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Yield and Yield Attributes of Wheat (*Triticum aestivum* L.) Crop under Different Thermal and Moisture Regimes

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ABSTRACT

A field experiment was carried out at Agrometeorological Research Farm of ANDUA&T., Kumarganj, Ayodhya (UP) during *rabi* 2022-23 and 2023-24 to study the impact of different thermal regimes/sowing environments and moisture levels on wheat yield and yield attributes. Treatment consisted of three thermal regimes viz.15th November, 25th November and 5th December in main plot with four moisture levels viz, I1 at CRI, I2-CRI+tillering, I3-CRI+ jointing and milking, I4-CRI+ jointing+anthesis and dough stage in sub plot. Results reveal that 15th November thermal regime and I4 moisture level obtained higher values of effective tillers m^{-2}, length of the spike, no. of spikes/plant, no. of grains/ear, no. of spikelet/spike, test weight followed by 25th November and minimum values were observed for crops sown on 5th December thermal regime during both year of experiment. There was significant variation observed in the grain yield, straw yield, biological yield, and harvest index among the three distinct thermal regimes. The highest yield 47.25 and 47.73 q ha^{-1} were recorded under the 15th November thermal regime, followed by 25th November (44.75 and 45.2 q ha^{-1}) and minimum at 5th December 36.75 and 37.1 q ha^{-1} during both year of experiment respectively. Among the moisture level I4 has obtained the maximum values of yield 46.67 and 47.1 q ha^{-1}during 2022-23 and 2023-24, respectively.

Keywords Wheat, Thermal regime, Moisture level, Yield.

INTRODUCTION

Wheat, at present, is among the most cultivated crops. It is the most consumed one globally. Wheat is considered as a good source of dietary fiber, minerals, B-group vitamins, and protein, despite the nutritional makeup of wheat grains might vary depending on the surrounding conditions. Wheat growth is influenced by the time it gets sown and how much irrigation water is used. Sowing time and irrigation control the wheat crop's growth characteristics. Early planting significantly affects the growth factors (Sattar *et al.* 2010). One significant variable that can be adjusted to alleviate the injuries impacts of environmental stress is the date of sowing. Any environmental stress during the key stages of crop can be avoided by altering the

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sowing date. Due to high-temperatures at the vegetative stages of crop growth, too early sowing of wheat results in weak plants with a poor root system, conversely, excessively late sowing causes poor tillering due to extremely low temperatures throughout crop growth. One significant weather factor that affects wheat phenophases and growth is temperature. Before reaching a particular phenological stage, plants need a certain amount of warmth. Due to its temperature sensitivity, it has turned out that late seeding accelerates crop maturity and forces crops to mature earlier in North Indian conditions. Correspondingly, maximizing yield and effectively converting biological production into economic yield depend on optimizing the sowing timing (Gupta *et al.* 2017).

Regular irrigations are necessary for increased crop yields, however in times of water scarcity, it is crucial to identify the vital growth stages of crop so that irrigation needs can be avoided without noticeably lowering grain yields. According to Kumar *et al.* (2014), the absence of irrigation during an important growth stage could result to a significant decrease in grain yield because of a reduction in test weight. As one of the best hydrological management techniques, effective water management likewise increases crop yield and reduces crop vulnerability to disease and insect pests in a habitat that is conducive to the growth of these biotic stresses (Singh *et al.* 2012).

Lower moisture and/or low soil temperature inhibit or delay seed germination, which leads to irregular growth of seedlings and ultimately decreases the final grain yield of crops because soil temperature and moisture availability both control seed germination. When water deficiencies are provided during the stages of stem elongation and heading, wheat yields are greatly decreased (Tari 2016).

The objective of this study is to find out the impact of various thermal regimes and moisture levels on yield and yield attributes of wheat crop.

MATERIALS AND METHODS

Study area

The experiment was carried out during *rabi* season of 2022-23 and 2023-24 on Wheat variety HD-2967 at the Agrometeorological Research Farm of ANDUA &T, Kumarganj, Ayodhya (UP) which is situated at 26°.47'N, 82°.12'E and 113 m above mean sea level.

Experimental details

Experiment was laid out with thermal regimes/ sowings environments D1-15th November, D2-25th November, D3-5th December along with four moisture levels were applied at different phenophases (I1-CRI, I2- CRI+tillering, I3- CRI+ jointing and milking, I4- CRI+ jointing +anthesis and dough stage) under split plot design with four replication at semi-arid climatic condition of eastern plain zone of Uttar Pradesh zone.

No. of tillers m^{-2}

In each plot, five randomly chosen locations were used to count the no. of tillers per m^{-2} at 30, 60 and 90 days following sowing. The average value was then calculated.

Effective tillers m^{-2}

Before the crop was harvested from a one-meter row length, the no. of effective tillers (m^{-2}) was counted in each treatment. The results were then presented in terms of square meters, and an average value was selected for further analysis.

Length of spike (cm)

By averaging the lengths of the sampled spikes, the length of each spike was reported in centimeters. The measurements were taken from the node at the base of the spike to the tip of the highest spikelet.

No. of spike /plant and No. of spikelets/ spike

Ten randomly chosen spikes at maturity from each plot were used to record the following spike attributes for the research of spike characteristics.

No. of grains/spike

All the 10 spikes were manually threshed and no.s of total grains were counted after cleaning. The no. of grains per spike was computed by averaging them.

Grain yield (q ha^{-1})

Total bundle weight was recorded from each plot at the time of harvesting. The crop was threshed and grain were weighted and presented in quintal/hectare.

Straw yield (q ha^{-1})

By deducting the weight of the grains from the total weight of the harvested crop in each net plot, the straw yield in kg plot^{-1} was computed.

Biological yield (q ha^{-1})

Crops were packed and weighed in kg plot^{-1} after harvest, and the results were converted to q ha^{-1}.

Harvest index (%)

The ratio of biological yield to economic yield is known as the harvest index. It is computed using the following formula, which expresses the fraction of photosynthesis that is directed toward grains :

$$HI = \frac{Grain\ yield}{Biological\ yield} \times 100$$

Statistical analysis

Statistical analysis of the data were done using analysis of variance (ANOVA) technique recommended for the design. Critical difference (CD) values were calculated at the 5% level of significance.

RESULTS AND DISCUSSION

Effect of treatments on yield attributing characters of wheat crop

No. of tillers m^{-2}

The no. of effective tillers m^{-2} varied notably across different thermal regimes during both crop seasons. Specifically, crops sown on D1 (15th November) exhibited significantly higher no.s of tillers m^{-2} (348.6 and 352.0), followed closely by D2 (346.1 and 349.6). Conversely, a reduced no. of effective tillers m^{-2} (344.3 and 347.7) was observed in crops sown later on D3 (5th December) during both crop seasons in 2022-23 and 2023-24, respectively. The shorter grain filling time resulting from greater thermal stress associated with advanced sowing dates can be the reason for a reduction in the no. of effective tillers/square meter with later sowing. These findings are consistent with research findings reported by Sattar *et al.* (2023). Within the various moisture levels evaluated, the treatment involving four irrigations (I4) at critical stages consistently recorded a significantly maximum no. of tillers m^{-2} (361.7 and 333.9) compared to other moisture treatments. Conversely, the I_1 treatment recorded the minimum no. of tillers m^{-2} (330.6 and 331.9) in both crop seasons, respectively (Table 1). These findings are in line with Patel *et al.* (2022).

Length of spike (cm)

The length of the spike exhibited significant variability under different thermal regimes and sowing dates across both crop seasons. Notably, crops sown on D1 (15th November) consistently obtained significantly longer spike length (13.2 and 13.1 cm), followed by D2 (12.2 and 12.0 cm), respectively for 2022-23 and 2023-24. Conversely, the lowest spike length (11.0 and 11.5 cm) was observed in D3 crops during both seasons, respectively. Specifically, sowing on the 15th of November was associated with longer ear lengths, potentially due to enhanced synthesis and allocation of resources towards seed development. These findings align with previous research by Tomar *et al.* (2014). Among the moisture levels during the both the crop seasons, treatments with four (I4) irrigation at critical stages recorded significantly higher length of spike (13.6 and 14.1cm) while lowest length of spike were obtained in I1 (10.5 and 10.4 cm) in *rabi* season 2022-23 and 2023- 24, respectively (Table 1). The treatment receiving four irrigations (I4) at critical growth stages were significantly better than others moisture levels i.e. I1, I2 and I3 both throughout the growing seasons. Similar results were reported by Idnani and Kumar (2012) and Ram *et al.* (2013).

No. of spikes/plant

The no. of spikes/plant exhibited significant variation

Table 1. Yield attributes of wheat crop as affected by thermal regimes and moisture levels.

Treatments	Spike length (cm)		No. of spike per plant		No. of spikelet per spike		No. of grain per ear		At harvest no. of effective tillers per meter^2		Test weight (g)	
Year	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
Thermal regimes												
D1	13.2	13.1	8.4	8.6	20.0	20.4	49.4	53.1	348.6	352.0	40.3	41.7
D2	12.2	12.1	7.7	7.9	19.4	19.7	46.9	50.5	346.1	349.6	39.3	40.8
D3	11.0	11.5	6.8	6.9	17.5	17.9	39.1	41.9	344.3	347.7	37.0	38.7
SEm±	0.19	0.02	0.02	0.02	0.03	0.04	0.14	0.17	0.46	0.07	0.58	0.05
CD at 5%	0.66	0.08	0.06	0.08	0.10	0.13	0.50	0.58	1.59	0.23	2.00	0.16
Moisture levels												
11	10.5	10.4	7.3	7.5	18.4	18.7	41.3	44.3	330.6	333.9	36.7	37.9
12	11.7	11.6	7.5	7.6	18.8	19.1	43.4	46.6	339.9	343.3	38.3	39.3
I3	12.7	12.6	7.8	7.9	19.1	19.5	46.5	49.9	353.0	356.5	39.7	41.2
I4	13.6	14.1	8.0	8.2	19.6	19.9	49.6	53.6	361.7	365.4	40.7	43.1
SEm±	0.16	0.08	0.06	0.05	0.14	0.14	0.30	0.33	2.50	2.64	0.64	0.28
CD at 5%	0.47	0.24	0.17	0.16	0.41	0.40	0.86	0.96	7.26	7.67	1.87	0.81

under different thermal regimes during both crop seasons. Crops sown on D1 (15th November) consistently recorded significantly higher no.s of spikes/plant (8.4 and 8.6), followed by D2 (7.7 and 7.9), respectively for 2022-23 and 2023-24. Conversely, the lowest no.s of spikes/plant (6.8 and 6.9) were recorded in the D3 crop throughout the two years, respectively. Similar results were reported by Singh *et al*. (2016) and Gupta *et al.* (2017). Among the moisture levels, four irrigations (I4) at various critical stages recorded significantly higher no. of spikes/plant (8.1 and 8.2) as compared to the remaining moisture levels in each of the two crop seasons, respectively. Lowest no. of spikes per plant (7.3 and 7.5), respectively for 2022-23 and 2023-24 were obtained in treatment receiving one irrigation (I1) at CRI stage in both seasons (Table 1).

No. of grains/ear

The no. of grains/ear exhibited significant variation due to different treatments during both seasons. Crops sown on D1 (15th November) consistently recorded significantly higher no.s of grains/ear (49.4 and 53.1), followed by D2 (46.9 and 50.5) during both crop seasons. Conversely, the lowest no. of grains/ear (39.1 and 41.9) were recorded in the D3 (5th December) sown crop during 2022-23 and 2023-24, respectively. These results were also supported by Yusuf *et al.* (2019). Among the moisture levels, four irrigations (I4) at various critical stages recorded significantly higher no. of grains/ear (49.6 and 53.6) as compared to the rest of the moisture levels during both the experimentation years, respectively. Lowest no. of grains/ear (41.3 and 44.3) was noted in treatment receiving one irrigation (I1) at CRI stage in both of the years (Table 1).

No. of spikelets/spike

The no. of spikelets/spike also exhibited significant variation under different thermal regimes during both crop seasons. Crops sown on D_1 (15th November) consistently recorded significantly higher no. of spikelets/spike (20.0 and 20.4), followed by D2 (19.4 and 19.7) during both crop seasons, respectively (Table 1). Conversely, the lowest no. of spikelets/spike (17.5 and 17.9) were observed in the late-sown D3 (5th December) crop during both the years 2022-23 and 2023-24, respectively. These findings are consistent with those reported by Singh *et al*. (2016) and Gupta *et al.* (2017). The moisture level treatment with four irrigation levels (I4) at various critical stages consistently exhibited significantly higher no. of spikelets/spike (19.6 and 20.0 compared to the other moisture levels during both crop seasons. Conversely, the

Table 2. Yield of wheat crop as affected by thermal regimes and moisture levels.

Treatments	Grain yield (q ha^{-1})		Straw yield (q ha^{-1})		Biological yield (q ha^{-1})		Harvest index (%)	
Year	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
Thermal regimes								
D1	47.15	47.73	62.25	62.87	109.5	110.60	43.14	43.57
D2	44.75	45.20	59.75	60.35	104.5	105.55	42.79	43.22
D3	36.75	37.66	51.75	52.27	88.5	89.39	41.52	41.93
SEm±	0.65	0.10	0.55	0.11	0.93	0.21	0.46	0.05
CD at 5%	2.25	0.36	1.91	0.37	3.23	0.73	1.59	0.19
Moisture levels								
I1	40.00	40.40	55.00	55.55	95.00	95.95	42.05	42.47
I2	41.67	42.65	56.67	57.23	98.33	99.32	42.31	42.74
I3	43.33	43.76	58.33	58.92	101.67	102.68	42.56	42.98
I4	46.67	47.1	61.67	62.28	108.33	109.42	43.00	43.43
SEm±	0.39	0.33	0.49	0.45	0.86	0.78	0.36	0.32
CD at 5%	1.14	0.97	1.42	1.29	2.48	2.26	NS	NS

lowest no. of spikelets/spike (18.4 and 18.7) were obtained under the treatment with only one irrigation (I1) at the CRI stage in respective years. These findings are consistent with those reported by Zhao *et al.* (2020).

Test weight (g)

Test weight of crop significantly varied under different thermal regimes during both the crop seasons. The crop sown on D1 (15th November) recorded significantly higher (40.3 and 41.7) test weight followed by D2 (39.3 and 40.8) during both the crop seasons. The lowest test weight (37.0 and 38.7) was recorded in late sown D3 (5th December) crop during both the year (2022-23 and 2023-24), respectively. These results corroborate those reported by Singh *et al.* (2016) and Gupta *et al.* (2017). The moisture level treatments with four irrigations (I_4) at various critical stages consistently resulted in significantly higher test weights (40.7 and 43.7g) compared to the other moisture levels during both 2022-23 and 2023-24, respectively. Conversely, the lowest test weights (36.7 and 37.9 g) were recorded under moisture level treatment I1, where irrigation was given at the CRI stage (Table 1). These results validate those reported by Patel *et al*. (2022).

Effect of various treatments on yield of wheat crop

Grain yield (q ha^{-1})

Grain yield exhibited significant variation under different thermal regimes and sowing dates during both crop seasons. Notably, crops sown on thermal regime D1 (15th November) consistently recorded the highest grain yield, with values of 47.25 and 47.73 q ha^{-1}, followed by D2 (25th November) with yields of 44.75 and 45.2 q ha^{-1}, while the minimum yields were observed for crops sown on D3 (5th December) with values of 36.75 and 37.1 q ha^{-1} during 2022-23 and 2023-24, respectively (Table 2).

Crop season 2023-24 observed higher yield this might be due that, this season experienced lesser heat stress and effect of western disturbance at the reproductive phase in comparison to season 2022-23. These findings are in line with those reported by Alam *et al.* (2022) and Sachan *et al*. (2019). The increased yield in early sowing (D1) can be attributed to early emergence, taller plants, higher LAI and a greater no. of spikelet/spike compared to D2 and D3. Conversely, the decrease in yield due to delayed sowing was caused by factors such as reduced light interception percentage, low accumulated growing degree days (GDD), and a shorter grain filling period in both years. These findings are consistent with those reported by Jat *et al.* (2013), Suleiman *et al.* (2014), and Tomar *et al.* (2014). Additionally, the reduction in grain yield due to delayed sowing may also be attributed to the exposure of the crop to high temperatures, leading to a shortened growing duration, as reported by Gupta *et al*. (2017). Among the various moisture levels, the treatment receiving four irrigations (I4) at critical stages consistently demonstrated significantly higher grain yield, with values of 46.67 and 47.1 q ha^{-1}, compared to the other moisture levels during both crop seasons. Conversely, the lowest grain yield was observed under moisture level I1 at the CRI stage, with values of 40.00 and 40.4 q ha^{-1} during the *rabi* seasons of 2022-23 and 2023-24, respectively. The increased yield in the I4 irrigation level can be attributed to factors such as early emergence, taller plants, higher leaf area index (LAI), and a greater no. of spikelet/spike compared to I1, I2 and I3. These findings are dependable with those reported by Rathod and Vadodaria (2004), Li (2006), Idnani and Kumar (2012) and Prasad *et al.* (2016).

Straw yield (q ha^{-1})

Straw yield exhibited significant variation under different thermal regimes during both crop seasons. Notably, crops sown on D1 (15th November) consistently recorded the highest straw yield, with values of 62.25 and 62.87 q ha^{-1}, followed by D2 (25th November) with yields of 59.75 and 60.35 q ha^{-1}, while the minimum yields were obtained for crops sown on D3 (5th December) with values of 51.75 and 52.27 q ha^{-1} during both crop seasons, respectively (Table 2). These findings closely align with those reported by P Praveen *et al.* (2018) and Nizamuddin *et al.* (2014). Among the different moisture levels, the treatment receiving four irrigations (I4) at critical stages exhibited the highest straw yield, recording 61.67 and 62.28 q ha^{-1} during both crop seasons, respectively. Conversely, the lowest straw yield of 55.00 and 55.55 q ha^{-1} was recorded with the I1 (CRI) treatment, involving only one irrigation, during the *rabi* seasons of 2022-23 and 2023-24, respectively. These findings align with those reported by Nayak *et al.* (2015).

Biological yield (q ha^{-1})

Biological yield exhibited significant variation under different thermal regimes and sowing dates throughout both crop seasons. Crops sown on D1 (15th November) consistently achieved the highest biological yield, with values of 109.5 and 110.60 q ha^{-1}, followed by D2 (25th November) 104.5 and 105.55 q ha^{-1} and lowest D3 (5th December) 88.5 and 89.39 q ha^{-1} sowings during both crop seasons, respectively (Table 2). These findings align with those reported by Nayak *et al.* (2015). Among the various moisture levels, the treatment receiving four irrigations (I4) at critical stages consistently achieved the highest biological yield, with values of 108.33 and 109.42 q ha^{-1} during both crop seasons. Conversely, the lowest biological yield 95.0 and 95.6 q ha^{-1}) was observed in the treatment that received only one irrigation (I1) at CRI stage during the *rabi* 2022-23 and 2023-24, respectively. These results corroborate those reported by Patel *et al.* (2022).

Harvest index (%)

Significant variations were observed in harvest index values under different thermal regimes during both the crop seasons. Crops sown on D1 (15th November) exhibited significantly higher harvest index values (43.14% and 43.57%), followed by those sown on D2 (42.79% and 43.22%), while the minimum harvest index was recorded for crops sown on D3 (5th December), with values of 41.52% and 41.93% during the *rabi* 2022-23 and 2023-24, respectively, (Table 2). These findings are consistent with the results reported by Yusuf *et al.* (2019). Among the different moisture levels, crops subjected to four irrigations (I4) at critical stages exhibited significantly higher harvest indices (43.00% and 43.43%) compared to other moisture levels, while the lowest values were observed in crops subjected to I1 moisture level (43.57% and 42.47%) during both crop seasons, respectively. These findings align with those reported by Patel *et al.* (2022).

CONCLUSION

The yield attributes viz; no. of tillers/meter square, length of spike, no. of grains/spike, no. of spikelets/spike and weight of 1000 grains (test-weight) were significantly maximum in D1 (15th Nov.) thermal regimes as compared to D2 (25th November), and D3 (5th December) thermal regimes. Wheat under treatments of more moisture level (I4) significantly improved yield attributes as compared to one (I1) moisture level during both the year of experimentation. During consecutive crop seasons (2022-23 and 2023-24) the highest yield recorded under the D1 thermal regime (47.25 and 47.73 q ha^{-1}), followed by D2 (44.75 and 45.2 q ha^{-1}) and minimum at D3 (36.75 and 37.1 q ha^{-1}). There was significant variation observed in the grain yield, straw yield, biological yield and harvest index among the three distinct thermal regimes and moisture levels.

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