



Influence of Planting Pattern and Nitrogen Requirement on Growth and Yield of Wheat (*Triticum aestivum* L.)

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ABSTRACT

Background: India's agriculture scenario currently faces several interconnected issues that affect long-term sustainability, agricultural productivity and resource efficiency. Many of these problems can be solved practically by focusing on planting strategies (e.g., bed planting vs. flat sowing) in conjunction with nitrogen level management. An experiment was performed at the agricultural research farm of Lovely Professional University, Phagwara, Punjab, India to investigate the influence of planting pattern and nitrogen requirement on growth and yield of wheat during the rabi season of 2023-2024.

Methods: The investigation was laid out in a split-split plot design with three replications with the objective to study the role of methods of planting patterns and nitrogen levels on growth and yield of wheat. The main treatments comprised of three planting patterns, viz. M₁-Flat sowing (22.5 row to row planting), M₂- Bed sowing with two rows per bed of 67.5 cm each (37.5 cm bed top + 30 cm furrow), M₃- Bed sowing with three rows per bed of 90 cm (60 cm flat top + 30 cm furrow), sub-plot treatments comprised of three nitrogen levels viz. N₁- 0 kg N/ha, N₂ -50 % of RDN and N₃ -100% of recommended dose of fertilizers i.e. 125:60:40kg/ha and sub-sub plot treatments included foliar application of nitrogen viz. F₁- 2% foliar nitrogen application at crown root initiation stage, F₂- 2% foliar nitrogen application at tillering stage, F₃- 2% foliar nitrogen application at boot stage.

Result: The results of the investigation revealed that among the main plot treatments, bed sowing with three rows per bed of 90 cm (60 cm flat top + 30 cm furrow) recorded higher grain yield (5.09 t/ha) than other treatments whereas as Bed sowing with two rows per bed of 67.5 cm each (37.5 cm bed top + 30 cm furrow) yielded equivalent results from a statistical standpoint (5 t/ha). Among sub-plots, the application of N₃ -100% of Recommended dose of nitrogen has obtained significantly higher grain yield (6.4 t/ha) when compared to other treatments. Among sub-sub plots 2% foliar nitrogen application at boot stage showed higher grain yield (5.2 t/ha) when compared to other treatments whereas 2% foliar nitrogen application at tillering stage where statistically on par (5.1 t/ha) with 2% foliar nitrogen application at boot stage.

Key words: Foliar nitrogen application, Nitrogen levels, Planting patterns, Weed control treatments.

INTRODUCTION

Wheat, a member of the Poaceae family, is a widely cultivated grain and a key source of nutrition for humans, ranking it third among cereal crops globally. It plays a significant role in global food systems, contributing 65% of human dietary needs and 17% to animal feed. As one of the richest sources of calories among major cereals, wheat provides a substantial portion of dietary energy, despite containing limited quantity of animal or legume protein. It supplies around 20% of the total calories and proteins in the human diet, making it a vital component of food security worldwide ("Indian Farmer and Government Initiatives: Policies, Gaps and Way Forward," 2022).

By 2050, the world population is reported to reach around 9.7 billion, necessitating an increase in wheat cultivation to meet growing food demands. To achieve this, it is necessary to adopt advanced agronomic practices that ensure sustainable expansion and higher yields. In India, wheat production stands at 108.8 million tonnes, cultivated over 31.8 million hectares, with a productivity rate of 3425 kg per hectare (Annual Report, 2021). This highlights the need of optimizing agricultural practices to enhance productivity and support world food security. In India, Uttar Pradesh leads as the top wheat-producing

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state, contributing 359 lakh metric tonnes, while Punjab boasts the highest productivity per unit area. Wheat grains are highly nutritious, containing 8-15% protein, 1-5% oil and fat, 62-71% carbohydrates, 1.5-2% mineral matter and 2-2.5% cellulose (Ramadas *et al.*, 2020). This composition underscores wheat's significance as an important source of essential nutrients in the diet.

The planting pattern plays a crucial role in attaining high returns and maximizing crop yield. Planting patterns are significant in agriculture because they optimize resource utilization such as sunlight, water and nutrients,

thereby directly influencing crop growth and ultimate yield (Keerthi *et al.*, 2017). Both the flat method and the bed method have their unique benefits and drawbacks. However, when it comes to growth parameters and yield, bed sowing has proven to be more effective compared to traditional flat sowing (Tang *et al.*, 2024). Additionally, proper row spacing is essential for maintaining the optimal plant population, which further influences the overall productivity of the crop. Since it increases the mechanical strength of wheat plant roots, encourages water conservation, increases fertilizer use efficiency and lessens crop-weed competition, the bed sowing method outperforms flat sowing (Garg *et al.*, 2022). It provides solutions for mitigating the impact of waterlogging, particularly in heavy-textured soils and enhances the efficient distribution of irrigation water in high-yield irrigated systems (Fischer *et al.*, 2019). This method plays a significant role in optimizing wheat performance under varying planting patterns and nitrogen levels.

Nitrogen (N) fertilizer is known for its diverse and essential roles in plant development, including chlorophyll formation, amino acid synthesis and enhancing overall plant vigor for improved growth and productivity. Effective nitrogen management strategies help optimize fertilizer use, promoting sustainable practices that boost both crop quality and yield (Noor *et al.*, 2023). Nitrogen is paramount in farming because it fundamentally governs crop productivity and robust plant development. Sufficient nitrogen is crucial as a major constituent of chlorophyll, which is necessary for photosynthesis; amino acids, which form proteins; and nucleic acids like DNA (Saud *et al.*, 2016). The timing of nitrogen application plays a critical role in optimizing wheat growth and yield. Application of nitrogen at stages such as crown root initiation (CRI) stage supports early root development and tillering, establishing a strong foundation for subsequent growth. Supplementing nitrogen during the tillering stage enhances the formation of productive tillers and supports vegetative expansion. And application at the boot stage coincides with the plant's peak nitrogen demand for spikelet development and grain filling, thereby improving grain number and weight. Strategically timed nitrogen applications ensure efficient nutrient uptake, reduce losses and contribute to improved crop productivity (Kumar *et al.*, 2018). Insufficient N application can result in stunted plant growth and lower yields. Therefore, it is essential to apply N fertilizer at the appropriate times, aligning with key growth stages, to optimize nitrogen uptake and assimilation (Zhang *et al.*, 2022). This approach ensures sustainable and high-quality wheat production. Nitrogen fertilizer is regarded as a key strategy for enhancing grain yield and protein content. Applying nitrogen in split doses has been shown to produce higher grain yields compared to a single application. Efficiently splitting the nitrogen dose and aligning it with the crop's growth requirements improves nitrogen uptake and utilization, ultimately leading to increased biomass and higher grain yields (Govindasamy *et al.*, 2023).

MATERIALS AND METHODS

The field research was performed during *Rabi* season 2023-2024 at the research farm facility of Lovely Professional University, Phagwara. The soil texture was sandy having a pH of 6.03. The available nitrogen content in the soil was 298.4 kg/ha. The experimental research was performed in split-split plot design with 3 planting patterns as main plot treatments, 3 nitrogen levels as sub plot treatment and foliar application of nitrogen at three different stages as the sub-sub plot treatments with three replications. The three planting methods *i.e.* M1- Flat sowing (22.5 row to row sowing), M2- Bed sowing with two rows per bed of 67.5cm each (37.5cm bed top + 30 cm furrow), M3-Bed sowing with three rows per bed of 90cm (60 cm flat top + 30 cm furrow). Nitrogen levels *i.e.* T1- 0 kg/ha, T2- 50% N, T3- 100 % N, in sub-plots and the sub-sub factor consisted of foliar application of nitrogen at F1-2% foliar nitrogen application at Crown root initiation stage, F2- 2% foliar nitrogen application at tillering stage and F3-2% foliar nitrogen application at boot stage. As 4% foliar application of nano urea is recommended dosage, half the recommended dosage was applied at three different stages in sub-sub plots to evaluate their effects. The size of each sub-sub plot was 5 × 3 m, sub plot was 15 × 3 m and main plot was 45 × 3 m. PBW824 -wheat variety was sown which was developed by Punjab Agriculture University, Ludhiana. The field preparation was done with mould board plough and after fine preparation, layout was made with three main plots, 3 sub-plots and 3 sub-sub plots with three replications. Flat sowing being the first main plot treatment was done by maintaining row to row spacing of 22.5 cm. Followed by second main plot treatment was bed top with 37.5 cm and furrow of 30 cm. Third main plot treatment was constructed with bed top of 60 cm and furrow of 30 cm two rows/bed were sown on bed top in bed sowing method. The crop was sown on 19 November 2023 as per treatment. The sowing was done manually using labours. The spray of ACM-9 (metribuzin+clodinafop) was done as post-emergence after 35 days of sowing uniformly on the whole experiment. Nitrogen was applied in four split doses in accordance with the treatments. Foliar application of nitrogen was performed according to the treatments at certain stages of crop. The 3-4 irrigations were provided for crop. The first irrigation was provided after 21 DAS at CRI stage followed by the second at tillering, third at booting and fourth at dough stage according to rainfall conditions. To limit the infestation of aphid and jassids, the crop was sprayed with Malathion 50 EC @ 1.0 lit./ha. Plant height (cm) and periodic dry matter accumulation (g /plant) were recorded from five randomly selected plants from each plot. A quadrant of 50 cm × 50 cm was used to count the periodic number of tillers at an interval of 45, 90, 135 days after sowing and harvest. Then crop was harvested after 145-150 days after sowing, determining the symptoms of maturity, *i.e.* hardness of seed and change in the colour of the plant. The harvest of the crop was done using sickle.

A net plot area of 4 m² was harvested from each plot separately, the harvested bundles were tagged and left in the sun to drain the moisture. At 14% moisture content of grains, harvested bundles were weighed separately to record biological yield. After that, the crop was threshed with sticks and the seeds were weighed plot-by-plot on an electronic balance to obtain the grain yield. The mean values were generated using excel and the statistical analysis was performed in excel as well as OPSTAT.

RESULTS AND DISCUSSION

Plant height (cm)

Plant height plays a crucial role in assessing crop yield. This characteristic is primarily influenced by genetic traits and various agronomic practices. Measurements taken at 45, 90 and 135 days after sowing revealed that the three-row-per-bed planting pattern resulted in significantly taller plants compared to other methods such as two-row-per-bed and flat sowing as shown in (Table 1). However, at the time of harvest, plant height in the three-row-per-bed (97.3 cm) and two-row-per bed (96.2 cm) methods were statistically similar, with both surpassing the flat planting method (94.6 cm). The increased plant height in bed planting systems may be attributed to the loose soil structure and more uniform availability of nutrients, which supports improved crop

growth (Bhatt *et al.*, 2021). Similarly, the greater plant height observed in two-row-per-bed compared to flat sowing could be linked to same reasons but had less plant density and canopy coverage among plants compared to three-rows per bed planting.

Plant height showed significant difference in different rate of nitrogen application (% recommended dose of nitrogen-RDN) with tallest crops recorded in 100% RDN followed by 50% RDN and 0 kg N/ha every 45,90,135 and at harvest (Table 1). The application of 0 kg N/ha resulted in significantly lower plant height compared to all other nitrogen treatments, likely due to restricted growth in the absence of nitrogen. In contrast, the application of 100% RDN led to greater plant height, which can be attributed to enhanced vegetative growth, as nitrogen plays a crucial role in promoting plant development. Similar results were observed in studies conducted by (Liu *et al.*, 2021).

Significant height difference was observed in 2% Foliar nitrogen application at Tillering stage at 45,90 and 135 days whereas at harvest 2% foliar nitrogen application at booting stage was on par with that of foliar application at tillering stage (Table 1). 2% foliar nitrogen application showed the least growth compared to other stages. The increased growth observed during nitrogen application at tillering stage may be due to the availability of nitrogen which enhances the photosynthetic capability and canopy

Table 1: Influence of planting methods, nitrogen levels and foliar application of nitrogen on periodic plant height (cm) of wheat crop.

Treatments	Plant height (cm) at 45 DAS	Plant height (cm) at 90 DAS	Plant height (cm) at 135 DAS	Plant height (cm) at Harvest
Main plots (methods of planting)				
Flat sowing (22.5 row to row planting)	38.3	82.5	97.7	94.6
Bed sowing with two rows per bed of 41.2 90 cm (37.5 cm flat top + 30 cm furrow)	83.8	99.4	96.2	
Bed sowing with three rows per bed of 90 cm (60 cm flat top + 30 cm furrow)	41.9	85.5	101.2	97.3
S.E (m)	0.31	0.06	0.24	0.18
C.D. (5%)	1.23	0.24	0.97	0.70
Sub plots (Nitrogen levels-soil application)				
N1- 0 kg N/ha	36.9	80.7	96.2	91.7
N2 -50% of RDN	40.5	83.7	99.3	96.6
N3- 100% of RDN	44.0	87.3	102.8	99.8
S.E(m)	0.26	0.10	0.24	0.35
C.D. (5%)	0.81	0.31	0.75	1.09
Sub-sub plot (Foliar application of Nitrogen)				
2% foliar nitrogen application at CRI stage	39.6	83.3	98.3	96.0
2% foliar nitrogen application at tillering stage	41.5	84.7	100.4	95.9
2% foliar nitrogen application at boot stage	40.3	83.8	99.6	96.2
S.E(m)	0.14	0.16	0.22	0.27
C.D. (5%)	0.42	0.46	0.65	N/S
C.D (<5%) Interaction				
A × B	1.41	0.54	1.30	1.89
A × C	N/S	N/S	N/S	N/S
B × C	N/S	N/S	N/S	N/S
A × B × C	N/S	N/S	N/S	N/S

formation which promote increased growth in crops. Similar results were observed in studies conducted by (Wu *et al.*, 2022). This study indicated significant interaction between Main plot treatment(A) and sub plot treatment (B) in all the different time periods (Table 1) i.e. three rows per bed (Main plot treatment -3) with 100 percent nitrogen (sub plot treatment -3) was identified to be the best combination with highest growth at all different time periods i.e. 45.6cm at 45, 89.3cm at 90, 104.5cm at 135 days after sowing and 101.4cm at harvest due to higher nutrient use efficiency compared to other combinations. Least growth was observed in a combination of flat sowing (main plot treatment 1), 0 kg/ha nitrogen (sub plot treatment 1) and 2% foliar nitrogen application at CRI stage (sub-sub plot treatment).

Periodic dry matter accumulation (g /plant)

The accumulation of dry matter in crops results from various metabolic processes taking place within the plant. Dry matter accumulation yielded statistically similar results in two-row-per bed and three-row-per bed planting whereas it was significantly lower in flat sowing at 45,90 and 135 days after sowing (Table 2) i.e. 6.51 g/plant at 45,18.13 g/plant at 90 and 22.16 g/plant at 135 days after sowing for

three rows per bed and 6.63 g/plant at 45,17.57 g/plant at 90 and 22.06 g/plant at 135 days after sowing for two rows per bed. Favourable soil conditions and efficient resource utilization in bed planting has necessarily contributed to increased dry matter production compared to flat sowing in wheat crops. Similar findings were observed by (Majeed *et al.*, 2015) who reported that bed planting method generates more crop dry matter compared to flat method.

Among the nitrogen treatments, the crop dry matter accumulation was significantly lower in the 0 kg/ha N compared to all other nitrogen levels. Observations taken at various growth stages indicated that applying 100% RDN resulted in the highest dry matter accumulation across all recorded stages, including 45 (8.99 g/plant), 90 (19.73 g/plant) and 135 days after sowing (24.11 g/plant) (Table 2). The increased dry matter at higher nitrogen levels can be attributed to improved crop growth and development compared to lower nitrogen applications. These findings are consistent with the studies conducted by (Zhai *et al.*, 2022).

Dry matter accumulation was significantly higher in 2% foliar nitrogen application at boot stage compared to other treatments at 90 (18.03 g/plant) and 135 days after sowing (22.29 g/plant) whereas 2% foliar nitrogen

Table 2: Influence of planting methods, nitrogen levels and foliar application of nitrogen on periodic dry matter accumulation (g /plant) of wheat crop.

Treatments	Dry matter accumulation at 45 DAS	Dry matter accumulation at 90 DAS	Dry matter accumulation at 135 DAS
Main plots (methods of planting)			
Flat sowing (22.5 row to row planting)	6.3	16.8	21.5
Bed sowing with two rows per bed of 90 cm (37.5 cm flat top + 30 cm furrow)	6.6	17.5	22
Bed sowing with three rows per bed of 90 cm (60 cm flat top + 30 cm furrow)	6.5	18.1	22.1
S.E (m)	0.05	0.03	0.06
C.D. (5%)	0.20	0.14	0.24
Sub plots (Nitrogen levels-soil application)			
N1- 0 kg N/ha	4.1	15.1	19.4
N2 -50% of RDN	6.2	17.7	22.2
N3- 100% of RDN	8.9	19.7	24.1
S.E(m)	0.04	0.01	0.07
C.D. (5%)	0.13	0.06	0.23
Sub-sub plot (Foliar application of Nitrogen)			
2% foliar nitrogen application at CRI stage	6.7	17.1	21.5
2% foliar nitrogen application at tillering stage	6.3	17.4	21.9
2% foliar nitrogen application at boot stage	6.3	18	22.2
S.E(m)	0.03	0.04	0.04
C.D. (5%)	0.10	0.11	0.11
C.D (<5%) Interaction			
A × B	0.23	0.10	0.40
A × C	N/S	N/S	N/S
B × C	N/S	N/S	N/S
A × B × C	0.32	0.16	0.34

application at CRI stage showed significant results at 45 days after sowing (6.76 g/plant) (Table 2). Nitrogen application at boot stage aligns with crop's peak nitrogen demand which supports the development of grain bearing organs helping ensure high yield potential. This study indicated significant interaction between Main plot(A), sub plot (B) and sub-sub plot (C) treatment in all the different time periods (Table 2) i.e. three rows per bed (main plot treatment -3) with 100 per cent nitrogen (sub plot treatment -3) and 2% foliar application at boot stage (sub-sub plot-3) was identified to be the best combination with highest dry matter at 90 (21.01 g/plant) and 135 days after sowing (24.69 g/plant). Three rows per bed (main plot treatment -3) with 100 percent nitrogen (sub plot treatment -3) and 2% foliar application at crown root initiation stage (sub-sub plot treatment-1) showed the best results at 45 days after sowing (9.3 g/plant). This was due to high nutrient use efficiency in correlation with availability of nitrogen at the certain stages of growth. Interactions between main plot (A) and sub plot (B) also showed synergetic effects.

Periodic number of tillers (m²)

A significantly higher number of tillers were observed in the three-row-per-bed planting method at 45 (290.3 per m²), 90 (381.8 per m²) and 135 (371.1 per m²) days after sowing (DAS) compared to two-row-per-bed planting method and

flat sowing (Table 3). The higher number of tillers at harvest in the bed planting system may be attributed to reduced water contact with plant roots, improved soil friability, lower weed infestation and overall better crop growth.

Number of tillers were observed to be significantly higher in 100% recommended dose of nitrogen compared to other treatments i.e. 319.7 per m² at 45 DAS, 410 per m² at 90 DAS and 399.3 per m² at 135 DAS (Table 3). All growth treatments showed significant results at this treatment compared to others. Optimum rates of nitrogen directly correlate to better overall growth of the plant.

Number of tillers were significantly higher in 2% foliar nitrogen application at tillering at 45 (293 per m²) days after sowing whereas it was significantly higher in 2% foliar nitrogen application at boot stage at 90 (382.8 per m²) and 135 (372.1 per m²) days after sowing (Table 3). 2% foliar nitrogen application at crown root initiation stage (CRI) showed the least results. Nitrogen application at tillering and boot stage supported the development of more tillers. These findings are consistent with the studies conducted by (Iqbal *et al.*, 2025). This study indicated significant interaction between Main plot (A), sub plot (B) and sub-sub plot (C) treatment in all the different time periods (Table 3) i.e. three rows per bed (main plot treatment -3) with 100 per cent nitrogen (sub plot treatment -3) and 2% foliar application at tillering stage (sub-sub plot-2) was identified

Table 3: Influence of planting methods, nitrogen levels and foliar application of nitrogen on periodic number of tillers (m²) of wheat crop.

Treatments	Number of tillers at 45 DAS	Number of tillers at 90 DAS	Number of tillers at 135 DAS
Main plots (methods of planting)			
Flat sowing (22.5 row to row planting)	283.5	375.4	364.8
Bed sowing with two rows per bed of 90 cm (37.5 cm flat top + 30 cm furrow)	289.4	379.4	368.7
Bed sowing with three rows per bed of 90 cm (60 cm flat top + 30 cm furrow)	290.3	381.8	371.1
S.E(m)	0.59	0.53	0.53
C.D. (5%)	2.32	2.09	2.09
Sub plots (Nitrogen levels-soil application)			
N1- 0 kg N/ha	245.5	336.4	325.7
N2 -50% of RDN	298	390.3	379.6
N3- 100% of RDN	319.7	410	399.3
S.E(m)	0.58	0.87	0.88
C.D. (5%)	1.81	2.68	2.70
Sub-sub plot (Foliar application of Nitrogen)			
2% foliar nitrogen application at CRI stage	283.8	375.1	364.4
2% foliar nitrogen application at tillering stage	293	378.7	368.1
2% foliar nitrogen application at boot stage	286.4	382.8	372.1
S.E (m)	0.35	0.66	0.67
C.D. (5%)	1.01	1.91	1.92
C.D (<5%) Interaction			
A × B	3.14	4.65	4.25
A × C	N/S	N/S	N/S
B × C	1.75	3.32	3.12
A × B × C	3.03	5.75	5.25

to be the productive combination with highest periodic number of tillers/m² at 45 (per m²), 90 (per m²) and 135 days after sowing (per m²). Three rows per bed (main plot treatment -3) with 100 per cent nitrogen (sub plot treatment -3) and 2% foliar application at boot stage (sub-sub plot-3) also showed similar results at 90 and 135 days after sowing. The superior performance of the treatment combination can be attributed to the synergistic effect of optimal plant geometry, adequate basal nitrogen supply and timely foliar feeding at a physiologically critical stage. Together, these factors likely enhanced the crop's nutrient uptake efficiency and tiller initiation. Interactions between main plot (A) and sub plot (B) and sub plot (B) and sub-sub plot (C) also showed significant synergetic effects.

Grain yield (q/ha), straw yield (q/ha), biological yield (q/ha) and harvest index (HI)

The grain yield (q/ha) is the ultimate economic output of a crop, which is influenced by its growth parameters and yield attributes under specific treatments. In wheat, planting patterns and nitrogen levels had a significant impact on seed yield. The three-row and two-row per bed planting patterns resulted in significantly higher seed yields compared to flat sowing. The grain yield recorded in the three-row per bed system was 4.59 t/ha, which was

statistically on par with the two-row per bed system (4.54 t/ha) but notably higher than flat sowing (4.38 t/ha) (Table 4). The superior yield in the three- and two-row per bed techniques could be attributed to improved growth and yield attributes. The higher grain yield observed in the bed planting method may be due to increased plant height; greater dry matter accumulation, higher total tiller count and improved yield parameters compared to other planting techniques.

Furthermore, the biological yield and straw yields were significantly greater in the three-row per bed system (biological yield -11.07 t/ha, straw yield-6.45 t/ha) than in the two-row per bed (biological yield -10.49 t/ha, straw yield-5.95 t/ha) and flat sowing methods (biological yield -10.12 t/ha, straw yield-5.69 t/ha) (Table 4). The harvest index values were statistically similar between the bed planting patterns but significantly greater than in the flat sowing method. Additionally, the biological yield (13.66 t/ha), grain yield (5.95 t/ha), straw yield (7.68 t/ha) and harvest index (43.5%) were considerably higher in the 100% recommended nitrogen dose treatment compared to all other nitrogen levels. This increase can be attributed to better growth and improved yield parameters. Grain yield, straw yield, biological yield and harvest index were statistically similar between the 2% foliar nitrogen applications at the boot and tillering stages, while they

Table 4: Influence of planting methods, nitrogen levels and foliar application of nitrogen on grain yield (q/ha), straw yield (q/ha), biological yield (q/ha) and harvest index (HI) of wheat crop.

Treatments	Biological yield (t/ha)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (HI)
Main plots (methods of planting)				
Flat sowing (22.5 row to row planting)	10.12	4.39	5.69	4.10
Bed sowing with two rows per bed of 90 cm (37.5 cm flat top + 30 cm furrow)	10.49	4.54	5.95	4.31
Bed sowing with three rows per bed of 90 cm (60 cm flat top + 30 cm furrow)	11.07	4.59	6.45	4.36
S.E(m)	0.04	0.02	0.01	0.06
C.D. (5%)	0.16	0.09	0.07	0.24
Sub plots (Nitrogen levels-soil application)				
N1- 0 kg N/ha	7.16	2.97	4.17	4.14
N2 -50% of RDN	10.86	4.59	6.26	4.23
N3- 100% of RDN	13.66	5.95	7.68	4.35
S.E(m)	0.12	0.06	0.06	0.15
C.D. (5%)	0.37	0.18	0.18	0.48
Sub-sub plot (Foliar application of Nitrogen)				
2% foliar nitrogen application at CRI stage	9.97	4.2	5.74	4.17
2% foliar nitrogen application at tillering stage	10.76	4.61	6.1	4.26
2% foliar nitrogen application at boot stage	10.95	4.72	6.26	4.29
S.E(m)	0.08	0.05	0.05	0.32
C.D. (5%)	0.24	0.16	0.16	0.93
C.D (<5%) Interaction				
A × B	0.64	0.32	0.32	0.83
A × C	0.42	0.28	0.28	N/S
B × C	0.42	0.28	0.28	N/S
A × B × C	0.74	0.48	0.49	N/S

Table 5: Interactive effect of planting methods (A) nitrogen levels (B) and foliar application of nitrogen (C) on biological yield (q/ha).

	Flat sowing			Two rows/bed			Three rows/bed			Mean
	0% kg/ha	50% N	100% N	0% kg/ha	50% N	100% N	0% kg/ha	50% N	100% N	
CRI	3.83	10.24	12.85	7.53	10.37	13.09	7.34	10.36	14.15	9.97
Tillering	7.11	11.3	12.95	7.42	10.34	13.78	7.44	11.48	15.02	10.76
Boot	8.29	11.52	13.0	7.52	10.8	13.61	7.97	11.37	14.48	10.95
Mean	6.41	11.02	12.93	7.49	10.5	13.49	7.58	11.07	14.55	
SE(m±)					0.25					
C.D (<5%)					0.74					

Table 6: Interactive effect of planting methods (A) nitrogen levels (B) and foliar application of nitrogen (C) on grain yield (q/ha).

	Flat sowing			Two rows/bed			Three rows/bed			Mean
	0% kg/ha	50% N	100% N	0% kg/ha	50% N	100% N	0% kg/ha	50% N	100% N	
CRI	1.53	4.44	5.66	3.22	4.41	5.68	2.72	4.13	6.01	4.2
Tillering	2.96	4.86	5.63	3.2	4.39	6.15	3.02	4.71	6.48	4.6
Boot	3.68	5.03	5.66	3.26	4.7	5.84	3.19	4.67	6.38	4.7
Mean	2.72	4.78	5.65	3.23	4.5	5.89	2.98	4.5	6.29	
SE(m±)					0.17					
C.D (<5%)					0.48					

Table 7: Interactive effect of planting methods (A) nitrogen levels (B) and foliar application of nitrogen (C) on straw yield (q/ha).

	Flat sowing			Two rows/bed			Three rows/bed			Mean
	0% kg/ha	50% N	100% N	0% kg/ha	50% N	100% N	0% kg/ha	50% N	100% N	
CRI	2.36	5.94	7.17	4.23	5.91	7.38	4.71	6.13	7.89	57.5
Tillering	3.93	6.33	7.16	4.2	5.89	7.92	4.31	6.71	8.49	61
Boot	4.68	6.53	7.17	4.26	6.2	7.64	4.83	6.66	8.38	62.6
Mean	3.65	6.26	7.16	4.23	6.0	7.65	4.62	6.5	8.25	
SE(m±)					0.174					
C.D (<5%)					0.499					

were significantly lower in the 2% foliar nitrogen application at the CRI stage (Table 3). Similar findings were reported by (Devi *et al.*, 2017) and (Ali *et al.*, 2018). This study indicated significant interaction between Main plot (A), sub plot (B) and sub-sub plot (C) treatments in all the different time periods (Table 4) for grain yield, straw yield and biological yield *i.e.* three rows per bed (main plot treatment -3) with 100 per cent nitrogen (sub plot treatment -3) and 2% foliar application at tillering stage (sub-sub plot-2) was identified to be the most productive combination with highest grain (6.48 t/ha) (Table 6), straw (8.49 t/ha) (Table 7) and biological yield (15.02 t/ha) (Table 5). This result is due to the synergistic effect of optimized planting geometry, sufficient nitrogen availability and well-timed nutrient supplementation. Three rows per bed (main plot treatment -3) with 100 per cent nitrogen (sub plot treatment -3) and 2% foliar application at boot stage (sub-sub plot-2) also showed statistically significant results in grain yield (6.48 t/ha) and straw yield (8.49 t/ha). The least results were observed in a combination of flat sowing (main plot treatment -1) with 0 percent nitrogen (sub plot treatment -1) and 2% foliar application at CRI stage (sub-sub plot-1) in

grain (1.5t/ha), straw (2.3 t/ha) and biological yield (3.83 t/ha). Interactions between main plot (A) and sub plot (B), sub plot (B) and sub-sub plot (C) and main plot (A) and sub-sub plot (C) also showed significant synergetic effects in terms of grain, straw and biological yield. Harvest Index also showed significant interaction between main plot (A) and sub plot (B) in all the three yield attributes.

CONCLUSION

The analysed parameters indicate that the three-row-per-bed planting method significantly improved growth and physiological traits compared to two-row-per-bed and flat planting techniques. Yield parameters also showed similar trend other than in grain yield where bed planting systems were at par. Regarding nitrogen application, the 100 kg N/ha treatment demonstrated the highest in growth, yield and physiological parameters, leading to improved characteristics compared to other nitrogen levels. 2% foliar application at boot stage was found to exhibit higher characteristics compared to foliar application at different stages.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Conflict of interest

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