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Evaluation of Crop Establishment Methods and Nitrogen Management Strategies for Improving Growth Attributes of Wheat

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Abstract

A field experiment was conducted during the rabi seasons of 2022–23 and 2023–24 at Integral University, Lucknow, Uttar Pradesh, to study the effect of crop establishment methods and nitrogen management on the growth attributes of wheat (*Triticum aestivum* L.). The experiment was laid out in a split-plot design with three replications. The main-plot treatments included three crop establishment methods: conventional tillage, zero tillage, and raised-bed planting. The subplot treatments included five nitrogen management practices: control, 100% recommended dose of nitrogen (RDN), 75% RDN + 25% nitrogen through nano urea, 50% RDN + 50% nitrogen through nano urea and 25% RDN + 75% nitrogen through nano urea. The wheat variety DBW-187 was sown on 20 November 2022 and 22 November 2023. Growth observations such as plant height and leaf area index were recorded at different crop stages. The results showed that raised-bed planting produced better growth than conventional tillage and zero tillage. Among nitrogen treatments, 75% RDN + 25% nitrogen through nano urea recorded the highest plant height and leaf area index in both years. The control treatment showed the lowest growth due to nitrogen deficiency. The study concluded that raised-bed planting, along with 75% RDN + 25% nitrogen through nano urea, may be a better practice for improving wheat growth under the Central Plain Zone of Uttar Pradesh.

Introduction

Wheat remains one of the most important food grains in the world, supplying roughly one-fifth of the food calories and protein consumed globally. In India, it is also one of the principal cereal crops; the Government of India's 2024–25 annual report states that wheat production in 2023–24 was estimated at a record 1132.92 lakh tonnes (Miner *et al*., 2023). In wheat-based systems, crop establishment is not simply a planting decision; it is a decision about root-zone environment, water movement, trafficability, and sowing timeliness. Past field studies have shown that raised-bed and related resource-conserving systems can maintain or improve wheat productivity while reducing irrigation requirements. In New Delhi, furrow-irrigated raised beds and broad beds recorded 18.2–19.5% irrigation-water savings compared with conventional flat beds, while water-use efficiency increased by 8.3–24.8%. In the Indo-Gangetic Plains, precision land levelling combined with furrow-irrigated raised beds produced about 16.6% higher wheat yield with nearly 50% less irrigation water than traditional flat-bed practice (Behera & Sharma, 2014).

Nitrogen management is equally central because canopy expansion, chlorophyll formation, and post-anthesis photosynthesis in wheat respond strongly to nitrogen supply. Field and physiological studies show that nitrogen rate significantly alters chlorophyll content, photosynthetic traits, and final grain formation and that leaf chlorophyll status is closely linked to soil nitrogen supply and canopy development (Kubar *et al.,* 2022).

Nano urea has therefore attracted interest as a supplement to conventional nitrogen fertilization. The recent literature is promising, but not uniformly optimistic. In a rice–wheat system, replacing about one-third of conventional N with nano-N slightly improved wheat grain yield, while larger substitutions reduced yield. In another wheat–rice sequence, 65 kg N ha^{-1} plus foliar nano-urea reduced wheat yield and N uptake compared with a full 130 kg N ha^{-1} treatment. By contrast, irrigated-wheat work from Bihar reported that 75% RDN with two nano-urea sprays improved plant height, LAI, and nitrogen-use efficiency, while broader systems research showed that 75% recommended N combined with nano fertilizers could remain comparable to full recommended rates in wheat and related cereals. Nano urea can be beneficial as a supplement, but cannot fully replace a substantial basal dose of conventional urea in wheat (Kumar *et al*., 2024).

Materials and methods

The field experiment was conducted during two consecutive rabi seasons of 2022–23 and 2023–24 at Integral University, Lucknow, Uttar Pradesh, India, to evaluate the effect of crop establishment methods and nitrogen management on the growth attributes of wheat (*Triticum aestivum* L.). The experimental site falls under the Central Plain Zone of Uttar Pradesh. The wheat crop was sown on 20 November during 2022–23 and on 22 November during 2023–24. The experiment was laid out in a split-plot design with three replications. The main-plot treatments consisted of three crop establishment methods, namely conventional tillage (CT), zero tillage (ZT), and raised-bed planting (RB), while the subplot treatments comprised five nitrogen management practices, namely control, 100% recommended dose of nitrogen (RDN), 75% RDN + 25% nitrogen through nano urea, 50% RDN + 50% nitrogen through nano urea, and 25% RDN + 75% nitrogen through nano urea. Thus, the experiment included 15 treatment combinations and 45 plots in total. The recommended dose of fertilizer was 120 kg N, 60 kg P_2O_5 and 60 kg K_2O ha^{-1}. The wheat variety DBW-187 was sown at a seed rate of 100 kg ha^{-1} with a row spacing of 22.5 cm. The gross plot size was 4.4 m × 3.0 m, while the net plot size was 3.5 m × 2.0 m. All agronomic operations, including land preparation, sowing, irrigation, weed management and plant protection, were carried out uniformly as per recommended practices for wheat cultivation, except for the imposed crop establishment and nitrogen management treatments. In raised-bed planting, wheat was sown on prepared beds, whereas under zero tillage, it was sown directly without prior conventional field preparation. In conventional tillage, the field was prepared through normal tillage operations before sowing. The required nitrogen was applied according to the respective treatment combinations, while phosphorus and potassium were applied uniformly to all plots at the recommended dose. Observations on growth attributes were recorded at different crop growth stages, primarily at 30, 60, and 90 days after sowing (DAS) and at harvest. Plant height was measured from the base of the plant to the tip of the uppermost leaf or spike, as applicable, and expressed in centimetres. Leaf area index was recorded at 30, 60 and 90 DAS to assess canopy development. The collected data were subjected to statistical analysis according to the standard procedure for a split-plot design, and treatment differences were tested using the critical difference (CD) at the 5% level of significance.

Results

The data showed a consistent and biologically coherent pattern across both years. Crop establishment primarily altered canopy structure through the superiority of raised-bed planting, while nitrogen management primarily altered canopy magnitude through the superiority of treatments receiving either full conventional N or moderate nano-urea supplementation. The clearest treatment separations appeared from 60 DAS onward for plant height and from 60 to 90 DAS for LAI.

Table 1. Effect of crop establishment methods and nitrogen management on plant height

Treatments	Plant height (cm)							
	30 DAS		60 DAS		90 DAS		At harvest	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
Main-plot: Crop establishment methods								
T_1: CT (Conventional Tillage)	22.37	23.42	56.14	56.21	84.75	79.82	88.99	85.28
T_2: ZT (Zero Tillage)	21.60	23.61	52.68	56.67	78.88	80.94	82.56	86.39
T_3: RB (Raised Bed Planting)	24.23	25.18	59.81	62.96	89.72	91.00	94.21	96.75
SEm±	0.53	0.42	1.28	1.43	2.00	2.25	1.99	1.74
CD (p=0.05)	NS	NS	5.01	5.61	7.85	8.81	7.83	6.81
Sub-plot: Nitrogen management								
N_1: Control	21.58	21.55	49.61	51.60	74.19	73.28	77.90	76.94
N_2: 100% RDN	23.04	24.97	57.61	61.93	87.30	87.94	91.66	95.00
N_3: 75% RDN + 25 % N through nano urea	23.94	26.25	60.64	65.33	90.96	93.54	95.51	99.67
N_4: 50% RDN + 50% N through nano urea	22.67	24.03	56.91	57.67	85.36	83.67	89.63	90.52

N_5: 25% RDN + 75% N through nano urea	22.43	23.56	56.30	56.53	84.45	81.16	88.23	85.22
SEm±	0.64	0.51	1.58	1.79	2.46	2.47	2.59	2.45
CD (p=0.05)	NS	1.49	4.62	5.22	7.17	7.20	7.55	7.15

Raised-bed planting maintained the tallest plants at every stage, exceeding conventional tillage by about 7.9% at 30 DAS and 9.6% at harvest, and exceeding zero tillage by about 9.3% at 30 DAS and 13.0% at harvest. In 2024–25, raised beds significantly exceeded both CT and ZT at every later stage; at harvest, RB recorded 96.75 cm versus 85.28 cm under CT and 86.39 cm under ZT, and the RB advantage over both was larger than the reported CD of 6.81 cm. In 2023–24, RB was significantly taller than ZT at 60 DAS and harvest, while its differences from CT were numerically positive but did not exceed the reported CD in those stages.

Nitrogen management exerted the strongest numerical effect on plant height. Across pooled descriptive means, 75% RDN + 25% N through nano urea was highest at every stage, followed closely by 100% RDN. Relative to the control, the pooled advantage of the 75% RDN + 25% nano treatment reached 16.4% at 30 DAS, 24.5% at 60 DAS, 25.1% at 90 DAS, and 26.1% at harvest. Non-significant nitrogen effect was observed at 30 DAS in 2023–24, but a significant effect at 30 DAS in 2024–25 and at all later stages in both years. At harvest in 2023–24, the 75% RDN + 25% nano treatment reached 99.67 cm. The difference from 100% RDN (95.00 cm) was only 4.67 cm, which did not exceed the reported CD of 7.15 cm, so the two treatments were statistically equivalent. By contrast, both were clearly superior to the control and to the most heavily substituted nano treatment (25% RDN + 75% nano), which ended at 85.22 cm.

Table 2. Effect of crop establishment methods and nitrogen management on leaf area index

Treatments	**Leaf Area Index**					
	30 DAS		**60 DAS**		**90 DAS**	
	2022-23	**2023-24**	**2022-23**	**2023-24**	**2022-23**	**2023-24**
Main-plot: Crop establishment methods						
T_1: CT (Conventional Tillage)	0.56	0.67	3.14	3.24	3.36	3.34
T_2: ZT (Zero Tillage)	0.54	0.68	2.94	3.29	3.12	3.38
T_3: RB (Raised Bed Planting)	0.61	0.73	3.38	3.65	3.61	3.75
SEm±	0.01	0.01	0.08	0.07	0.09	0.07

CD (p=0.05)	NS	NS	0.30	0.27	0.36	0.27
Sub-plot: Nitrogen management						
N_1: Control	0.54	0.60	2.76	3.09	2.95	3.19
N_2: 100% RDN	0.58	0.72	3.25	3.48	3.44	3.58
N_3: 75% RDN + 25 % N through nano urea	0.61	0.77	3.42	3.77	3.66	3.88
N_4: 50% RDN + 50% N through nano urea	0.57	0.70	3.19	3.35	3.41	3.44
N_5: 25% RDN + 75% N through nano urea	0.56	0.68	3.15	3.28	3.37	3.37
SEm±	0.02	0.02	0.09	0.09	0.10	0.09
CD (p=0.05)	NS	0.06	0.27	0.25	0.30	0.26

LAI closely mirrored the plant-height response. Pooled over the two seasons, raised beds produced the largest canopy, averaging 3.51 at 60 DAS and 3.68 at 90 DAS, compared with 3.19 and 3.35 under CT and 3.12 and 3.25 under ZT. Year-wise inference again showed that 30 DAS establishment differences were non-significant, whereas 60 and 90 DAS differences were significant in both years. The strongest late-season separation appeared in 2023–24: RB reached 3.75 at 90 DAS, whereas CT and ZT reached 3.34 and 3.38, respectively. The 95% CI half-width from the reported SEm was about 0.19, and the RB differences over both CT and ZT exceeded the reported CD of 0.27.

Nitrogen management affected LAI more sharply than crop establishment did. The pooled descriptive hierarchy remained stable across both years: 75% RDN + 25% nano > 100% RDN > 50% RDN + 50% nano > 25% RDN + 75% nano > control. Compared with the control, the pooled 75% RDN + 25% nano treatment increased LAI by about 21.1% at 30 DAS, 22.9% at 60 DAS, and 22.8% at 90 DAS. LAI showed a non-significant response to nitrogen at 30 DAS in 2022–23, but was significant at 30 DAS in 2023–24 and at both later stages in both years. The strongest contrast occurred at 90 DAS in 2023–24: the 75% RDN + 25% nano treatment recorded LAI 3.88 (95% CI: 3.69–4.07), while 100% RDN recorded 3.58 and the control 3.19. The N3–N2 difference (0.30) exceeded the reported CD of 0.26, indicating that the moderate nano-supplemented treatment formed a significantly denser canopy than full conventional N in that season.

Discussion

The results clearly showed that the crop establishment method significantly affected wheat growth. Among the three methods, raised-bed planting recorded better plant growth than conventional tillage and zero tillage. Plants grown in raised beds were taller and had higher leaf area index at most growth stages. This may be because raised beds provide better soil aeration, better drainage, easier root growth and more

efficient use of irrigation water.
Due to these favourable conditions, wheat plants established on raised beds developed stronger root systems and better above-ground growth (Momtazi *et al*., 2024). In the present experiment, raised-bed planting recorded the highest plant height at harvest in both years, with 94.21 cm during 2022–23 and 96.75 cm during 2023–24, while conventional tillage and zero tillage recorded lower values. Similarly, raised-bed planting also gave higher leaf area index at 60 and 90 DAS, showing better canopy development. This indicates that raised-bed planting created a more suitable environment for wheat growth than the other establishment methods.

The better performance of raised-bed planting may also be due to proper spacing and better utilization of light, nutrients and moisture. In conventional tillage, soil disturbance is higher, which may sometimes reduce soil structure and moisture conservation. In zero tillage, although soil disturbance is reduced, early crop growth may be affected by compact soil conditions or

less favourable seed placement (Yadav *et al*., 2018). Raised-bed planting balances these conditions by providing a loose, well-drained seedbed that supports better germination, tillering, and canopy growth. Therefore, the higher plant height and leaf area index under raised-bed planting suggest that this method is more suitable for improving the vegetative growth of wheat under the conditions of the experiment.

Nitrogen management also significantly influenced wheat growth attributes. Among the nitrogen treatments, 75% RDN + 25% nitrogen through nano urea gave the best results for plant height and leaf area index. This treatment produced taller plants and a better leaf canopy than the control and other nitrogen substitution treatments. At harvest, this treatment recorded the highest plant height, with 95.51 cm during 2022–23 and 99.67 cm during 2023–24. The same treatment also recorded the highest leaf area index at 90 DAS, with 3.66 during 2022–23 and 3.88 during 2023–24. This shows that partial replacement of conventional nitrogen with nano-urea improved wheat growth more effectively than either complete reliance on conventional urea or higher replacement rates with nano-urea (Kumar *et al*., 2024).

The improvement in plant growth under 75% RDN + 25% nano urea may be due to greater nitrogen availability during key growth stages. Conventional urea supplies nitrogen through the soil, while nano urea applied through foliage may provide quick and efficient nitrogen absorption through leaves. This combined effect may have helped the plants maintain better chlorophyll formation, photosynthesis, leaf expansion and stem elongation. As nitrogen is directly related to protein formation, chlorophyll synthesis and cell division, better nitrogen supply resulted in taller plants and higher leaf area index (Dumre *et al*., 2025).

The control treatment recorded the lowest values for plant height and leaf area index at all stages. This was expected because nitrogen is one of the most important nutrients for wheat growth. Without nitrogen application, plants remain weak, leaves become smaller, photosynthesis is reduced, and total growth is limited (Yadav, 2024). In this experiment, the control treatment recorded plant heights of only 77.90 cm and 76.94 cm at harvest in 2022–23 and 2023–24, respectively, which were much lower than those of the nitrogen-applied treatments. This clearly shows that nitrogen application is essential for the proper vegetative growth of wheat.

The treatments where a higher proportion of nitrogen was replaced by nano urea, such as 50% RDN + 50% nano urea and 25% RDN + 75% nano urea, showed lower growth than 75% RDN + 25% nano urea. This indicates that nano urea can support crop growth, but it may not completely replace soil-applied nitrogen. Wheat requires a good amount of nitrogen through the soil, especially during early vegetative growth and tillering. If basal nitrogen supply is reduced too much, foliar nano-urea alone may not be sufficient to meet the crop's full nitrogen demand (Kumar *et al*., 2025). Therefore, the results suggest that nano urea should be used as a supplement to conventional nitrogen, not as a complete substitute.

Conclusion

Overall, the results indicate that both crop establishment methods and nitrogen management played an important role in improving wheat growth. Raised-bed planting improved the crop's

physical growing conditions, while 75% RDN + 25% nitrogen via nano urea improved nutrient availability and nitrogen-use efficiency. The combination of better crop establishment and balanced nitrogen supply helped in producing taller plants and greater leaf area. Therefore, to improve wheat growth attributes, raised-bed planting, along with partial nitrogen replacement with nano urea, appears to be a promising practice.

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