Examining the Effects of Diverse Irrigation Regimens and Planting Timelines on Wheat Growth, Yield, and Yield Characteristics

ABSTRACT

In the Rabi season spanning 2021 to 2022, a field trial was carried out on sandy loam soil. at a research station near the Center for Advanced Studies on Climate Change, Dr. RPCAU, Pusa, Bihar (India). Positioned at a latitude of 25°98' N and a longitude of 85°66' E. the experimental plot ascended to an elevation of 52.3 meters above mean sea level. The primary objective was to assess the effects of different irrigation levels and planting dates on the development, yield, and yield characteristics of wheat. The investigation included four irrigation management protocols (irrigation at 0.6, 0.8, 1.0, and 1.2 IW/CPE) assigned to the main plot, along with four sowing dates (15 Nov, 30 Nov, 15 Dec, and 30 Dec) allocated to the sub plot. This layout was replicated thrice in a split-plot configuration. The results indicated that the maximum values of growth factors (specifically plant height), yield factor (effective tillers/m^2), and yield (both grain and straw) were observed when irrigation was administered at 1.2 IW/CPE (I_4). This method, statistically comparable to irrigation at 1 IW/CPE (I_3), exhibited notable superiority over the other treatments. Conversely, the minimum values of plant height, effective tillers/m^2, grain yield, and straw yield were documented under the irrigation regimen

Keywords: [Wheat, Date of sowing, IW/CPE, Plant height, Effective tillers/m^2}

1. INTRODUCTION

Wheat, one of the world's most essential cereal crops, serves as a fundamental staple in global food security. Because wheat accounts for about 17% of the world's agricultural land area and yields 35% of food grains, this crop is essential to the world's food security both today and in the future [1]. According to the USDA, 2018, It holds a position of utmost significance among cereal crops., covering an area of 225.6 million hectares and producing 758.3 million tonnes overall. India produces 93.50 million tonnes of goods annually on a total land area of 30.17 million hectares [2]. National cereal production in 2023, including wheat crops to be harvested in March 2024, is estimated at 4.1 million tonnes, 46 percent below the output obtained in the previous year and about 40 percent below the average of the past five years (FAO 2023),[3]. In financial year 2021, Uttar Pradesh had the highest production volume of wheat at over 35 million metric tons across India. As agricultural landscapes evolve to meet increasing demands amidst environmental challenges, optimizing wheat production becomes imperative. Among the pivotal factors influencing wheat cultivation, irrigation regimens and planting timelines stand out as primary determinants of growth, yield, and yield characteristics.

The efficacy of irrigation practices profoundly shapes agricultural outcomes, particularly in regions prone to water scarcity or variability. Diverse irrigation techniques, ranging from traditional flood irrigation to modern precision methods, offer varying degrees of water efficiency and crop productivity. Understanding how different irrigation regimens impact wheat growth parameters such as biomass accumulation, water use efficiency, and physiological traits is critical for sustainable agriculture.

The important methods for planning wheat irrigation schedules are soil moisture depletion, environmental conditions Irrigation water (IW)/Cumulative pan evaporation (CPE), and physiological growth stages. The climatological technique is widely acknowledged by scientists and researchers worldwide as being scientific and practical. The fixed irrigation water IW to CPE ratio determines the crop irrigation schedule. Selecting the time and volume of water for irrigation is called irrigation scheduling. Sensible scheduling is possible by knowing the plant's initial soil water content. This makes it possible to figure out when to use the system for optimal irrigation. Timing of irrigation more effectively reduces costs and improves crop quality. Scientists and researchers usually acknowledge the scientific and advantageous climatological irrigation scheduling technique. So, IW/CPE ratio is a practical and informative metric in agronomy that helps farmers and stakeholders make informed decisions about irrigation management, contributing to sustainable crop production and efficient water use in agriculture.

Equally crucial is the timing of planting, which intersects with seasonal climate patterns and agronomic considerations. Planting timelines dictate the developmental trajectory of wheat plants, influencing key developmental stages such as tillering, flowering, and grain filling. Moreover, planting dates profoundly interact with environmental factors, including temperature, rainfall, and photoperiod, thereby modulating crop phenology and yield potential.

Despite the wealth of research on irrigation and planting effects individually, a comprehensive understanding of their combined influence on wheat production remains elusive. Addressing this knowledge gap is paramount for devising tailored agronomic strategies that maximize wheat productivity while minimizing resource inputs and environmental impacts.

In this study, we undertake a systematic investigation into the interactive effects of diverse irrigation regimens and planting timelines on wheat growth, yield, and yield characteristics. Through rigorous experimentation and data analysis, we aim to elucidate the complex dynamics shaping wheat cultivation in diverse agroecological contexts. Our findings hold implications for optimizing agricultural practices to enhance food security and sustainability in an era of climate uncertainty and burgeoning population pressures.

2. MATERIAL AND METHODS

2.1 Experimental Site and Treatment Details

During (2021–2022), an experimental plot was established at coordinates (25°98' N latitude and 85°66' E longitude), situated at an elevation of 52.3 meters above mean sea level. This plot was located within a research farm adjacent to the Center for Advanced Studies on Climate Change, Dr. RPCAU, Pusa, Bihar (India). The region experienced its typical annual rainfallof 1270 mm, out of which 80 to 90 % coming during the south west monsoon season. The highest RH was around 99% and lowest value was 31% in the entire crop growth period. The maximum temperature was up to 19.4-39.7°C with an average of 27.6°C. The minimum temperature was lowered around 8.6-18.1°C with an average of 12.91°C during the research programme from mid-November to mid-April. Various soil properties were noted, indicating a calcareous nature with a pH of 8.36 and an electrical conductivity (EC) of 0.46 dS/m. Additionally, the soil contained organic carbon at 0.38%, nitrogen (N) at 193.66 kg/ha, phosphorus (P) at 16.15 kg/ha, and potassium (K) at 87.04 kg/ha, with a determined texture of sandy loam. Utilizing a split-plot design, the investigation was replicated thrice, incorporating sixteen distinct treatments. per replication. The main plot consisted of four irrigation levels, indicated as IW/CPE=0.6, 0.8, 1, and 1.2, while the subplots replicated four different dates of sowing. The wheat variety under investigation was HD 2967, with a plant spacing of 10 cm between individuals and a row spacing of 20 cm. To minimize nitrogen fertilizer loss, the recommended dose of

120:60:40 was applied as a basal fertilizer during sowing, with full doses of phosphorus and potassium incorporated alongside one-third of the nitrogen dose. The residual nitrogen was divided and applied during two key stages: Crown Root Initiation (CRI) at 21 Days After Sowing (DAS) and the flag leaf stage, which typically arises at 58 DAS. During the vegetative phases, the height of the plants was recorded in centimeters (cm). by measuring from the base to the apex of each fully-grown leaf or from the awn tip to the tip at harvest. The count of effective tillers per square meter was determined by counting tillers per meter of row length at different intervals such as 30, 60, 90, and 120 days post-sowing, with each plant typically exhibiting three to five tillers. Yield attributes, including grain and straw yields, were derived from the collected data, which underwent statistical analysis utilizing a conventional split-plot design Further details regarding treatments are outlined in Table 1.

The IW/CPE ratio are calculated by the formula of $\frac{IW}{CPE} = \frac{Irrigation\ water}{Cumulative\ pan\ evaporation}$

The statistical analysis of the data was done as per procedure of analysis suggested by Gomez and Gomez(1984).

Fig. 1 Experimental location

Table 1. Details of the treatment

Symbol	Treatment details
Main plot (irrigation level)	

I_1	IW/CPE (0.6)
I_2	IW/CPE (0.8)
I_3	IW/CPE (1.0)
I_4	IW/CPE (1.2)
Subplot (Date of sowing)	
D_1	15th Nov
D_2	30th Nov
D_3	15th Dec
D_4	30th Dec

3. RESULTS AND DISCUSSION

3.1 Plant Height (cm)

During the initial 30 days after sowing (DAS), variations in irrigation schedules did not yield discernible effects on plant height, as evidenced by periodic measurements. However, significant increases in plant height were observed at 60, 90, and 120 DAS. Notably, treatment I_4 produced taller plants. While treatment I_4 demonstrated comparable performance to I_3), it notably surpassed I_2 and I_1. Conversely, treatment I_1, characterized by irrigation at 0.6 IW/CPE, resulted in the shortest plants. The pronounced increase in plant height observed under treatments I_4 and I_3 can be attributed to the provision of optimal moisture levels throughout both vegetative and reproductive phases, facilitating vigorous and vertical plant growth. Stem elongation, fueled by enhanced cell division and expansion induced by irrigation treatments I_4, notably contributed to overall plant height augmentation. In contrast, reduced cell enlargement due to moisture stress in plots subjected to treatment I_1 likely constrained plant growth, resulting in diminished plant height. These observations align with the findings of Bikrmaditya et al.[4], Singh et al. [5], and Vishuddha et al. [6], reinforcing the significance of irrigation management in influencing wheat plant height dynamics.

Furthermore, the data highlighted the significant impact of sowing dates on plant height during the recorded intervals of 30, 60, 90, and 120 days post-seeding. Notably, wheat sown on Nov 15 displayed substantially greater plant height in contrast to later sowings on Nov 30, Dec 15, and Dec 30. This difference can likely be attributed to the favorable environmental conditions experienced during the crop period associated with the Nov 15 sowing date Meena et al. [7], Mumtaz et al. [8]. Compared to the later dates, the extended period available for vegetative development after the Nov. 15 seeding most likely contributed to this result. Significant reductions in growth attributes were observed with delayed sowings, potentially arising from earlier crop maturation and delayed germination. Premature crop maturation may have been triggered by a sudden temperature surge during the reproductive phase, leading to delayed emergence associated with later sowing dates, possibly influenced by a decline in minimum temperatures at sowing. Consequently, adverse weather conditions have altered plant growth characteristics, resulting in the natural variations observed across sowing dates.

The interaction effect of irrigation level and date of sowing for plant height found to be non-significant.

Table 2. Effect of Irrigation level and sowing date on plant height (cm) at different growth stages of wheat

Treatment Details	30 DAS	60 DAS	90 DAS	120DAS
Main plot: Irrigation level				

I1: IW/CPE (0.6)	19.59	69.92	88.87	88.05
I2: IW/CPE (0.8)	19.76	74.50	91.61	90.22
I3: IW/CPE (1.0)	20.21	80.28	98.98	98.94
I4: IW/CPE (1.2)	20.21	83.56	100.00	99.98
SEm(±)	0.59	2.22	2.17	2.76
CD (p=0.05)	NS	7.70	7.51	9.54
Subplot: Date of sowing				
D1: 15 Nov	20.13	80.08	99.54	98.79
D2: 30 Nov	19.96	77.72	94.74	94.54
D3: 15 Dec	19.86	75.96	93.62	93.35
D4: 30 Dec	19.82	74.50	91.57	90.51
SEm(±)	0.04	0.65	1.34	1.28
CD (p=0.05)	0.11	1.96	4.02	3.83
Interaction (Main × Sub)				
SEm(±)	0.08	1.31	2.68	2.56
CD (p=0.05)	**NS**	**NS**	**NS**	**NS**

(DAS= Days after sowing, NS= Non-significant, SEM= Standard Error of Mean, CD= Critical difference)

3.2. Number of effective tillers/m^2

The data analysis revealed that the number of effective tillers per square meter at 60, 90, and 120 days after sowing (DAS) was significantly affected by the irrigation level treatments, as indicated in (Table 3). Treatment I_4 displayed a notable increase in the total number of tillers, comparable to treatment I_3, and significantly outperformed the other treatments. This improvement may be attributed to ample water availability and a more favorable rhizosphere environment, facilitating enhanced nutrient uptake and, consequently, accelerated growth and greater tiller production. These results are in agreement with earlier studies carried out by Singh et al. [9] and Kumar et al. [10] regarding wheat farming.

Similarly timing of sowing also significantly influenced the number of effective tillers per square meter, with late sowing notably diminishing these characteristics. Notably, the crop sown on Nov 15th exhibited the highest number of effective tillers per square meter, contrasting with the lowest observed by Dec 30th. This difference could be attributed to the delayed sowing, resulting in lower initial temperatures. However, the rapid increase in temperature from February onwards likely deprived the plants of sufficient favorable conditions to realize their full potential. Similar observations on this matter have been documented by Kumar and Sharma [11], Shahzad et al. [12], Kumar et al. [13], and Tomar et al. [14].

The interaction effect of irrigation level and date of sowing for effective tillers/m2 found to be non-significant.

Table 3. Effect of Irrigation level and sowing date on effective tiller/m2 at different growth stages of wheat

Treatment Details	60DAS	90DAS	120DAS
Main plot: Irrigation level			
I1: IW/CPE (0.6)	300.79	306.77	288.52
I2: IW/CPE (0.8)	310.81	317.34	299
I3: IW/CPE (1.0)	330.63	337.98	318.78
I4: IW/CPE (1.2)	346.19	354.31	334.83
SEm(±)	9.30	9.73	9.73
CD (p=0.05)	32.18	33.66	33.66
Subplot: Date of sowing			
D1: 15 Nov	358.60	365.60	348.66
D2: 30 Nov	333.62	340.45	322.30
D3: 15 Dec	309.98	317.08	296.95
D4: 30 Dec	286.23	293.28	273.22
SEm(±)	8.14	8.14	8.16
CD (p=0.05)	24.42	21.40	24.48
Interaction (Main × Sub)			
SEm(±)	16.29	16.27	16.33
CD (p=0.05)	NS	NS	NS

(DAS= Days after sowing, NS= Non-significant, SEM= Standard Error of Mean, CD= Critical difference)

3.3. Grain yield (t/ha)

This study revealed that plant nutrients, particularly N:P:K, were more readily available and potentially mobilized to enhance dry matter production under the I_4 irrigation regimen when soil moisture levels were optimal. Furthermore, increased yields under maximum irrigation levels may be attributed to water's crucial role in Enhance root growth., including reduced Soil resilience, increased transpiration, enhanced Absorption of nutrients, and heightened photosynthesis due to increased plant Biochemical processes Bhunia et al. [15]. Another factor that might have led to the enhanced yield could be the prolonged reproductive periods and expanded photosynthetic areas stemming from irrigation scheduling at 1.2 and 1.0 IW/CPE during both growth and reproductive stages. This enabled a larger distribution of net photosynthates to grains. These results align with earlier investigations by Sharma and Pannu [16] ,Sarwar et al. [17], Kumar et al [18], and Mishra and Kushwaha [19]. Additionally, yields from irrigation under I_4 were comparable to those from the I_3 system, although there were yield variations among treatments. This could be attributed to consistent water application in both I_4 and I_3, meeting atmospheric evaporative requirements during vegetative and reproductive phases regardless of the crop stage. Same findings have been Stated by Bandyopadhyay and Malick [20], Parihar and Tiwari [21], Sharma and Pannu [16] ,Bikrmaditya et al. [4] and Narolia et al.[22].

Similarly, grain yield exhibited a notable increase when sown on Nov 15 compared to Nov 30, as evidenced by statistical analysis (Table 4). The delay in seeding, starting from Nov 15th, significantly reduced grain yield. This decline is likely due to the delayed crop's inadequate expression of yield-contributing traits. Additionally, adverse environmental conditions characterized by high temperatures and strong winds accelerated crop maturation, thereby reducing grain yield. Conversely, early-sown crops experienced increased productivity due to an extended growth period and cooler temperatures, which facilitated superior yield characteristics Kulhari et al [23] .Notably, findings consistent with these observations have been reported by Kumar and Sharma [11], further supported by similar results documented by Mumtaz et al. [8]

In case of grain yield, the interaction effect of irrigation level and date of sowing was found to be significant. In this study, the I4D1 treatment combination yielded significantly higher grain yield compared to the I1D4 treatment combination, which had the lowest grain yield.

3.4 Straw yield (t/ha)

In terms of irrigation level, I_4 shows significant parity with I_3, which notably outperforms the remaining treatments. The crop displayed vigorous growth under conditions of optimal water availability, particularly during the vegetative phase, thereby enhancing growth characteristics. This phenomenon also offers a clear explanation for the increased production of straw under optimal irrigation regimes. These findings are consistent with previous research conducted by Sarwar et al.[17],Bandyopadhyay and Malick [20], Bikrmaditya et al.[4] and Narolia et al. [22].

Similarly, wheat straw production exhibited a notable increase when sown on Nov 15. However, the delayed commencement of sowing from Nov 15th led to a significant decrease in straw yield. This decline could be attributed to the reduced expression of yield-contributing traits in crops sown late, including spike count, ear length, grains per spike, and test weight. Moreover, adverse environmental factors such as high temperatures and strong winds hastened crop maturation, thereby reducing straw yield. Conversely, early-sown crops experienced heightened production due to their extended growing season and cooler temperatures, resulting in enhanced yield characteristics Kulhari et al. [23] . Similar findings were reported by Kumar and Sharma [11] closely aligning with those of Mumtaz et al. [8].

In case of straw yield, the interaction effect of irrigation level and date of sowing was found to be significant. In this study, the I4D1 treatment combination demonstrated a notably elevated straw yield in comparison to the I1D4 treatment combination, which exhibited the lowest straw yield.

Table 4. Effect of Irrigation level and date of sowing on grain yield and straw yield of wheat

Treatment Details	Grain yield (t/ha)	Straw yield (t/ha)
Main plot: Irrigation level		
I1: IW/CPE (0.6)	3.16	5.10
I2: IW/CPE (0.8)	3.97	5.98
I3: IW/CPE (1.0)	4.39	6.46
I4: IW/CPE (1.2)	4.66	6.73
SEm($\pm$)	0.10	0.16
CD (p=0.05)	0.34	0.54
Subplot: Date of sowing		

D1: 15 Nov	4.70	6.73
D2: 30 Nov	4.46	6.51
D3: 15 Dec	3.72	5.70
D4: 30 Dec	3.29	5.34
SEm(±)	0.06	0.07
CD (p=0.05)	0.19	0.21
Interaction (Main × Sub)		
SEm(±)	0.12	0.10
CD (p=0.05)	0.37	0.29

(S=significant, SEM= Standard Error of Mean, CD= Critical difference)

4. CONCLUSION

The irrigation regimen at (IW/CPE=1.2) notably resulted in the tallest plant height found to be significantly superior over other treatments at 30, 60, 90, and 120 DAS in terms of plant growth, yield, and yield attributes. Treatment I_4 also exhibited a substantially Increase in the quantity of productive tillers per square meter. comparable to I_3 yet significantly outperforming the rest of the treatment. Notably, wheat grain yield showed significant responsiveness to various irrigation schedules. Recording a yield of 4.66 tons per hectare (t/ha), treatment I_4 demonstrated markedly superior grain yield compared to other treatments, comparable to I_3 yet significantly outperforming the rest. Moreover, wheat straw yield exhibited profound sensitivity to irrigation timing, with treatment I_4 yielding the highest straw output at 6.73 t/ha, surpassing treatment I_3 and other treatments by a substantial margin.

Wheat plants subjected to delayed seeding, ranging from Nov 15 to Dec 30, exhibited diminished stem heights. Particularly, wheat sown on Nov 15 yielded significantly taller plants at 30, 60, 90, and 120 DAS compared to those sown on Nov 30, Dec 15, and Dec 30. The abundance of effective wheat tillers varied significantly with different planting dates, with seeding wheat on Nov 15 resulting in substantially more effective tillers compared to seeding on Nov 30, Dec 15, and Dec 30. Moreover, grain yield derived from seeding wheat on Nov 15 surpassed that from seeding on subsequent dates, including Nov 30, Dec 15, and Dec 30. The timing of wheat sowing exerted a considerable influence on straw output as well, with straw yield noticeably higher from wheat sown on Nov 15 compared to Nov 30, Dec 15, and Dec 30.

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COMPETING INTERESTS

The authors have stated that there are no conflicting interests.

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