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Influence of sowing dates, nitrogen levels and irrigation scheduling on growth dynamics and yield attributes of wheat (*Triticum aestivum* L.)

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Abstract
A field experiment was conducted during the *Rabi* season of 2019-20 at the Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology, and Sciences, Prayagraj, Uttar Pradesh, to assess the effects of sowing dates, nitrogen levels and irrigation scheduling on the growth and yield attributes of wheat (*Triticum aestivum* L.). The soil of the experimental site was sandy loam with low organic carbon (0.38%) and available nitrogen (174.62 kg/ha), and medium phosphorus (19.50 kg/ha) and potassium (223.28 kg/ha). Wheat variety HD 2967 was selected due to its regional adaptability. The experiment comprised eighteen treatment combinations arranged in a split-plot design with two sowing dates (20 November and 20 December) and three irrigation levels in the main plots, and three nitrogen levels (80, 120 and 160 kg N/ha) in sub-plots, each replicated thrice. The results indicated that 20 November sowing significantly enhanced growth attributes, recording higher plant height (83.06 cm) at 80 DAS and tillers per running meter (97.50 at 60 DAS) whereas leaf area index was found to be non-significant. Early sowing also produced superior yield attributes including effective tillers (352.54/m²), spike length (10.60 cm), grains per spike (40.61) and test weight (35.01 g). Among irrigation treatments, four irrigations (CRI, tillering, booting and milk stage) resulted in significantly higher growth parameters such as plant height (83.34 cm), dry weight (8.906 g), LAI (4.532), along with improved yield attributes. Nitrogen application at 160 kg/ha also produced the most favourable growth and yield traits, recording maximum plant height (79.60 cm), dry weight (9.246 g), LAI (4.492) and superior yield components. Overall, early sowing (20 November), four irrigations, and 160 kg N/ha were found most effective in enhancing wheat growth and productivity.

Keywords: Wheat, sowing dates, irrigation scheduling, nitrogen levels, growth attributes, yield attributes, HD 2967

Introduction

Wheat (*Triticum aestivum* L.) falls under the category of thermo-sensitive and long-day cereal crops and is a member of the Poaceae family, cultivated worldwide, but is a native of Southern Asia. The crop is cultivated as winter wheat in cold countries, such as Europe, the USA, Australia, and the Russian Federation, but spring wheat is cultivated in Asia and in some parts of the USA (FAO, 2023) [3]. In our country, wheat is sown during the rabi season, after the kharif crops, typically in November-December, but harvested in March-April.

Recent multi-location evidence shows that late sowing exposes the crop to terminal heat, depressing grains spike^{-1} and test weight, whereas on-time sowing in late November aligns sensitive stages with a congenial thermal regime and boosts grain yield by ~35-50% versus late December planting in the IGP (Sattar *et al.*, 2023) [11]. This high-temperature stress at the reproductive phase of wheat results in poor yield due to the reduced number of grains per spike and shrivelled grains of low quality (Sharma and Prasad, 2007) [14]. Wheat is sown during winter and needs a required temperature and light for emergence, growth and flowering (Dabre *et al.*, 1993) [1].

Irrigation is an important agronomic package of practices for meeting the water demand for wheat cultivation, particularly in arid and semiarid regions. It mitigates the impact of insufficient rainfall (Kumar *et al.*, 2014) [8]. Water stress-induced accelerated senescence after anthesis shortens the duration of grain filling by causing premature desiccation of the endosperm, and limiting embryo volume has also been reported (Westage, 1994) [17].

Fertilizer application is an integral part of improved crop-production technologies considered proper fertilizer application as a key to bumper crop production (Tariq *et al.*, 2007) [16].

Given the interactive nature of these three management components, a comprehensive field investigation is required to understand their combined impact on crop performance. Such studies help refine location-specific recommendations for improving wheat productivity under varying climatic and edaphic conditions.

Materials and Methods

A field experiment was conducted in *Rabi* seasons 2019-20 at the Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology, and Sciences (SHUATS), Prayagraj, Uttar Pradesh. The soil at the experimental site was sandy loam in texture, with estimated organic carbon (0.38%), available nitrogen (174.62 kg/ha) levels in the low category while available phosphorus (19.50 kg/ha) and potassium (223.28 kg/ha) were medium. Meanwhile, the wheat variety HD 2967 was selected for experimentation due to its popularity among farmers in the region. It had a pH of 7.7 and an Electrical conductivity (0.45 ds/m). The experiment included eighteen treatment combinations: two sowing dates viz., D_1 (20 November) and D_2 (20 December), and three levels of Irrigation. I_1: [Two irrigation at CRI stage (21 DAS) and booting stage (75 DAS)], I_2: [Three irrigation at CRI stage (21 DAS), tillering stage (40 DAS) and booting stage (75 DAS)], I_3: [Four irrigation at CRI stage (21 DAS), tillering stage (40 DAS), booting stage (75 DAS) and milk stage (100 DAS)] and three levels of Nitrogen viz. N_1: 80 kg N/ha, N_2: 120 kg N/ha and N_3 : 160 kg N/ha. Sowing was done manually in lines spaced 22.5 cm apart. The recommended dose of phosphorus and potassium was applied uniformly as a basal dose. Nitrogen was applied in split doses as per treatment—half at sowing and the remaining half at CRI and tillering stages. Irrigations were scheduled according to the treatment combinations. The statistical design, a split-plot design, was assigned with dates of sowing and irrigation levels as main plot treatments and nitrogen levels as sub-plot treatments, with three replications. Observations such as growth attributes viz., plant height, tillers per running meter and leaf area index (LAI) were recorded at periodic intervals. Yield attributes including effective tillers per square meter, spike length, grains per spike and test weight were measured at physiological maturity.

Results and Discussions

Effect of dates of sowing

Sowing dates markedly influenced the growth and yield attributes of wheat. The crop sown on 20 November exhibited significantly superior growth performance, recording maximum plant height (83.06 cm) and the highest number of tillers per running meter (97.50) at 60 DAS, compared to the late-sown crop on 20 December. However, the effect of sowing dates on leaf area index (LAI) remained non-significant (Table 1). In terms of yield attributes, the timely sowing on 20 November also resulted in appreciably higher values of effective tillers per square meter (352.54), spike length (10.60 cm), grains per spike (40.61) and test weight (35.01 g) compared with the late sowing on 20 December (Table 2). These findings underscore the importance of timely sowing in optimizing the physiological growth and yield potential of wheat. 20 November sowing produce significantly higher growth and yield attributes than 20 December sowing which is likely due to a more extended crop period and a more favourable growing environment, allowing for greater vegetative development and stem elongation (Dar *et al.* 2018) [2]. The superiority of 20 November sowing over 20 December sowing may be attributed to the optimal temperature and photoperiodic conditions prevailing during the vegetative growth phase of the 20 November-sown crop, which allows for greater leaf development and expansion (Slafer and Andrade, 1996) [15]. Sowing in mid-November allows favourable temperature and photoperiod during vegetative initiation, which promotes tillering and biomass accumulation. This aligns with the principle that timely sowing exploits optimal temperatures and photoperiods, reducing competition for resources and minimizing exposure to terminal heat stress during grain filling (Kumar *et al.*, 2018) [7]. Delayed sowing significantly reduced the number of grains per spike due to shorter vegetative and reproductive phases, as well as exposure to suboptimal temperatures during critical development stages (Sharma *et al.* 2018) [13].

Effect of irrigation scheduling

Irrigation scheduling exerted a significant influence on the growth and yield attributes of wheat. The highest values for major growth parameters were observed under the I_3 irrigation regime (CRI + Tillering + Booting + Milk), where the crop attained maximum plant height (83.34 cm) at 80 DAS, along with the highest number of tillers per running metre (98.86) at 60 DAS and the greatest leaf area index (4.532) at 80 DAS (Table 1). Similarly, the I_3 treatment also resulted in significantly enhanced yield attributes, including effective tillers per square meter (366.33), spike length (10.94 cm), grains per spike (41.67) and test weight (34.68 g) (Table 2). Notably, the I_2 irrigation schedule (CRI + Tillering + Booting) remained statistically at par with I_3 for most of the growth and yield parameters, indicating that irrigation applied up to the booting stage is nearly as effective as irrigation extended to the milk stage. The superiority of I_3 treatment (CRI + Tillering + Booting + Milk) in respect of growth characters can be due to consistent water availability to the wheat crop at these most critical stages (CRI + Tillering + Booting + Milk) thereby supporting physiological processes like cell growth and stem elongation more efficiently resulting in higher results compared to those experiencing moisture deficits (I_1 and I_2). The results are corroborated by the research findings of (Saren *et al.* 2004) [12] and (Mandal *et al.* 2005) [10]. Water stress during the grain-filling period directly impacts grain weight and density, resulting in reduced test weight (Gupta and Patel 2018) [4].

Effect of nitrogen levels

Nitrogen application had a marked and significant impact on the growth and yield attributes of wheat. The highest nitrogen level, 160 kg N/ha (N_3), recorded maximum values for most growth and yield parameters; however, 120 kg N/ha (N_2) remained statistically at par with N_3, indicating its comparable efficiency. Growth attributes such as plant height (79.60 cm) at 80 DAS, tillers per running metre (95.94) at 60 DAS, and leaf area index (4.492) at 80 DAS were significantly higher under N_3 (Table 1). Similarly, yield attributes—including effective tillers per square meter (348.35), grains per spike (40.17) and test weight (34.64 g)—were also significantly enhanced with the application of 160 kg N/ha (Table 2). However, spike length exhibited a non-significant response to nitrogen levels, suggesting that this trait is relatively stable across the applied nitrogen treatments. The superiority of N_3 treatment (160 kg N/ha) in respect of the number of tillers as compared to 80 kg N/ha and 120 kg N/ha may be due to the direct role of nitrogen in enhancing photosynthesis, meristematic activity, root development, and delaying senescence, collectively driving greater stem elongation and overall plant vigour compared to lower nitrogen rates. Thereby supporting physiological processes such as cell growth and stem elongation more efficiently, resulting in more tillers compared to lower doses of nitrogen application (N_1 and N_2) (Ladha *et al.* 2005) [9]. Higher nitrogen application rates promote leaf production and their expansion significantly, resulting in higher LAI values in the wheat crop (Kumar and Singh 2020) [6]. A higher N level increases the number of spikelets initiated and strengthens the sink capacity of the developing spike, allowing it to accumulate more photosynthates and grow longer (Kiba *et al.*, 2011) [5].

Table 1: Effect of sowing dates, irrigation scheduling and nitrogen levels on growth attributes of Wheat

Treatments	Plant height (cm) 80 DAS	Tillers per running meter 60 DAS	Leaf Area Index (LAI) 80 DAS
A. Sowing Dates			
D_1 (20 November)	83.06	97.5	4.094
D_2 (20 December)	71.58	86.92	3.998
SE(d ±)	1.89	2.62	0.119
CD(P = 0.05)	4.2	5.84	NS
B. Irrigation Levels			
I_1 (CRI+ Booting)	70.26	85.86	3.173
I_2 (CRI+ Tillering+ Booting)	78.35	91.9	4.432
I_3 (CRI+ Till+ Boot+ Milk)	83.34	98.86	4.532
SE(d ±)	2.31	3.21	0.146
CD(P = 0.05)	5.11	7.15	0.326
C. Nitrogen Levels			
N_1 (80 kg/ha)	74.44	88.62	3.460
N_2 (120 kg/ha)	77.92	92.07	4.186
N_3 (160 kg/ha)	79.60	95.94	4.492
SE(d ±)	2.06	2.81	0.135
CD(P = 0.05)	4.26	5.81	0.279

Table 2: Effect of sowing dates, irrigation scheduling and nitrogen levels on yield attributes of Wheat

Treatments	Effective tillers per square meter	Spike length (cm)	Number of grains per spike	Test weight (g)
A. Sowing Dates				
D_1 (20 November)	352.54	10.60	40.61	35.01
D_2 (20 December)	318.79	9.81	37.17	33.38
SE(d ±)	11.53	0.29	1.08	0.33
CD(P = 0.05)	25.68	0.65	2.41	0.73
B. Irrigation Levels				
I_1 (CRI+ Booting)	311.42	9.54	35.74	33.73
I_2 (CRI+ Tillering+ Booting)	329.24	10.14	39.26	34.17
I_3 (CRI+ Till+ Boot+ Milk)	366.33	10.94	41.67	34.68
SE(d ±)	14.12	0.36	1.33	0.40
CD(P = 0.05)	31.45	0.80	2.96	0.89
C. Nitrogen Levels				
N_1 (80 kg/ha)	320.30	9.83	37.33	33.52
N_2 (120 kg/ha)	338.35	10.27	39.17	34.42
N_3 (160 kg/ha)	348.35	10.51	40.17	34.64
SE(d ±)	12.64	0.34	1.24	0.47
CD(P = 0.05)	26.08	NS	2.57	0.97

Conclusion

The present study clearly demonstrated that the timely sowing of wheat, efficient irrigation scheduling, and optimum nitrogen application are critical determinants of achieving higher productivity in the central-cum-Vindhyan region of Uttar Pradesh. Sowing on 20 November consistently produced superior growth and yield attributes compared to late sowing on 20 December, underscoring the importance of adhering to recommended sowing windows. Among irrigation regimes, the application of water at CRI, Tillering, Booting, and Milk stages (I_3) resulted in the highest growth and yield advantages, while I_2 (CRI + Tillering + Booting) performed statistically at par, indicating that irrigation up to the booting stage can sufficiently support crop performance under the region's conditions. Nitrogen application at 160 kg N/ha (N_3) maximized growth and yield parameters; however, 120 kg N/ha (N_2) produced comparable results, suggesting it as a more efficient and economically viable nitrogen dose. Overall, the integrated approach of 20 November sowing, four irrigations, and 160 kg N/ha proved most effective for enhancing wheat growth, yield, and profitability. Although the finding is based on one year further research is needed to conform the findings and its recommendation.

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