

Interactive Effects Of Irrigation Deficit And Foliar Npk Fertilization On Wheat Performance And Soil Dynamics In Water-Limited Environments

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Received 18 July 2025, Accepted 7 August 2025, Available online 25 August 2025

ABSTRACT

This study evaluated the combined effects of irrigation depletion levels and fertilization treatments on wheat (*Triticum aestivum* L.) yield, nutrient uptake, soil chemical properties, and irrigation water productivity under field conditions in Northern Egypt. A split-plot design with three replicates was implemented over two winter seasons (2022/2023 and 2023/2024) at Qarada Research Station. The main factors comprised two irrigation regimes defined by 50% (I1) and 75% (I2) depletion of available soil moisture. Subplots involved four fertilization treatments: (F1: soil- applied fertilizers as a recommended NPK application (control), F2: F1 + foliar application of NPK (20:20:20) F3: foliar NPK (20:20:20) + supplementary fertilizers, and F4: supplementary soil fertilization only. Results demonstrated a significant interaction between irrigation and fertilization strategies.

The I1F2 treatment yielded the highest grain production (3.55 t/fed) and enhanced nutrient assimilation and biomass accumulation. In contrast, the I2F2 treatment exhibited superior irrigation water productivity (up to 2.05 kg m⁻³), indicating improved irrigation water productivity with a slight yield reduction. Moderate irrigation combined with balanced fertilization improved soil nutrient status and organic matter content, while reduced irrigation and fertilization increased soil salinity. These findings highlight a critical balance between maximizing yield and conserving water resources.

The integration of moderate irrigation with foliar and soil NPK fertilization represents a viable strategy to optimize wheat productivity and sustainability under water-limited conditions prevalent in Northern Egypt.

Keywords: Foliar NPK fertilization, irrigation regimes, irrigation water productivity, nutrient uptake, soil fertility, wheat productivity

INTRODUCTION

Wheat (*Triticum aestivum* L.) is a principal cereal crop integral to global food security, particularly in regions characterized by arid and semi-arid climates where water scarcity and soil constraints limit agricultural productivity (Sharma and Sharma, 2025). Increasing demand for wheat, driven by population growth and climate-induced stressors, necessitates improved management of water and nutrient resources to sustain yield gains and mitigate environmental degradation (Erenstein *et al.*, 2022 and Halecki and Bedla, 2022). In Egypt, wheat is a dietary staple; however, domestic production is insufficient to meet consumption demands, resulting in heightened import dependence and vulnerability to external supply disruptions. This production deficit is further aggravated by the fixed allocation of Nile water to Egypt, the decline in precipitation patterns, and the intensification of upstream water use, collectively amplifying water scarcity and imposing substantial constraints on soil and crop management (Abd Ellah, 2020 and Elbeltagi *et al.*, 2020).

Water deficit conditions adversely affect wheat physiological processes, reducing nutrient uptake efficiency and compromising grain yield and quality (Zhao *et al.*, 2020 and Ingrao *et al.*, 2023). Deficiencies in essential macronutrients are exacerbated under drought due to diminished root functionality and altered soil chemical properties, including increased salinity, which further restricts water and nutrient availability (Wen *et al.*, 2020, Ke *et al.*, 2024 and Lyu *et al.*, 2025).

Foliar application of NPK fertilizers offers a targeted approach to circumvent soil nutrient constraints, enhancing plant physiological resilience and stress tolerance mechanisms under drought (Basvantrao, 2024 and Sulaman *et al.*, 2025). Coordinating irrigation scheduling with balanced nutrient management has demonstrated potential to optimize water use efficiency and nutrient uptake, while reducing environmental risks such as soil salinization (Verma *et al.*, 2023 and Shoukat Hafiza *et al.*, 2025). Nonetheless, comprehensive field-based assessments of the synergistic effects of irrigation regimes and fertilization strategies on wheat growth, soil fertility, and water productivity in arid agro-ecosystems remain limited.

This study addresses these knowledge gaps by investigating the combined impacts of irrigation depletion levels and fertilization addition, including soil and foliar NPK applications, on wheat physiological performance, nutrient uptake, yield, soil chemical properties, and water use efficiency under drought-prone field conditions in Northern Egypt. T

Therefore the outcomes aim to inform integrated soil and water management practices that promote sustainable wheat production and resource conservation in water-limited environments.

MATERIALS AND METHODS

Study Site and Experimental Setup

Site Location and Climate

Field experiments were conducted over two consecutive winter seasons (2022/2023 and 2023/2024) at the Qarada Research Station, Kafr El-Sheikh Governorate, Egypt (latitude 31°6' N, longitude 30°56' E, and elevation 6 m above sea level). Meteorological data (temperature, relative humidity, wind speed, rainfall) were obtained from the adjacent Sakha agro-meteorological station (Table 1).

Table 1. Monthly Meteorological Parameters during Wheat Growing Seasons 2022/2023 and 2023/2024 at Qarada Research Station, Egypt

Seasons	Month	T min (°C)	T max (°C)	RH (%)	WS (m/s)	Rainfall (mm)
2022/2023	Dec.	13.02	23.90	68.00	2.26	43.51
	Jan.	10.51	21.08	73.86	2.34	28.50
	Feb.	8.98	19.38	69.66	2.57	45.16
	Mar.	11.79	25.18	61.15	3.03	18.71
	Apr.	13.73	28.81	54.85	3.15	14.70
	May	17.28	32.86	52.17	3.65	0.58
	Average	12.55	25.20	63.28	2.83	151.16
2023/2024	Dec.	13.50	23.61	72.51	2.45	35.65
	Jan.	10.22	20.59	68.00	2.64	26.65
	Feb.	9.99	21.49	71.00	2.44	13.88
	Mar.	11.68	25.38	62.00	2.75	7.77
	Apr.	15.32	30.92	58.00	3.41	2.88
	May	18.05	33.70	48.00	3.26	0.88
	Average	13.13	25.95	63.25	2.83	87.71

* T: temperature; RH: relative humidity; WS: wind speed; min and max: minimum and maximum

Soil Characterization

Composite soil samples were collected pre-planting from the surface soil layer (0-30 cm depth). Physical and chemical properties (Table 2), including texture, bulk density, pH, electrical conductivity (EC), field capacity, wilting point, available water content, available nitrogen (N), phosphorus (P), potassium (K), and organic matter were analyzed using standard protocols.

Experimental design and treatments

Design

A split-plot design with three replicates was employed. Main plots received two irrigation regimes; subplots received four fertilization treatments.

Irrigation Treatments

- I1: Irrigation at 100% water requirement.
- I2: Irrigation at 75% water requirement.

Fertilization Treatments

- F1: Soil-applied as a recommended NPK application (control).
- F2: F1 + foliar application of NPK (20:20:20).
- F3: Foliar NPK (20:20:20) + Soil-applied supplementary fertilizer.
- F4: Soil-applied supplementary fertilizer only (no foliar NPK)

Table 2. Physical and Chemical Properties of Experimental Soil at Qarada Research Station in 2022 and 2023

Soil Properties	2022	2023	Methods	Ref.
Sand (%)	20.59	20.61	Pipette Method	Gee and Or (2002)
Silt (%)	28.12	28.09		
Clay (%)	51.29	51.3		
Soil Texture	Clay	Clay	Core Sampler	
Bulk Density (g/cm ³)	1.38	1.39		
Field Capacity (%)	44.2	44.95	Pressure membrane	Klute (1986)
Wilting Point (%)	20.4	20.85		
Available Water (%)	23.8	24.1		
pH (1:2.5 soil: water)	8.15	8.16	pH Meter	Pansu <i>et al.</i> (2006)
EC (dS/m)	2.38	2.36	Conductivity Meter	
Available nitrogen (mg/kg)	27.66	29.11	Micro Kjeldahl method	
Available phosphorus(mg/kg)	7.77	7.9	Colorimetric method	
Available potassium (mg/kg)	222.5	230	Flame photometry	
Soil Organic Matter (%)	1.9	1.98	Walkley-Black	Bhattacharya <i>et al.</i> (2015)

Cultivation and Fertilizer Application**Cultivation**

The experimental area covered 1,032 m², consisting of two main plots of 504 m² each. Each main plot was further subdivided into 12 subplots, each measuring 42 m², with 1 m buffer zones separating the subplots (24m²). The soil preparation followed according to the recommendations of the Wheat Research Department, utilizing precision leveling with a laser device. The wheat (cv Sakha 95) were obtained from the Field Crops Research Institute, Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt and it was sown at a rate of 40 kg/fed on November 20th during both growing seasons and harvest in April 21th during both growing seasons. The agricultural practices for wheat cultivation were conducted per the recommendation of the Egyptian Ministry of Agriculture.

Fertilizer application methods

The recommended N fertilizer dose for wheat was 161.29 kg/ fed, applied as urea containing 46% nitrogen. The total nitrogen was divided into two splits, administered after the first and second irrigations, corresponding to 30 and 60 days after sowing, respectively. Phosphorus fertilizer, in the form of calcium superphosphate (150 kg/fed), was incorporated into the soil prior to sowing. Potassium fertilizer was applied as potassium sulfate (48% K₂ O) at a rate of 50 kg/fed before planting (Farid *et al.*, 2023).

Supplementary NPK fertilization was implemented to compensate for nutrient deficiencies by calculating the difference between the crop's recommended nutrient requirements and the existing soil nutrient levels, as determined by pre-sowing soil analysis. Based on the soil test results, the quantities of available nutrients were subtracted from these recommended doses to determine the amount of fertilizer applied in the supplementary fertilization treatment.

Foliar fertilization was conducted using Supergro, a commercially available, water-soluble fertilizer provided by the Agricultural Research Center. The formulation contains 20% total nitrogen, 20% phosphoric acid, and 20% soluble potassium. The foliar solution was applied directly to the wheat canopy at 30 and 60 days after planting, at a concentration of 50 g per 300 liters of water.

Irrigation Scheduling and Soil Moisture Monitoring

Soil Moisture Assessment

Gravimetric soil moisture was determined at three depths (0–15, 15–30, 30–45 cm) by oven-drying samples at 105°C for 24 h. according to the method described by Garcia (1978).

Time-domain reflectance (TDR) sensors provided real-time volumetric moisture data to maintain targeted depletion levels.

Irrigation water applied

Irrigation amounts were calculated following Phocaides (2007) to restore soil moisture to field capacity, accounting for root zone depth progression.

$$W_a = f \times (FC - WP) \times BD \times D_s$$

Where:

W_a = water applied (m³/fed), f = allowable depletion fraction, FC = field capacity (%), WP = wilting point (%), BD = bulk density (g cm⁻³)

D_s = depth of soil layer (m), Effective rainfall (Pe) was estimated at 70% of total precipitation (Chavan *et al.*, 2009).

$$Pe = 0.7 \times P$$

Data Collection and Analysis

Soil sampling and analysis

Post-harvest soil samples were collected from the experimental plots to evaluate changes in soil electrical conductivity (EC), organic matter content, and available macronutrients (N, P, and K). Samples were taken from 0–30 cm soil layer at multiple points within each plot using a soil auger and then composited to obtain a representative sample.

Agronomic measurements

Wheat grain yield per plant was determined from a 1 m² harvest area and adjusted to 14% moisture content. The thousand-grain weight was measured by manually counting and weighing the grains.

Grain Nutrient Analysis

Dried grain samples were digested using sulfuric and perchloric acid. N, P, and K concentrations were measured following standard protocols (Cresser and Parsons, 1979). Crude protein content was calculated by multiplying the nitrogen percentage by a conversion factor of 5.7, while total nutrient uptake was estimated by multiplying the nutrient concentration by the corresponding grain yield (kg fed⁻¹), as described by Motsara and Roy (2008).

Irrigation water productivity (IWP):

Irrigation water productivity IWP was calculated according to Ali *et al.*, (2007) as the follows:

$$IWP = \frac{\text{grain yield (kg/fed)}}{\text{irrigation water applied (m3/fed)}}$$

Statistical Analysis

Data were analyzed using two-way ANOVA (SPSS v.25) to evaluate effects of irrigation and fertilization. Means were compared using LSD at $p \leq 0.05$. Data visualization was performed using Python 3.

RESULTS AND DISCUSSION

Seasonal Irrigation Water Applied (IWa)

Seasonal irrigation water applied (IWa), comprising irrigation water (Wa) and effective rainfall (Pe), varied between the two growing seasons due to inter-annual climatic differences (Table 3). Effective rainfall (Pe) was estimated at 105.81 mm (equivalent to 444.1 m³/fed) in 2022/2023 and decreased substantially to 61.40 mm (257.87 m³/fed) in 2023/2024, reflecting a 58.03% reduction.

Despite the increased irrigation frequency in the second season, total seasonal water inputs (IWa) rose only marginally (approximately 4-5.5%),

primarily due to the compensation for decreased rainfall. Treatments under I1 consistently received more water than I2, reflecting their higher irrigation frequency. Treatment I1F2 recorded the highest IWa values (1741.41 and 1829.88 m³/fed), whereas I2F4 registered the lowest (1578.41 and 1678.88 m³/fed). These variations reflect the cumulative influence of irrigation scheduling and fertilization strategy. The observed trend is **in** consistent with El-Agrodi *et al.* (2016), who reported significant water savings under irrigation at 75% available soil moisture depletion. The data highlight that irrigation scheduling had a greater influence on IWa than fertilization strategy.

Table 3. Seasonal irrigation water applied (IWa, m³/fed), irrigation water (Wa, m³/fed), effective rainfall (Pe, m³/fed), and number of irrigation events across treatments in both growing seasons.

Treatments	NO. Irr.		Wa (m ³ /fed)		Pe (m ³ /fed)		IWa (m ³ /fed)	
	2022/23	2023/24	2022/23	2023/24	2022/23	2023/24	2022/23	2023/24
I1F1	4	5	1295	1570	444.41	257.88	1739.41	1827.88
I1F2	4	5	1297	1572			1741.41	1829.88
I1F3	4	5	1293	1567			1737.41	1824.88
I1F4	4	5	1289	1562			1733.41	1819.88
I2F1	3	4	1136	1422			1580.41	1679.88
I2F2	3	4	1173	1464			1617.41	1721.88
I2F3	3	4	1139	1426			1583.41	1683.88
I2F4	3	4	1134	1421			1578.41	1678.88

* I1: Irrigation at 100% water requirement and I2: Irrigation at 75% water requirement. F1: soil-applied NPK, F2: F1 + foliar NPK, F3: foliar NPK + supplementary fertilizer, F4: soil-applied supplementary fertilizer only.

Soil Chemical Properties

Soil EC, organic matter, and available N, P, and K were significantly affected by irrigation regime and fertilization treatment ($P < 0.001$), with the exception of OM in 2024 (Figure 1-3).

As expected, soil EC was highest under the I2 regime, particularly with F1 fertilization (3.08 and 2.87 dS/m in 2023 and 2024, respectively), indicating salt accumulation under reduced irrigation (Figure 1). Conversely, I1F4 had the lowest EC (2.32 and 2.03 dS/m), likely due to increased leaching under frequent irrigation. These findings are in line with Wen *et al.* (2020), Ren *et al.* (2019), and Yuan *et al.* (2019), who reported that increased salinity under deficit irrigation due to reduced leaching capacity.

Organic matter content was highest under I2F2 (2.20% and 2.02%), reflecting the combined effect of foliar and soil-applied fertilization (Figure 2). While, the lower levels under I1F4 (1.87% and 1.85%). The effect of irrigation on organic matter was less pronounced in the second season ($P = 0.124$), the

combined application of soil and foliar fertilizers (F_2 and F_3) enhanced organic matter accumulation, likely due to increased root biomass and microbial activity (Khan *et al.*, 2023).

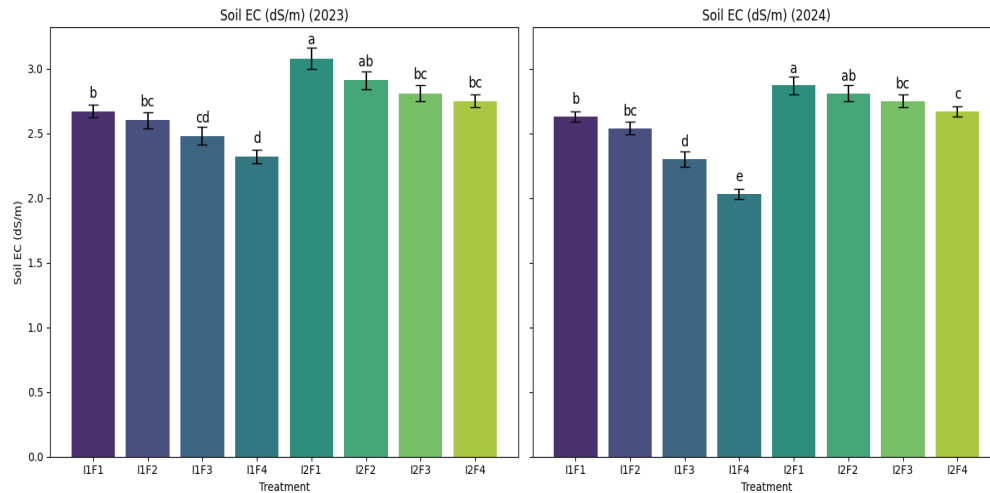


Figure 1. Soil EC (ds/m) under various irrigation and fertilization treatments in 2023 and 2024 seasons. Mean values $\pm$ Standard deviation of means of treatments.

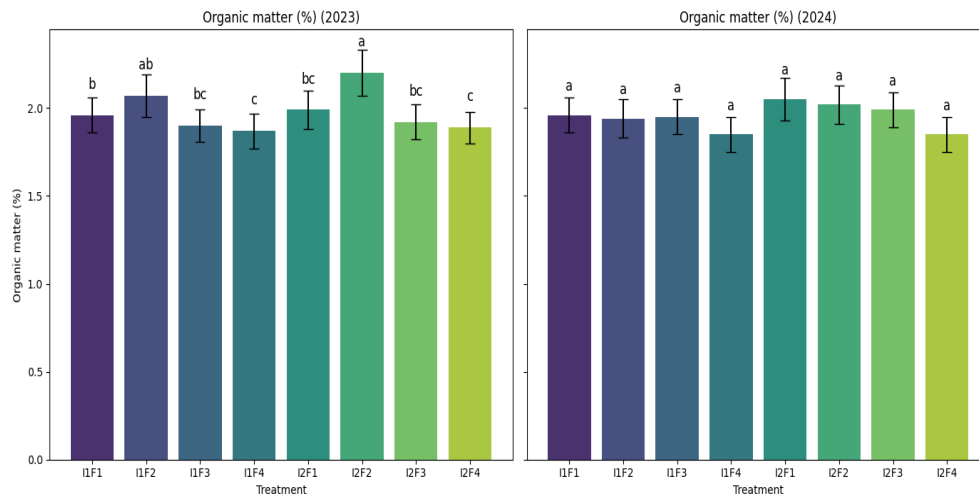


Figure 2. Organic matter content (%) under various irrigation and fertilization treatments in 2023 and 2024 seasons. Mean values $\pm$ Standard deviation of means of treatments.

Available N peaked under I2F1 (29.12 and 33.14 mg/ kg), indicating that irrigation under moderate depletion levels enhances N mineralization and retention (Amare *et al.*, 2024). Phosphorus and potassium followed similar

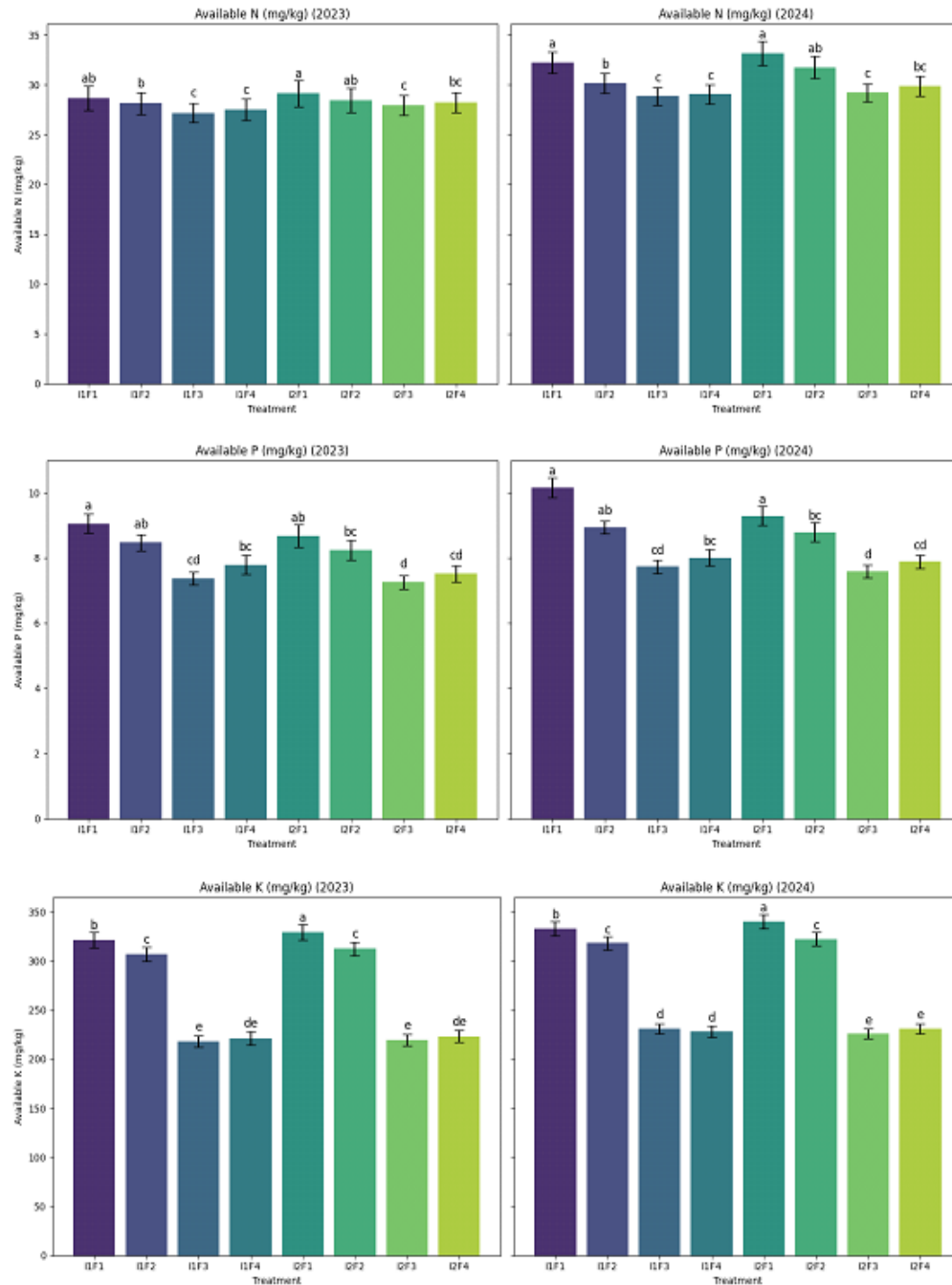


Figure 3. Some soil chemical properties under various irrigation and fertilization treatments in 2023 and 2024 seasons. Mean values $\pm$ Standard deviation of means of treatments.

trends, with maximum availability under I2F1 and I2F2, and minimal levels under I1F3 and I1F4 (Figure 3). These patterns affirm the role of both irrigation frequency and nutrient source in maintaining soil fertility under arid conditions (Zhang *et al.*, 2022).

Yield parameters

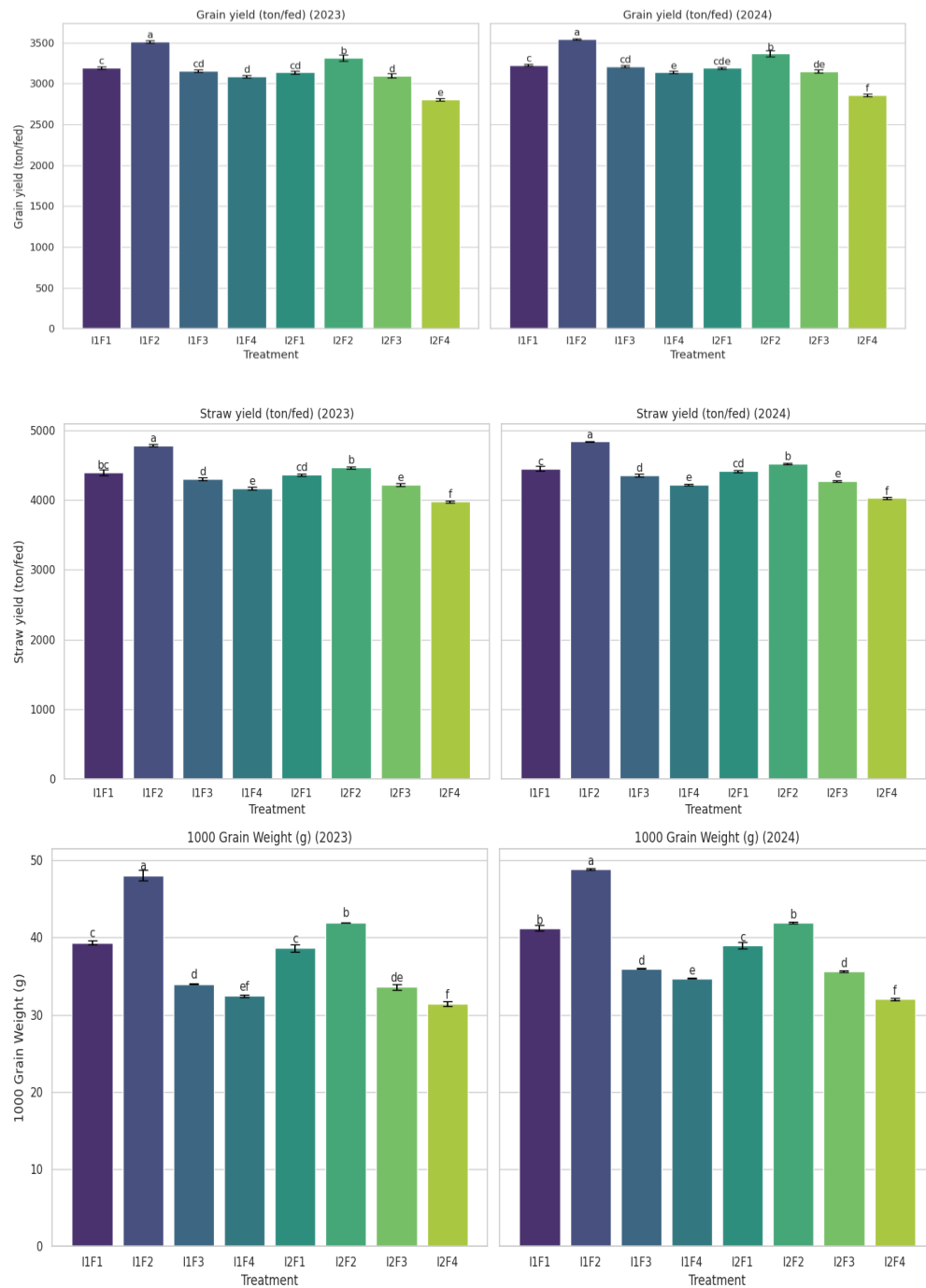
All yield parameters, including grain yield, straw yield, thousand-grain weight, and grain protein content, were significantly influenced by the interaction between irrigation regime and fertilization treatment ($P < 0.01$) (Figure 4).

The I1F2 treatment consistently produced the highest grain yields (3.51 and 3.55 t/fed in 2023 and 2024, respectively) and straw yields (4.79 and 4.84 t/fed), indicating that the combination of adequate irrigation (I1: Irrigation at 100% water requirement) with both soil-applied and moderate foliar fertilization (F2) optimized nutrient availability and uptake during critical growth stages. This combination likely promoted better vegetative growth, more efficient translocation of assimilates to the grains, and improved reproductive development, resulting in higher biomass and grain production.

In contrast, the I2F4 treatment recorded the lowest yields (2.81 and 2.86 t/fed), suggesting that under deficit irrigation (I2: Irrigation at 75% water requirement), even the highest rate of foliar NPK application (F4) could not compensate for limited water availability. Water stress likely restricted nutrient uptake, photosynthesis, and assimilate partitioning, thereby reducing both vegetative and reproductive growth.

Thousand-grain weight, a proxy for grain size and maturity, was also maximized under I1F2 (48.07 and 48.91 g), while the lowest values were recorded in I2F4 and I1F4, reflecting nutrient deficiency under reduced fertilization. Foliar fertilization has been shown to enhance assimilate translocation and grain filling, particularly under water-limited conditions (Kumar *et al.*, 2025).

Grain protein content was highest in I2F2 (12.71% and 14.62%), indicating improved N assimilation under moderate water stress and foliar nutrient supply. Lowest protein content was observed in F4 treatments, likely due to limited nitrogen availability. These findings align with previous studies (Basvantrao, 2024; Shoukat Hafiza *et al.*, 2025) that reported enhanced protein content with foliar NPK under drought stress.



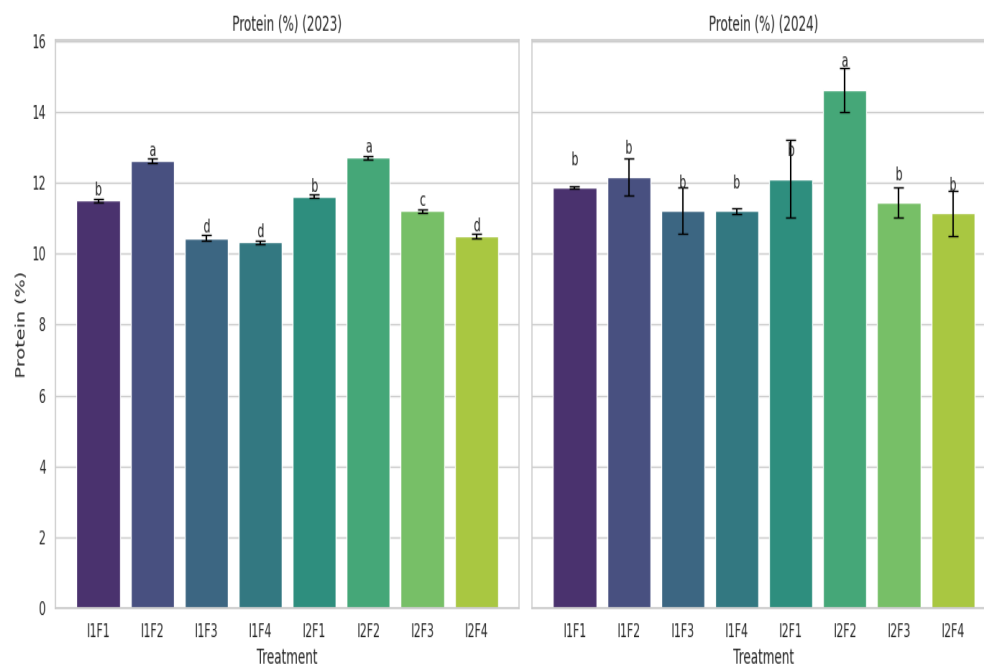


Figure 4. Grain yield, straw yield, 1000-grain weight, and protein content of wheat under various irrigation and fertilization treatments in 2023 and 2024 seasons.

Nutrient uptake and Irrigation water productivity

Nitrogen, phosphorus, and potassium uptake, as well as Irrigation water productivity (IWP), were significantly affected by the interaction during the 2023 and 2024 seasons (Figure 5-6).

The highest nutrient uptake occurred in treatment I1F2. This treatment resulted in the highest uptake of nitrogen (77.18 and 85.72 kg/fed), phosphorus (25.06 and 25.65 kg/fed), and potassium (18.74 and 19.15 kg/fed) in 2023 and 2024, respectively (Figure 5). In contrast, the lowest uptake was observed in treatment I2F4, where irrigation was low and fertilization was minimal. This highlights the advantage of balanced irrigation and nutrient application in enhancing plant nutrient availability and uptake. These results are supported by Khan *et al.*, (2023) and Zhang *et al.*, (2022), who observed that optimal irrigation and nitrogen levels improve nutrient mobility and uptake.

Irrigation water productivity (IWP), calculated as grain yield per cubic meter of water (kg/m^3), was also significantly affected by treatments (Figure 6). The highest IWP was recorded in I2F2 (2.05 and 1.96 kg/m^3). The lowest IWP was found in I2F4 (1.78 and 1.70 kg/m^3), where low irrigation requirements combined with low fertilizer application resulted in inefficient water use, likely contributing to lower grain yields.

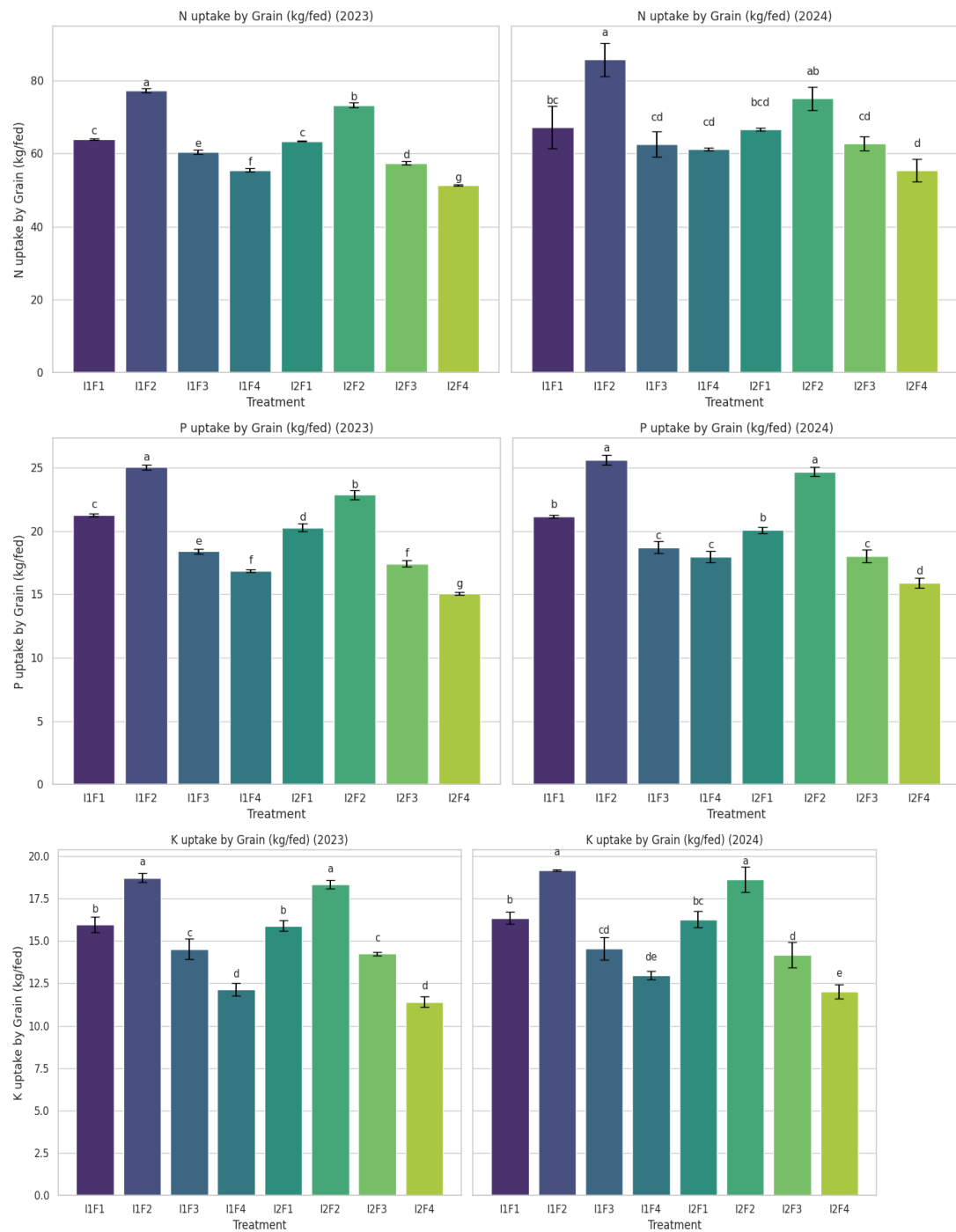


Figure 5. Nutrient uptake (N, P, K) and Irrigation water productivity (IWP) under different irrigation and fertilization treatments in the 2023 and 2024 seasons.

Similarly, El-Agrodi *et al.*, (2016) reported that the best nutrient uptake and IWP occurred when irrigating after 45% soil moisture depletion with increased nitrogen dosage. These results were observed when irrigating after 75% depletion and without nitrogen application. These results emphasize the importance of timely irrigation and adequate nutrient supply.

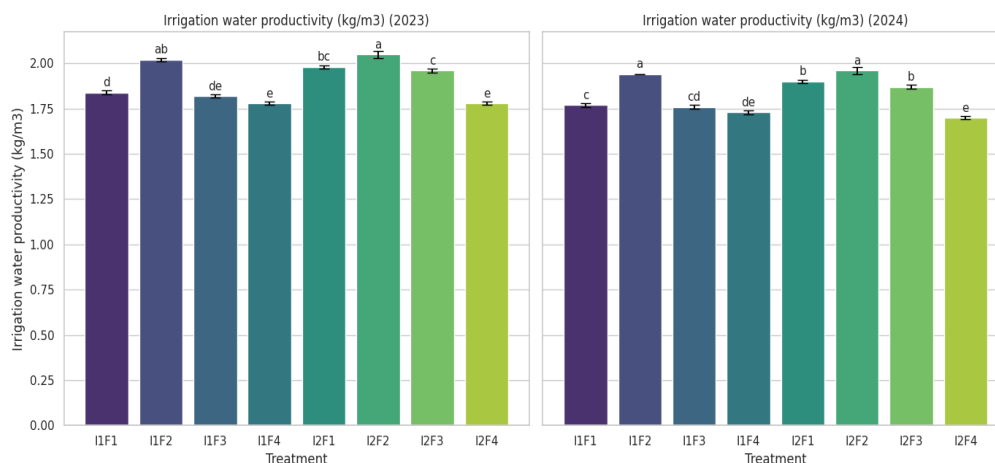


Figure 6. Irrigation water productivity (IWP) under different irrigation and fertilization treatments in the 2023 and 2024 seasons.

Adequate water supports vital metabolic processes such as photosynthesis and respiration, enhancing nutrient uptake and yield formation (Verma *et al.*, 2023). Shoukat Hafiza *et al.*, (2025) also found that the independent irrigation rate (IWP) remained stable under 100%, 80%, and 60% irrigation, but declined sharply under severe irrigation deficit (40%). Zhang *et al.*, (2023) noted that water use was highest between the budding and flowering stages, and that post-replanting irrigation improved flag leaf function and IWP.

In addition to soil-based fertilization, foliar fertilization has shown promising results in improving resource use efficiency, especially under water scarcity conditions (Sulaman *et al.*, 2025; Niu *et al.*, 2021).

Research by Pandya *et al.* (2023) and others (Amanullah *et al.*, 2021; Shabbir *et al.*, 2016) demonstrated that foliar application of nitrogen, phosphorus, and potassium enhances drought tolerance, antioxidant enzyme activity (e.g., nitrate reductase, catalase, peroxidase), and the accumulation of osmotic stress-preserving agents such as proline and soluble sugars, ultimately improving wheat yield and quality. Basvantrao (2024) also reported increased nitrogen uptake and protein content with foliar application under drought conditions.

In Conclusion

This study evaluated the interactive effects of irrigation scheduling and fertilization strategies on wheat yield, nutrient uptake, and irrigation water productivity in clay soils over two consecutive growing seasons. The results showed that irrigation at 50% depletion of available soil moisture, combined with both soil and foliar NPK fertilization (I1F2), significantly enhanced grain yield (up to 3.55 t/fed), 1000-grain weight, protein content, and nutrient uptake (N, P, K), compared to other treatments.

While I1F2 was optimal for maximizing yield and nutrient acquisition, the treatment combining 75% depletion with integrated fertilization (I2F2) achieved the highest irrigation water productivity (up to 2.05 kg/m³), indicating better water use efficiency under reduced irrigation. This suggests that moderate deficit irrigation supported by foliar fertilization can be a viable strategy for conserving water without major yield penalties.

The findings highlight the importance of integrated irrigation–fertilization management in optimizing crop productivity and resource efficiency. These results provide a practical framework for improving wheat production under water-limited conditions, supporting sustainable agriculture in semi-arid environments

Acknowledgement

The authors express their sincere gratitude to the Soils, Water, and Environment Research Institute (SWERI), Agricultural Research Center (ARC), Giza, Egypt, for their support throughout this study. Special thanks are extended to the Departments of Soil Chemistry and Physics, Soil Improvement and Conservation, and Soil Microbiology at Sakha Research Station, Kafr El-Sheikh, for their assistance in soil and plant analyses. The authors declare that this study received no financial support from internal or external sources.

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الملخص العربي

التأثيرات المشتركة للري الناقص والتسميد الورقي بالنيتروجين والفوسفور والبتواسيوم على سلوك القمح وديناميكيات التربة تحت ظروف محدودة المياه

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قيمت هذه الدراسة الآثار المشتركة لمستويات نقص الري ومعاملات التسميد على محصول القمح، وامتصاص العناصر الغذائية، والخصائص الكيميائية للتربة، والإنتاجية المياه تحت ظروف الحقل في شمال مصر. طُبِّق تصميم القطع المنشقة مرة واحدة بثلاث مكررات على مدار موسمين شتويين (٢٠٢٢/٢٠٢٣ و ٢٠٢٣/٢٠٢٤) في محطة بحوث القرصا. وكانت القطع الرئيسية مستويات نقص الري، الري ب ١٠٠% (I1) و ٧٥% (I2) من الاحتياجات المائية للقمح. بينما تضمنت القطع الفرعية أربع معاملات للتسميد: F1: إضافة التسميد الارضى من النيتروجين والفوسفور والبتواسيوم الموصى به (الكنترول)، F2: F1 + الرش الورقى بالنيتروجين والفوسفور والبتواسيوم (٢٠:٢٠:٢٠)، F3: تسميد ارضى تكميلى + الرش الورقى بالنيتروجين و الفوسفور و البتواسيوم (٢٠:٢٠:٢٠)، F4: تسميد ارضى تكميلى فقط. وشملت القياسات صفات نمو القمح، محصول الحبوب والقش، امتصاص العناصر الغذائية، الخصائص الكيميائية للتربة، وإنتاجية مياه الري. أظهرت النتائج تفاعلاً مهماً بين استراتيجيات الري والتسميد. أعطت المعاملة الري ب ١٠٠% من الاحتياج المائى مع إضافة التسميد الارضى والرش الورقى بالنيتروجين والفوسفور والبتواسيوم (I1F2) أعلى إنتاجية لمحصول الحبوب (٣.٥٥ طن/فدان) وحسنت من امتصاص العناصر الغذائية وتراكم الكتلة الحيوية. في

المقابل، اعطت المعاملة الري ب ٧٥% من الاحتياج المائي مع اضافة التسميد الارضى و الرش الورقى بالنيتروجين و الفوسفور و البوتاسيوم (I2F2) افضل إنتاجية لمياه الري (تصل إلى ٢.٠٥ كجم/ م^٢)، مما يشير إلى تحسن إنتاجية مياه الري مع انخفاض طفيف في محصول الحبوب. أدى تقليل الري و معاملات التسميد إلى تحسين محتوى التربة من العناصر الغذائية و المادة العضوية، بينما أدى إلى زيادة ملوحة التربة. تسلط هذه النتائج الضوء على ضرورة التوازن بين تعظيم محصول الحبوب والحفاظ على موارد المياه.

التوصية: يمكن ان يكون دمج نقص الري المعتدل مع التسميد الورقي والتربة بالنيتروجين والفوسفور والبوتاسيوم كاستراتيجية فعالة لتحسين إنتاجية القمح واستدامته تحت ظروف محدودة المياه السائدة في شمال مصر.