



International Journal of Agriculture Extension and Social Development

ISSN Print: 2618-0723
ISSN Online: 2618-0731
NAAS Rating (2026): 5.04
IJAESD 2026; 9(10): 326-329
www.extensionjournal.com
Received: 28-07-2026
Accepted: 24-09-2026
Published: 09-10-2026

Lakhan Singh

M.Sc. Scholar, Department of
Agronomy, Suresh Gyan Vihar
University, Jaipur, Rajasthan,
India

Hansraj Shivran

Assistant Professor,
Department of Agronomy,
Suresh Gyan Vihar University,
Jaipur, Rajasthan, India

Vaishali Chaturvedi

Assistant Professor,
Department of PBG, Suresh
Gyan Vihar University, Jaipur,
Rajasthan, India

Anil Jakhar

Assistant Professor,
Department of Agronomy,
Suresh Gyan Vihar University,
Jaipur, Rajasthan, India

LS Dhayal

Assistant Professor,
Department of Agronomy,
Suresh Gyan Vihar University,
Jaipur, Rajasthan, India

Corresponding Author: Lakhan Singh

M.Sc. Scholar, Department
of Agronomy, Suresh Gyan
Vihar University, Jaipur,
Rajasthan, India

Response of wheat (*Triticum aestivum* L.) to irrigation scheduling under varying fertility levels

Lakhan Singh¹, Hansraj Shivran², Vaishali Chaturvedi³, Anil Jakhar⁴, LS Dhayal⁵

DOI: <https://www.doi.org/10.33545/26180723.2026.v9.i10e.4399>

ABSTRACT

A field study was carried out during the rabi season of 2024 at the Agricultural Research Farm of Suresh Gyan Vihar University, Jaipur (Rajasthan) on loamy sand soil. The study was laid out in a split-plot design with three replications comprising combinations of four irrigation schedules and four fertility levels. The wheat variety Raj 4238 was used as the test crop.

The findings revealed that among the irrigation treatments, 1.0 IW/CPE (I_3) recorded the maximum plant height (110.05 cm), dry matter accumulation (10.77 g/plant) and chlorophyll content (43.43), along with the highest grain yield (4950 kg/ha), straw yield (6180 kg/ha) and biological yield (11130 kg/ha). The values recorded under 1.2 IW/CPE (I_4) remained statistically at par with I_3 for growth parameters. Fertility levels also significantly improved crop growth and productivity. Application of 100% RDF (F_3) resulted in the maximum plant height (110.91 cm), dry matter accumulation (10.72 g/plant), chlorophyll content (43.05), grain yield (4850 kg/ha), straw yield (6127 kg/ha) and biological yield (10977 kg/ha). The corresponding values under 125% RDF (F_4) remained statistically at par with F_3 . Harvest index was not significantly affected by either irrigation or fertility levels. Overall, the results indicated that irrigation scheduling at 1.0 IW/CPE with 100% RDF was effective in improving the growth and productivity of wheat under the experimental conditions.

Keywords: Fertility, Growth, IW/CPE, Yield

Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops and plays a central role in global food and nutritional security. In India, wheat is a major rabi cereal and contributes substantially to national foodgrain production. Its productivity, however, is strongly influenced by the availability of irrigation water and adequate nutrient supply, particularly under the semi-arid agro-climatic conditions of north-western India. Improving wheat productivity under such conditions requires efficient synchronization of crop water and nutrient requirements with available resources.

Water is one of the major limiting factors for wheat production in water-constrained environments. Both inadequate and excessive irrigation can adversely affect crop performance. Water deficit during critical growth stages may reduce tiller survival, leaf area development, photosynthetic activity, spike formation and grain filling, whereas excessive irrigation may increase water consumption and nutrient losses without corresponding improvement in yield. Therefore, irrigation scheduling based on crop water demand is essential for maintaining favourable soil-water conditions and improving water productivity. Recent research has demonstrated that appropriate irrigation management can improve wheat yield and resource-use efficiency, while the response depends on the timing and amount of irrigation (Farouk *et al.*, 2024; Meena *et al.*, 2024) [1, 2].

The irrigation water to cumulative pan evaporation (IW/CPE) ratio is a practical and widely used approach for scheduling irrigation in wheat. Under the semi-arid conditions of Rajasthan, irrigation scheduling around 0.9–1.0 IW/CPE has been associated with improved growth, yield attributes, grain and straw yield, nutrient uptake and economic returns. Studies conducted at Jobner have also demonstrated that suitable IW/CPE-based scheduling can improve wheat yield and water-use efficiency, while appropriate scheduling during vegetative and reproductive phases can save irrigation water without substantial yield reduction (Verma *et al.*, 2024; Meena *et al.*, 2024) [3, 2].

Nutrient availability is another important determinant of wheat productivity. Nitrogen plays a major role in leaf area development, chlorophyll formation, photosynthesis, tillering and grain protein accumulation, while phosphorus and potassium contribute to root development, energy transfer, assimilate transport and grain formation. An insufficient nutrient supply can restrict crop growth and yield formation, whereas excessive fertilizer application may reduce nutrient-use efficiency and increase production costs and nutrient losses. Consequently, optimizing fertility levels is essential for achieving higher productivity and economic returns.

Recent research has increasingly emphasized the importance of integrated water and nutrient management rather than optimizing irrigation and fertilization independently. Farouk *et al.* (2024) [1] reported that inte

grated management involving irrigation, nutrition and organic amendments improved wheat growth and yield, with drip irrigation producing greater productivity than sprinkler irrigation under their experimental conditions. Similarly, recent field studies have shown that irrigation and nitrogen fertilization can jointly influence wheat population development, canopy photosynthesis, root growth, yield formation and resource-use efficiency (Li *et al.*, 2025; Zhang *et al.*, 2025) [4].

The interaction between water and nitrogen is particularly important because soil moisture affects nutrient availability, movement and uptake, while adequate nutrient supply promotes root development and crop growth, thereby influencing crop water demand. A recent seven-year field study demonstrated that integrated optimization of irrigation and nitrogen management could improve wheat productivity while reducing nitrate leaching, with insufficient nitrogen primarily reducing yield through a decline in spike number (Li *et al.*, 2026) [5]. Another recent study reported that combining a water-saving irrigation schedule with optimized nitrogen supply improved wheat yield, crop water productivity, irrigation water productivity and profitability, demonstrating the potential for synchronizing water and nitrogen management (2026) [6].

Materials and methods

The field experiment entitled “Response of Wheat (*Triticum aestivum* L.) to Irrigation Scheduling under Varying Fertility Levels” was conducted during the *rabi* season of 2024 at the Agricultural Research Farm of Suresh Gyan Vihar University, Jaipur (Rajasthan), on loamy sand soil. The study was laid out in a split-plot design with three replications comprising combinations of four irrigation schedules and four fertility levels. The irrigation treatments were I_1 : 0.6 IW/CPE, I_2 : 0.8 IW/CPE, I_3 : 1.0 IW/CPE and I_4 : 1.2 IW/CPE, which were allocated to the main plots. The four fertility levels were F_1 : 50% RDF, F_2 : 75% RDF, F_3 : 100% RDF and F_4 : 125% RDF, which were assigned to the sub-plots. Thus, the experiment comprised 16 treatment combinations of irrigation scheduling and fertility levels. The wheat variety Raj 4238 was used as the test crop. The experimental farm is located in the south-eastern part of Rajasthan at an elevation of 548 m above mean sea level, between 26°92' N latitude and 75°77' E longitude, and falls under agro-climatic zone III-A (Semi-Arid Eastern Plain) of Rajasthan. The region experiences a typical semi-arid climate, characterized by wide variations in temperature during summer and winter seasons. The average annual rainfall of Jaipur ranges from 400 to 450 mm, of which nearly 80-85 per cent is received through the south-west monsoon, mainly from July to early September. During the cropping period, the maximum temperature varied from 27.41 to 31.71 °C, while the minimum temperature ranged between 7.71 and 12.85 °C. The relative humidity fluctuated up to 91 per cent during the season. Average daily sunshine hours ranged from 0.68 to 5.01 hours, whereas wind velocity varied between 0.88 and 2.82 km/h. The recorded observations were statistically analyzed using standard procedures as described by Fisher (1950) [7].

Results and discussion

The data on plant height, dry matter accumulation and chlorophyll content of wheat as influenced by irrigation scheduling and fertility levels are presented in Table 1. All the growth parameters showed a significant response to irrigation and fertility levels. Among the irrigation treatments, I_3 (1.0 IW/CPE) recorded the highest plant height (110.05 cm), dry matter accumulation (10.77 g/plant) and chlorophyll content (43.43), whereas the corresponding minimum values of 92.05 cm, 8.16 g/plant and 38.28, respectively, were recorded under I_1 (0.6 IW/CPE). The values under I_4 (1.2 IW/CPE) were 108.75 cm, 10.47 g/plant and 42.75, respectively, and remained statistically at par with I_3 for all the growth parameters. The improvement in growth under 1.0 IW/CPE may be attributed to more favourable soil moisture conditions, which enhanced root activity, nutrient absorption, leaf development and photosynthetic efficiency. Adequate moisture avail-

ability also facilitates maintenance of leaf water status and physiological activity, thereby promoting assimilate production and dry matter accumulation. However, increasing irrigation from 1.0 to 1.2 IW/CPE did not result in a significant improvement, indicating that the crop had adequate moisture availability at 1.0 IW/CPE and additional irrigation did not provide a proportional growth advantage. A recent meta-analysis reported that irrigation substantially improves wheat yield and yield components, although the magnitude of response depends on irrigation amount, timing and environmental conditions (Yang *et al.*, 2025) [8]. Similarly, Dwivedi *et al.* (2026) [6] observed that irrigation frequency had a stronger influence on wheat performance and water-use indices than increasing nitrogen beyond the recommended level under subtropical conditions.

Fertility levels also produced a marked improvement in the growth of wheat. F_3 (100% RDF) recorded the maximum plant height (110.91 cm), dry matter accumulation (10.72 g/plant) and chlorophyll content (43.05), while the minimum values (82.87 cm, 8.02 g/plant and 37.25, respectively) were obtained with F_1 (50% RDF). The values recorded under F_4 (125% RDF), viz., 108.23 cm, 10.43 g/plant and 42.43, respectively, were statistically at par with F_3 . The progressive improvement from 50 to 100% RDF may be attributed to greater availability of essential nutrients, particularly nitrogen, which promotes cell division, leaf expansion, chlorophyll synthesis and photosynthetic activity, thereby increasing biomass production. Nitrogen also plays an important role in the formation of chlorophyll and photosynthetic enzymes, resulting in greater assimilate production and vegetative growth. The absence of a significant advantage of 125% RDF over 100% RDF suggests that the recommended fertilizer level was sufficient to meet the crop nutrient requirement under the prevailing conditions. Similar findings have been reported in recent wheat studies, where increasing nitrogen supply improved crop growth up to an optimum level, while application beyond the recommended rate provided little additional benefit and reduced nutrient-use efficiency (Mandal *et al.*, 2024; Li *et al.*, 2026) [5]. The improvement in growth under optimum irrigation and fertility can also be explained by the interaction between soil moisture and nutrient availability. Adequate moisture favours nutrient dissolution, movement and uptake, while sufficient nutrient availability promotes root development and canopy growth, allowing the crop to utilize available water more effectively. Recent field research has demonstrated that integrated irrigation and nutrient management can improve wheat growth, dry matter production and resource-use efficiency compared with sub-optimal water or nutrient supply (Li *et al.*, 2026) [5]. Likewise, a recent Indian study reported that precise irrigation combined with appropriate nitrogen scheduling enhanced plant height, dry matter accumulation and other growth attributes of wheat (Kaur *et al.*, 2024) [9].

The data presented in table 2 indicated that irrigation levels significantly influenced grain, straw and biological yields of wheat, whereas harvest index remained statistically non-significant. Among the irrigation treatments, I_3 (1.0 IW/CPE) recorded the highest grain yield (4950 kg/ha), straw yield (6180 kg/ha) and biological yield (11130 kg/ha). It was followed by I_4 (1.2 IW/CPE), while the lowest values were recorded under I_1 (0.6 IW/CPE). The increase in yield with improved irrigation may be attributed to better soil-moisture availability during critical growth and grain-filling stages, which favoured assimilate production and translocation. Recent studies have similarly reported significant improvement in wheat grain yield with optimized irrigation regimes and adequate water availability during critical growth stages (2024).

Under fertility levels, grain, straw and biological yields increased significantly with increasing fertility up to F_3 (100% RDF), which recorded 4850, 6127 and 10977 kg/ha, respectively. F_4 (125% RDF) remained statistically comparable with F_3 for yield parameters. The higher yield under adequate fertility may be attributed to improved nutrient availability, crop growth and assimilate accumulation. Similar recent research has demonstrated that appropriate integration of irrigation and nutrient management can substantially improve wheat productivity and resource-use efficiency.

Harvest index varied from 43.74 to 44.47% under irrigation levels and from 42.15 to 44.29% under fertility levels; however, the differences were non-significant. This indicates that irrigation and fertility treatments increased total biomass and grain production in broadly similar proportions rather than substantially altering partitioning towards grain. The present findings are consistent with recent wheat research showing that irrigation and nutrient management primarily affect biomass and grain yield through improved crop growth and grain filling.

Conclusion

On the basis of the results obtained from the present investigation, it can be concluded that the irrigation levels, 1.0 IW/CPE (I_3), in combination with 100% RDF (F_3), significantly enhanced the growth and

yield of wheat. This integrated approach proved effective in improving crop performance under the prevailing agro-climatic conditions.

Acknowledgement

I express my sincere gratitude to my Major Advisor for their invaluable guidance, continuous encouragement and unwavering support throughout the course of this investigation. I am also deeply thankful to the members of my advisory committee for their constructive suggestions and insightful guidance, which greatly contributed to the successful completion of this work. I extend my heartfelt appreciation to the Head, faculty members and non-teaching staff of the Department of Agronomy, Suresh Gyan Vihar University, Jaipur (Rajasthan), for their kind cooperation, timely assistance and constant support during the course of the study.

Table 1. Effect of irrigation levels under varying fertility levels on growth parameters at harvest of wheat

Treatment	Growth parameters		
	Plant height (cm)	Dry matter accumulation (g/plant)	Chlorophyll content At 50 DAS
Irrigation			
I_1 : 0.6 IW/CPE	92.05	8.16	38.28
I_2 : 0.8 IW/CPE	100.58	9.24	41.15
I_3 : 1.0 IW/CPE	110.05	10.77	43.43
I_4 : 1.2 IW/CPE	108.75	10.47	42.75
SEM ($\pm$)	2.06	0.36	0.64
CD ($p = 0.5$)	6.19	1.09	1.91
CV (%)	8.14	8.83	8.35
Fertility level			
F_1 : 50% RDF	82.87	8.02	37.25
F_2 : 75% RDF	90.92	9.21	39.45
F_3 : 100% RDF	110.91	10.72	43.05
F_4 : 125% RDF	108.23	10.43	42.43
SEM ($\pm$)	1.96	0.34	0.57
CD ($p = 0.5$)	5.87	1.01	1.72
CV (%)	7.89	6.98	8.23

Table 2. Effect of irrigation levels under varying fertility levels on yields and harvest index of wheat

Treatment	Yield (kg/ha)			Harvest index (%)
	Grain yield	Straw yield	Biological yield	
Irrigation				
I ₁ : 0.6 IW/CPE	3948	5079	9027	43.74
I ₂ : 0.8 IW/CPE	4305	5480	9785	45.43
I ₃ : 1.0 IW/CPE	4950	6180	11130	44.47
I ₄ : 1.2 IW/CPE	4755	5952	10707	44.41
SEM (±)	134	138	181	0.83
CD (<i>p</i> = 0.5)	411	424	556	NS
CV (%)	8.20	8.42	8.76	7.84
Fertility level				
F ₁ : 50% RDF	3650	5009	8659	42.15
F ₂ : 75% RDF	4177	5403	9580	43.60
F ₃ : 100% RDF	4850	6127	10977	44.18
F ₄ : 125% RDF	4684	5892	10576	44.29
SEM (±)	126	131	178	0.81
CD (<i>p</i> = 0.5)	387	402	546	NS
CV (%)	7.82	7.89	8.07	7.84

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How to cite this article: Singh L, Shivran H, Chaturvedi V, Jakhar A, Dhayal L. Response of wheat (*Triticum aestivum* L.) to irrigation scheduling under varying fertility levels. *International Journal of Agriculture Extension and Social Development*. 2026;9(10):326–329. doi: <https://www.doi.org/10.33545/26180723.2026.v9.i10e.4399>