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Influence of Irrigation and Nitrogen levels on Growth and Yield of Wheat (*Triticum aestivum* L.) in Semi-Arid condition of Rajasthan

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Abstract
A field experiment was conducted during the Rabi season of 2025–26 at the Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, to evaluate the effect of irrigation scheduling and nitrogen levels on the growth and yield of wheat (*Triticum aestivum* L.) under semi-arid conditions. The experiment was laid out in a Factorial Randomized Block Design with four irrigation schedules, viz., I_1: five irrigations (CRI + tillering + jointing + flowering + grain filling), I_2: four irrigations (CRI + tillering + flowering + grain filling), I_3: three irrigations (CRI + flowering + grain filling) and I_4: IW/CPE ratio 0.8, along with three nitrogen levels, viz., N_1: 100 kg N ha^{-1}, N_2: 120 kg N ha^{-1} and N_3: 140 kg N ha^{-1}. The results revealed that growth and yield attributes of wheat were significantly influenced by irrigation and nitrogen levels. Among irrigation treatments, I_1 recorded the highest plant height (109.42 cm), number of tillers (91.48 m^{-1} row length), leaf area index (5.01) and dry matter accumulation (372.65 g row length^{-1}). Similarly, among nitrogen levels, N_3 recorded the maximum plant height (104.60 cm), tillers (92.52 m^{-1} row length), leaf area index (4.86) and dry matter accumulation (365.57 g row length^{-1}). Yield parameters were also significantly enhanced by higher irrigation frequency and nitrogen application. Treatment I_1 produced the highest grain yield (46.65 q ha^{-1}) and straw yield (89.44 q ha^{-1}), whereas N_3 recorded the maximum grain yield (47.21 q ha^{-1}) and straw yield (86.82 q ha^{-1}). Harvest index remained statistically unaffected by both irrigation and nitrogen levels. Based on the findings, application of five irrigations at CRI, tillering, jointing, flowering and grain filling stages along with 140 kg N ha^{-1} is recommended for achieving higher growth, productivity and profitability of wheat under semi-arid conditions of Rajasthan.

Keywords: Wheat, Irrigation scheduling, Nitrogen levels, Grain yield

Introduction
Wheat (*Triticum aestivum* L.) is one of the most important staple cereal crops and a major source of food and nutrition worldwide. In India, it plays a vital role in food security and ranks second after rice among cereal crops (Sharma and Sharma 2025). Wheat provides more than 50% of the calories for populations that largely depend on it. Major wheat-producing countries include China, India, Russia, the United States, Canada, and Australia. In India, wheat is mainly cultivated in the north-western and central regions. During 2023–24, wheat occupied about 32 million ha with a production of 116.21 million tonnes. Among major cereals, wheat ranks second in area and production after rice but first in productivity, contributing significantly to the dietary energy supply (Gupta *et al*. 2025) [7]. Rajasthan is one of the major wheat-producing states in India, contributing about 9.8–10 million tonnes of wheat from nearly 3.0–3.2 million hectares during 2024–25, with an average productivity of 3500–3800 kg ha^{-1}. Important wheat-growing districts include Sri Ganganagar, Hanumangarh, Alwar, Bharatpur, Kota, and Jaipur. Irrigation facilities, particularly the Indira Gandhi Canal and groundwater resources, support wheat cultivation, although productivity is often affected by climatic variability and water availability. The major cultivated wheat species are *Triticum aestivum*, *Triticum durum*, and *Triticum dicoccum*, among which *Triticum aestivum* is the most widely grown due to its high yield potential and adaptability (Balla *et al*. 2022) [2]. Wheat grain contains about 11–13% protein along with carbohydrates, minerals, and other essential nutrients.

It is used for preparing chapati, bread, biscuits, and bakery products, while wheat straw serves as an important livestock feed and raw material for rural industries. With the increasing population and limited scope for expanding cultivated land, enhancing wheat productivity has become essential. Improved varieties and scientific agronomic practices such as optimum sowing time, balanced fertilization, efficient irrigation scheduling, and weed management are important for achieving higher yields. Irrigation management is particularly crucial in arid and semi-arid regions like Rajasthan (Farouk *et al.* 2024) [6]. Irrigation scheduling involves deciding the timing and quantity of water application according to crop requirements and environmental conditions. Scheduling may be based on soil moisture status, critical growth stages, or climatological approaches such as the IW/CPE ratio. Efficient irrigation methods improve water use efficiency and help meet crop water requirements effectively.

Nitrogen is an essential nutrient for plant growth as it is a major component of chlorophyll and proteins. Its requirement varies with soil type, climate, crop demand, and moisture availability. Nitrogen fertilization increases biomass production, root growth, grain yield, and soil fertility through greater residue addition. It also improves grain protein content and milling quality (Chevalier *et al.* 2025). Since most Indian soils are deficient in nitrogen, its balanced application is necessary. Nitrogen deficiency causes yellowing and stunted growth, whereas excessive application may increase pest incidence, weed growth, and cultivation costs. Therefore, judicious nutrient management is essential for sustainable wheat production, thus an experiment was carried out to see the influence of irrigation and nitrogen levels on growth and yield of Wheat (*Triticum aestivum* L.) in semi-arid condition of Rajasthan.

Materials and Methods

The experiment was conducted in *Rabi* season of the year 2025-2026 in the *Department of Agriculture, Vivekananda Global University*, *Jaipur Rajasthan*, to influence of irrigation and nitrogen levels on growth and yield of Wheat (*Triticum aestivum* L.) in Semi-Arid condition of Rajasthan. The experimental site is situated at 26^0 5” N latitude, and 75^0 28” E longitude at the elevation of 427 m above the MSL. The climate of this region is typically semi-arid, characterized by extremes of temperature during both summers and winters. During summers, the temperature may go as high as 48 °C, while in winters, it may fall as low as -1.0°C. The experiment was laid out in Randomized Block Design (Factorial analysis) with a total of 36 plots, with 4 m × 3 m plot size. The experiment consisted of the four levels of irrigation scheduling, viz. I1- 5 Irrigation (CRI + Tillering+ Jointing+ Flowering+ Grain Filling), I2- 4 Irrigation (CRI + Tillering+ Flowering+ Grain Filling), I3 3 Irrigation (CRI +Flowering+ Grain Filling) and I4 IW/CPE ratio 0.8 (5 irrigations) and three nitrogen level *i.e.*, N1 100 Kg/ha, N2 120 Kg/ha and N3 140 Kg/ha. Wheat Raj 4079 variety was sown at 22.5 cm row spacing. The entire dose of phosphorus (DAP) and potassium (MOP) were applied across the field before sowing. However, nitrogen was applied in desired quantity as per treatment requirement. At harvest, crop growth attributes were assessed using five randomly selected plants per plot. grain and stover yield were collected from the net plot at the harvest time and values are expressed in q ha^{-1}. Analysis followed Cox and Cochran, (1957) [5] method, with significance tested at $p < 0.05$.

Results

The data pertaining to growth attributes as influenced by different irrigation and nitrogen levels are presented in Table 1. The growth parameters of wheat were significantly affected by irrigation and nitrogen levels. Among the irrigation levels, I_1: 5 irrigations (CRI + Tillering + Jointing + Flowering + Grain Filling) recorded the maximum plant height at harvest (109.42 cm), which was significantly superior to all other irrigation treatments. It was followed by I_2: 4 irrigations (CRI + Tillering + Flowering + Grain Filling) with a plant height of 100.24 cm. The minimum plant height (89.42 cm) was recorded under I_3: 3 irrigations (CRI + Flowering + Grain Filling), which remained statistically at par with I_4: IW/CPE ratio 0.8 (91.26 cm). Among the nitrogen levels, N_3: 140 kg N ha^{-1} recorded the tallest plants at harvest (104.60 cm), followed by N_2: 120 kg N ha^{-1} (100.22 cm), while the shortest plants (97.25 cm) were recorded under N_1: 100 kg N ha^{-1}. The number of tillers m^{-1} row length at harvest was significantly influenced by irrigation scheduling. The highest number of tillers m^{-1} row length (91.48) was recorded under I_1: 5 irrigations, followed by I_2: 4 irrigations (86.41). The lowest number of tillers m^{-1} row length (82.10) was observed under I_4: IW/CPE ratio 0.8, which remained statistically at par with I_3: 3 irrigations (84.62). Similarly, among nitrogen levels, N_3: 140 kg N ha^{-1} recorded the maximum number of tillers m^{-1} row length (92.52), followed by N_2: 120 kg N ha^{-1} (86.32), whereas the minimum number of tillers m^{-1} row length (81.15) was recorded under N_1: 100 kg N ha^{-1}. Leaf area index (LAI) at 90 DAS was also significantly affected by irrigation levels. The maximum LAI (5.01) was recorded under I_1: 5 irrigations, followed by I_2: 4 irrigations (4.78) and I_4: IW/CPE ratio 0.8 (4.70). The minimum LAI (4.32) was recorded under I_3: 3 irrigations. Among the nitrogen levels, N_3: 140 kg N ha^{-1} recorded the maximum LAI (4.86), followed by N_2: 120 kg N ha^{-1} (4.75), whereas the minimum LAI (4.52) was recorded under N_1: 100 kg N ha^{-1}. Dry matter accumulation was significantly influenced by different irrigation treatments. The maximum dry matter accumulation (372.65 g row $length^{-1}$) was recorded under I_1: 5 irrigations, followed by I_2: 4 irrigations (346.38 g row $length^{-1}$). The minimum dry matter accumulation (306.79 g row $length^{-1}$) was observed under I_3: 3 irrigations, which remained statistically at par with I_4: IW/CPE ratio 0.8 (317.22 g row $length^{-1}$). Among the nitrogen levels, the maximum dry matter accumulation (365.57 g row $length^{-1}$) was recorded under N_3: 140 kg N ha^{-1}, followed by N_2: 120 kg N ha^{-1} (344.33 g row $length^{-1}$), whereas the minimum dry matter accumulation (324.36 g row $length^{-1}$) was recorded under N_1: 100 kg N ha^{-1}.

The data pertaining to grain yield, straw yield and harvest index as influenced by different irrigation and nitrogen levels are presented in Table 2. Among the irrigation levels, I_1: 5 irrigations (CRI + Tillering + Jointing + Flowering + Grain Filling) recorded the highest grain yield (46.65 q ha^{-1}), which was significantly superior to all other irrigation treatments. It was followed by I_2: 4 irrigations (41.23 q ha^{-1}). The lowest grain yield (36.43 q ha^{-1}) was recorded under I_3: 3 irrigations (CRI + Flowering + Grain Filling), which remained statistically at par with I_4: IW/CPE ratio 0.8 (38.07 q ha^{-1}). Among the nitrogen levels, N_3: 140 kg N ha^{-1}

recorded the maximum grain yield (47.21 q ha^{-1}), which was significantly higher than N_2: 120 kg N ha^{-1} (40.67 q ha^{-1}) and N_1: 100 kg N ha^{-1} (38.08 q ha^{-1}). The minimum grain yield was recorded under N_1: 100 kg N ha^{-1}. However, N_1 and N_2 remained statistically at par. Straw yield was significantly influenced by irrigation and nitrogen levels. Among the irrigation treatments, the maximum straw yield (89.44 q ha^{-1}) was recorded under I_1: 5 irrigations, followed by I_2: 4 irrigations (80.59 q ha^{-1}). The minimum straw yield (71.03 q ha^{-1}) was observed under I_3: 3 irrigations, which remained statistically at par with I_4: IW/CPE ratio 0.8 (72.15 q ha^{-1}), as the difference between these treatments was less than the CD value (8.81 q ha^{-1}). Among the nitrogen levels, N_3: 140 kg N ha^{-1} recorded the highest straw yield (86.82 q ha^{-1}), followed by N_2: 120 kg N ha^{-1} (81.64 q ha^{-1}), while the lowest straw yield (73.72 q ha^{-1}) was recorded under N_1: 100 kg N ha^{-1}. The treatments N_2 and N_3 remained statistically at par, whereas both were significantly superior to N_1. Harvest index was not significantly affected by different irrigation and nitrogen levels.

Table 1: Effect of different levels of irrigation and nitrogen on growth attributes of wheat

Treatments	Plant height (cm) At harvest	Number of tillers m^{-1} row length at harvest	LAI At 90 DAS	Dry matter accumulation (g) row length
Irrigation levels				
I_1: 5 Irrigation (CRI + Tillering+ Jointing+ Flowering+ Grain Filling)	109.42	91.48	5.01	372.65
I_2: 4 Irrigation (CRI + Tillering+ Flowering+ Grain Filling)	100.24	86.41	4.78	346.38
I_3: 3 Irrigation (CRI +Flowering+ Grain Filling)	89.42	84.62	4.32	306.79
I_4: IW/CPE ratio 0.8	91.26	82.10	4.70	317.22
SEm±	1.97	1.73	0.08	8.84
CD (P=0.05)	7.74	6.80	0.25	34.70
Nitrogen levels				
N1: 100 Kg/ha	97.25	81.15	4.52	324.36
N2: 120 Kg/ha	100.22	86.32	4.75	344.33
N3: 140 Kg/ha	104.60	92.52	4.86	365.57
SEm±	1.12	1.29	0.06	5.90
CD (P=0.05)	3.45	3.99	0.18	18.20

Table 2: Effect of different levels of irrigation and nitrogen on grain yield, straw yield and harvest index of wheat

Treatments	Grain yield (q/ha)	Straw yield (q/ha)	Harvest index (%)
Irrigation levels			
I_1: 5 Irrigation (CRI + Tillering+ Jointing+ Flowering+ Grain Filling)	46.65	89.44	35.28
I_2: 4 Irrigation (CRI + Tillering+ Flowering+ Grain Filling)	41.23	80.59	34.98
I_3: 3 Irrigation (CRI +Flowering+ Grain Filling)	36.43	71.03	34.51
I_4: IW/CPE ratio 0.8	38.07	72.15	34.65
SEm±	1.07	2.24	0.56
CD (P=0.05)	4.20	8.81	NS
Nitrogen levels			
N1: 100 Kg/ha	38.08	73.72	34.87
N2: 120 Kg/ha	40.67	81.64	33.92
N3: 140 Kg/ha	47.21	86.82	35.99
SEm±	1.02	1.60	0.53
CD (P=0.05)	3.16	4.90	NS

Discussion

The increase in plant height under higher irrigation frequency might be due to adequate soil moisture availability throughout the crop growth period, which enhanced nutrient uptake, cell elongation and photosynthetic activity. The lowest plant height was observed under I_3: 3 Irrigation (CRI + Flowering + Grain Filling) with values of 48.12 cm, 76.21 cm and 89.42 cm at respective stages. This reduction may be attributed to moisture stress during critical growth stages, resulting in restricted vegetative growth and reduced metabolic activities. Similar results are observed by Ali *et al*. (2025) [1]. The increase in plant height with higher nitrogen application might be due to enhanced chlorophyll formation, protein synthesis and vigorous vegetative growth. The lowest plant height was recorded under 100 kg N ha^{-1} (N_1), which produced 49.46 cm, 79.96 cm and 97.25 cm plant height at respective growth stages. Nitrogen plays an important role in promoting meristematic activity and internodal elongation, thereby increasing plant height. The present findings are in close conformity with the findings of Baviskar *et al.* (2013) [3]. The improvement in tiller production under higher irrigation frequency might be attributed to the continuous availability of adequate soil moisture, which enhanced nutrient uptake, cell division and overall vegetative growth. The lowest number of tillers m^{-1} row length (82.10) was recorded under I_4, indicating that reduced moisture availability adversely affected tiller initiation and development. The present findings are in close conformity with the findings of Kumar *et al.* (2019) [8]. The increase in tiller production with higher nitrogen application might be due to enhanced chlorophyll synthesis, vigorous vegetative growth and improved nutrient availability. The lowest number of tillers m^{-1} row length (81.15) was recorded under 100 kg N ha^{-1} (N_1), which might be attributed to restricted cell division and reduced vegetative growth under lower nitrogen availability. Similar results are observed by Malve, (2015) [10]. The increase in LAI under frequent irrigation might be due to adequate soil moisture availability, which promoted leaf expansion, photosynthetic activity and canopy development. Lower LAI values of 3.45 and 4.32 at 70 and 90 DAS, respectively, were recorded under I_3, indicating that moisture stress reduced leaf growth and canopy expansion. Higher nitrogen availability enhanced chlorophyll formation, leaf expansion and vegetative growth, resulting in improved canopy development. The lowest LAI values of 3.29 and 4.52 at 70 and 90 DAS, respectively, were recorded under 100 kg N ha^{-1} (N_1), which might be due to limited nitrogen availability restricting leaf development and crop growth. The present findings are in close conformity with the findings of Parihar and Tiwari (2003) [12]. The increase in dry matter accumulation under higher irrigation frequency might be due to adequate soil moisture availability throughout the crop growth period, resulting in enhanced nutrient uptake, photosynthetic efficiency and vegetative growth. The present findings are in close conformity with the findings of Shirazi *et al*. (2014) [14]. The increase in dry matter accumulation with higher nitrogen application might be due to enhanced chlorophyll formation, protein synthesis and vigorous vegetative growth, which improved photosynthetic activity and assimilate accumulation. The lowest dry matter accumulation was recorded under 100 kg N ha^{-1} (N1), which produced 69.68 g, 168.85 g and 324.36 g row $length^{-1}$ at respective growth stages. Lower nitrogen availability might have restricted plant growth and biomass production. The present findings are in close conformity with the findings of Tripathi *et al*. (2013) [15]. The increase in grain and straw yield under higher irrigation frequency might be due to adequate moisture availability throughout the crop growth period, which enhanced nutrient uptake, photosynthetic activity, dry matter accumulation and efficient translocation of assimilates towards sink organs. The lowest grain yield (36.43 q ha^{-1}) and straw yield (71.03 q ha^{-1}) were recorded under I_3: 3 Irrigation (CRI + Flowering + Grain Filling). Moisture stress under limited irrigation schedules might have adversely affected vegetative growth, grain filling and biomass production. The present findings are in close conformity with the findings of Mahmood *et al.*, (2002) [9]. The increase in grain and straw yield with higher nitrogen application might be due to enhanced vegetative growth, greater leaf area development, higher dry matter accumulation and improved translocation of assimilates towards grains. The lowest grain yield (38.08 q ha^{-1}) and straw yield (73.72 q ha^{-1}) were recorded under 100 kg N ha^{-1} (N_1). Lower nitrogen availability might have restricted crop growth, yield attributes and biomass production. The present findings are in close conformity with the findings of Narolia *et al.*, (2016) [11].

Conclusion

The results of the present investigation revealed that growth and yield of wheat were significantly influenced by irrigation and nitrogen levels. Application of five irrigations at CRI, tillering, jointing, flowering and grain filling stages (I_1) recorded significantly higher plant height (109.42 cm at harvest), grain yield (46.65 q ha^{-1}) and straw yield (89.44 q ha^{-1}). Among nitrogen levels, application of 140 kg N ha^{-1} (N_3) recorded significantly higher grain yield (47.21 q ha^{-1}), straw yield (86.82 q ha^{-1}). Hence, these irrigation scheduling and nitrogen management practices can be increasing the growth and grain yield of wheat growers.

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