen application (240 kg N ha⁻¹) resulted in increased nitrogen concentration in stem, leaf, and grain, indicating improved nitrogen uptake and assimilation. Conversely, lower nitrogen levels led to reduced nitrogen accumulation, highlighting the importance of adequate nitrogen supply for optimal crop performance. The study also revealed a dilution effect of nitrogen concentration under higher irrigation frequency due to increased biomass production. Furthermore, the interaction between irrigation scheduling and nitrogen levels was non-significant, suggesting independent effects of these factors on nitrogen partitioning.

Overall, the findings emphasize that maintaining optimum soil moisture through appropriate irrigation scheduling, along with adequate nitrogen fertilization, is essential for enhancing biomass production and improving nitrogen use efficiency in maize. These results provide valuable insights for developing efficient water–nitrogen management strategies to sustain maize productivity under variable climatic conditions.

Further research should focus on refining irrigation and nitrogen management strategies through the integration of precision agriculture tools, such as soil moisture sensors and real-time nutrient monitoring, to enhance water and nitrogen use efficiency. Studies on split nitrogen application, fertigation, and controlled-release fertilizers may improve synchronization between crop demand and nutrient supply. Additionally, multi-location trials under varying climatic conditions and inclusion of physiological and soil health parameters would help in developing climate-resilient and sustainable maize production systems.

4.11.3 Interaction effect

The interaction effect of irrigation scheduling and nitrogen levels on nitrogen concentration (%) in different plant parts was not significant.

Competing Interests: Authors have declared that no competing interests exist.

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