Journal of Applied Biology & Biotechnology Vol. 13(1), pp. 46-50, Jan-Feb, 2025
Available online at http://www.jabonline.in
DOI: 10.7324/JABB.2024.200916

Leaf area index, quality, and nutrient uptake in wheat (*Triticum aestivum* L.) affected by different planting patterns and nitrogen levels

Harmanpreet Kaur Gill*, Ujagar Singh Walia

Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India.

ARTICLE INFO

Article history:
Received on: July 08, 2024
Accepted on: September 12, 2024
Available online: November 15, 2024

Key words:
Chlorophyll index,
Leaf area index,
Planting patterns,
Protein,
Uptake,
Wheat.

ABSTRACT

A study was conducted during two seasons, Rabi 2022-23 and 2023-24, on the farm of Lovely Professional University in Jalandhar, Punjab, focusing on the "leaf area index, quality, and nutrient uptake in wheat (*Triticum aestivum* L.) affected by different planting patterns and nitrogen levels." The experiment was set up in a split-plot design (SPD) with three planting techniques: two rows per bed, bidirectional sowing, and line sowing in the main plots, and five nitrogen levels: 0, 40, 80, 120, and 160 Kg N/ha. The findings concluded that among the main plots, significantly greater leaf area index, chlorophyll index, protein content (7.61%, 9.46%), and nitrogen content by grains (1.21%, 1.51%) and straw (0.63%, 0.66%) were obtained in the two rows per bed technique compared to bidirectional and line techniques. Additionally, there was an increased nitrogen uptake by grains and straw, significantly higher (39.98%, 33.97%, and 65.35%, 62.42%, respectively) in two rows per bed and (15.40%, 12.85%, and 24.53%, 21.46%, respectively) in bidirectional sowing during both years compared to flat sowing technique. Among the nitrogen level treatments, chlorophyll index (46.81 and 43.54), protein content (9.79% and 11.61%), nitrogen content (1.32%, 1.62% and 0.73%, 0.76%), and uptake (85.72 Kg/ha, 99.52 Kg/ha, and 47.80 Kg/ha, 48.96 Kg/ha) in grains and straw were significantly higher in the 160 Kg N/ha treatment compared to 0, 40, 80, and 120 Kg/ha.

1. INTRODUCTION

Rice is the most edible crop in India, yet wheat is the top food grain crop globally. While rice is the primary staple crop in India, wheat is the most widely cultivated food grain globally. According to ancient studies, emmer wheat was first cultivated around 9600 BC. By 7500 BC, wheat and barley were being cultivated, but the first cultivation of wheat occurred approximately 10,000 years ago, marking the beginning of agricultural practices during the Neolithic age [1]. According to statistical reports, wheat production was 592 million metric tons in 1990-1991, increased to 789.17 million metric tons in 2022-2023, and is estimated to be 784.91 million metric tons in 2023-2024, slightly lower than the previous year . India is the second-largest producer of wheat after China. In our country, wheat production reached 109.53 million tons, cultivated over an area of 316.14 lakh hectares, with a productivity of 3464 Kg/ha [2]. Wheat is the most common cereal crop, growing under 219 million hectares in the World and 29.8 million hectares in India. India is the second largest producer of wheat after China[3]. The main way to increase wheat productivity is by selecting the proper planting pattern. The selection of efficient planting patterns is crucial for enhancing crop productivity. Choosing the right planting pattern is essential for maximizing wheat productivity by optimizing resource use, minimizing competition, managing pests and diseases, and facilitating efficient agricultural operations. There are several common planting patterns used in agriculture, such as broadcasting, bi-directional sowing, furrow irrigated raised beds, and flatbed sowing. The row and bed methods of wheat sowing have their own pros and cons. In terms of growth parameters and yield, ridge and furrow sowing out performed traditional flat sowing. The row spacing is also important for maintaining the plant population. The bed method is more efficient than flat sowing because it provides mechanical strength to plants, saves water, increases fertilizer use efficiency, reduces competition between crops and weeds, reduces water logging, and causes less erosion [4]. The bed technique is superior to row or flat sowing because it provides support to plants, improves water usage efficiency, enhances nutrient utilization, reduces competition between weeds and plants, decreases water retention, and minimizes erosion. Cross-sowing or bidirectional sowing also contributes to increased grain yield through its smothering effect on weeds, improved resource utilization efficiency, and mitigation of risks associated with climate

*Corresponding Author:
Harmanpreet Kaur Gill,
Research scholar, Department of Agronomy, School of Agriculture,
Lovely Professional University, Phagwara, Punjab, India.
E-mail: gill82167@gmail.com

variability and extreme weather events. Different planting patterns also influence the growth and development of weeds, thereby affecting wheat production per unit area.

Nitrogen is the most important nutrient for the growth and maturation of all plants, including kernels. Nitrogen is an integral part of the nucleoplasm, polypeptides, nucleotides, catalysts, and proteins, enabling the proper formation of husks and florets [5]. Nitrogen is the foremost macronutrient continuously utilized by farmers. Nitrogen is essential for numerous physiological processes in plants, ranging from basic metabolism and growth to responses to environmental stimuli. Maintaining optimal nitrogen levels is crucial for promoting enzyme co-factors, chlorophyll formation, secondary metabolites, osmotic regulation, healthy plant growth, development, and productivity. Since nitrogen is a key component of proteins, vitamins, hormones, and other substances, it is essential for both plants and animals, critically impacting life [6]. It plays a significant role in various physiological processes, including photosynthesis, protein synthesis, enzyme activities, and overall plant metabolism. The maximum number of tillers, biological yield, and seed yield were reported with 203 Kg N/ha, while seed yield, test weight, and seed/spike were observed with the use of 145 Kg N/ha [7]. The supply of 120 Kg N/ha showed higher nitrogen use efficiency in the bed method (15.2%) when applied at the same rate as in flat sowing. Nitrogen use efficiency, recovery efficiency, and agronomic efficiency were also higher in bed planting than in flat planting. The main objectives of the study are given below:

1. To study the influence of planting patterns on N uptake by wheat crops under different N levels.
2. To determine the interactive effects between planting patterns and nitrogen levels.
3. To estimate the wheat quality and uptake of N as influenced by planting patterns and nitrogen level treatments.

2. MATERIAL AND METHODS

The field experiment on the wheat variety PBW 824 was grown at the demonstration farm of Lovely Professional University, Phagwara during *Rabi* 2022-2023 and 2023-24. The trial was sown on sandy loam soil in 2022-23 and 2023-24 with a 6.05 pH, 0.38 % organic carbon, 306.5 Kg/ha available nitrogen, 25.3 Kg/ha available phosphorus, and 190.1 Kg/ha available potassium. The trial was set out in SPD with three planting techniques in major plots and five N treatments in minor plots, with four replications during both years. The three planting patterns, that is, M_1- two rows per bed, M_2- bidirectional sowing, M_3- line/row sowing were stayed in major plots and 5 N treatments i.e. T_1- 0, T_2- 40, T_3- 80, T_4- 120, and T_5- 160 Kg N/ha were retained in minor plots. The field was prepared with discing and cultivators (twice), and sowing was done with the Kera method on November 4, 2022 in the first season and on November 6, 2023 in the second season. The subplot size was 5×3.20 m and the major plot size was 64 Sq. m. during both years. The bed size was 67.5 cm with a top of 37.5 cm and a 30 cm. Two rows per bed were grown on top of the bed. The spray of EMEK (metribuzin+clodinafop) at 240 g was made to keep the crop free from broad leaf weeds, *Phalaris minor,* and both, respectively. The spray of herbicides was finished as Post-emergence (POE) after

Table 1: Anova table.

Source of Variation	d.f	S.S	MS	F value
Replication	m-1	SSR	M_r = SSR/(m-1)	M_r/M_a
X	n-1	SSX	M_x = SSX/(n-1)	M_x/M_a
Error (a)	(m-1) (n-1)	SSE	M_a = SSE(a)/(m-1)(n-1)	
Y	k-1	SSY	M_y = SSY/(k-1)	M_y/M_b
Interaction XY	(n-1) (k-1)	SSXY	M_{xy} = SSXY/(n-1)(m-1)	M_{xy}/M_a
Error (b)	n(m-1)(k-1)	SSE	M_b= SSE(b)/n(m-1)(k-1)	
Total	mnk-1	SST		

Table 2: Effect of planting techniques and N levels on leaf area index.

Treatments 2022-23	Leaf area index								
	60 DAS			90 DAS			120 DAS		
	2022-23	2023-24	Pool	2022-23	2023-24	Pool	2022-23	2023-24	Pool
Planting patterns									
Two rows per bed	5.12	5.47	5.30	5.77	6.09	5.93	5.98	5.41	5.69
Cross sowing	5.04	5.39	5.22	5.67	5.98	5.82	5.54	4.97	5.25
Flat sowing	4.92	5.27	5.10	5.52	5.84	5.68	5.73	5.07	5.4
SE(m) ±	0.02	0.03	0.02	0.04	0.02	0.03	0.07	0.08	0.07
C.D.	0.14	0.14	0.14	0.1	1.1	0.1	NS	0.29	0.3
Nitrogen levels									
0 Kg N/ha	4.8	5.15	4.98	5.4	5.72	5.56	5.1	4.51	4.8
40 Kg N/ha	5.01	5.36	5.2	5.62	5.94	5.78	5.47	4.83	5.15
80 Kg N/ha	5.03	5.37	5.18	5.78	5.98	5.82	5.66	5.18	5.48
120 Kg N/ha	5.05	5.4	5.23	6.06	6.02	5.98	5.7	5.47	5.68
160 Kg N/ha	5.27	5.62	5.45	6.29	6.19	6.06	5.87	5.77	5.89
SE(m) ±	0.04	0.05	0.04	0.03	0.04	0.03	0.05	0.03	0.04
C.D.	0.13	0.13	0.13	0.11	0.12	0.12	0.12	0.1	0.11
Interaction	NS	NS	NS	0.21	0.2	0.21	NS	NS	NS

Table 3: Effect of planting techniques and N levels on chlorophyll index.

Treatments	Chlorophyll index 60 DAS			Chlorophyll index 90 DAS		
	2022-23	2023-24	Pool	2022-23	2023-24	Pool
Planting patterns						
Two rows per bed	43.21	40.02	41.62	39.66	39.6	39.64
Cross sowing	40.72	37.41	38.26	36.41	37.34	36.91
Flat sowing	39.96	36.53	39.05	37.38	37.68	37.44
SE(m) ±	0.53	0.51	0.52	0.43	0.49	0.46
C.D.	1.6	0.87	1.1	1.63	1.82	1.66
Nitrogen levels						
0 Kg N/ha	31.71	29.65	30.70	28.18	28.92	28.55
40 Kg N/ha	39.92	36.01	37.99	36.46	36.95	36.71
80 Kg N/ha	42.34	38.6	40.47	38.84	39.18	39.01
120 Kg N/ha	45.68	42.14	43.88	42.15	42.09	42.11
160 Kg N/ha	46.81	43.54	45.18	43.31	43.88	43.61
SE(m) ±	0.31	0.36	0.33	0.43	0.39	0.41
C.D.	1.01	0.85	0.73	0.97	1.04	0.95
Interaction	NS	1.55	1.37	NS	NS	NS

Table 4: Effect of planting techniques and N levels on nitrogen uptake by grains and straw (Kg/ha).

Treatments	Nitrogen uptake by grains (Kg /ha)			Nitrogen uptake by straw (Kg /ha)		
	2022-23	2023-24	Pool	2022-23	2023-24	Pool
Planting patterns						
Two rows per bed	53.07	63.88	58.60	27.63	27.92	28.0
Cross sowing	43.75	53.81	49.18	20.81	20.88	21.07
Flat sowing	37.91	47.68	42.73	16.71	17.19	17.17
SE(m) ±	0.61	0.65	0.63	0.56	0.43	0.49
C.D.	0.047	0.065	0.053	0.047	0.054	0.048
Nitrogen levels						
0 Kg N/ha	18.09	24.01	21.33	4.61	4.54	4.47
40 Kg N/ha	25.58	32.91	29.42	9.84	10.05	9.81
80 Kg N/ha	42.54	53.77	48.28	21.93	22.44	21.98
120 Kg N/ha	69.73	83.14	83.89	38.56	39.0	40.02
160 Kg N/ha	85.72	99.52	92.49	47.80	48.96	50.79
SE(m) ±	0.60	0.54	0.57	0.38	0.42	0.40
C.D.	0.054	0.053	0.05	0.051	0.041	0.043
Interaction	NS	0.17	0.16	NS	0.14	0.14

35 days of sowing, according to treatments. The N doses were supplied according to treatments at sowing time, and the 2nd half dose was appealed after 35 DAS. The 1st irrigation was appealed after 21 days after sowing at the crown stage, the 2nd at the initiation of tillers, the 3rd at the boot stage, and the 4th at the milky stage as an opinion to the precipitation situation.

To avoid damage to Jassids and Aphids, the plot was spritzed with malathion at 1.0 lit/ha. After that, the crop was culled with a sickle after 146 DAS in the first season and 143 DAS in the second season after considering the signs of maturity and switching the color of the plant. The net plot harvested was two Sq. m. from the central portion of each plot. The crop was bound after harvesting and kept in the sun for complete drying. Then the crop was beaded with stakes, and seeds were winnowed and plot-wise chewed over on the balance machine.

The analysis was completed by OPSTAT (two-factor analysis). All the above research data on different parameters of crops was analyzed by analysis of variance statistical method. The Critical difference values are at 5%, significance levels are at 1%, and non-significant data is denoted as NS. The data was analyzed through Operational Statistics (OPSTAT), Hisar Agriculture University (HAU).

Table 5: Effect of planting techniques and N levels on protein content, nitrogen content in grains and straw (%).

Treatments	Protein content (%)			Nitrogen content in grains (%)			Nitrogen content in straw (%)		
	2022-23	2023-24	Pool	2022-23	2023-24	Pool	2022-23	2023-24	Pool
Planting patterns									
Two rows per bed	7.61	9.46	8.54	1.21	1.51	1.36	0.63	0.66	0.65
Cross sowing	6.49	8.37	7.43	1.03	1.34	1.19	0.49	0.52	0.51
Flat sowing	5.81	7.59	6.71	0.93	1.22	1.07	0.41	0.44	0.43
SE(m) ±	0.07	0.09	0.08	0.03	0.01	0.02	0.02	0.01	0.01
C.D.	0.29	0.32	0.30	0.047	0.051	0.048	0.047	0.042	0.044
Nitrogen levels									
0 Kg N/ha	4.12	5.98	5.05	0.66	0.95	0.81	0.17	0.18	0.17
40 Kg N/ha	4.91	6.75	5.83	0.78	1.08	0.93	0.3	0.33	0.31
80 Kg N/ha	6.12	7.92	7.02	0.97	1.27	1.12	0.5	0.53	0.51
120 Kg N/ha	8.26	10.11	9.18	1.32	1.62	1.47	0.73	0.76	0.74
160 Kg N/ha	9.79	11.61	10.71	1.56	1.87	1.71	0.87	0.92	0.89
SE(m) ±	0.13	0.11	0.12	0.01	0.02	0.01	0.02	0.04	0.03
C.D.	0.28	0.33	0.29	0.046	0.053	0.048	0.043	0.041	0.041
Interaction	0.52	0.59	0.54	0.083	0.095	0.087	0.079	0.074	0.075

3. RESULTS AND DISCUSSION

3.1. Leaf Area Index

The leaf area index (LAI) represents the ratio of leaf area to ground area. It reached its peak in the bed-two-row technique, significantly surpassing the bidirectional sowing and flat planting methods [Table 2] at 60, 90, and 120 days after sowing in both years. LAI at 60 days after sowing was notably higher with 160 Kg nitrogen compared to other nitrogen levels (0, 40, 80, and 120 Kg N/ha) during both the 2022-23 and 2023-24 periods. However, LAI was highest at 90 days after sowing, attributed to the crop being at its full vegetative stage at that time. By 120 days after sowing, as the crop entered the heading stage, the leaf area decreased due to assimilation. Significant interactions were observed among main and sub-treatments at 90 days after sowing in both 2022-23 and 2023-24, while pooled means were non-significant at 60 and 120 days after sowing across both years. Similar observations were reported by [8].

3.2. Chlorophyll Index

The chlorophyll index directly correlates with photosynthesis and the greenness of plants, which are crucial factors governing crop yield. Chlorophyll content was found to be highest in the bed-two-row technique, significantly surpassing the bidirectional sowing and flat planting methods [Table 3] at 60 and 90 days after sowing in both years. At 60 days after sowing, chlorophyll content was notably higher with 160 Kg nitrogen compared to other nitrogen levels (0, 40, 80, and 120 Kg N/ha), significantly outperforming other treatments during both 2022-23 and 2023-24. Similarly, at 90 days after sowing, observations revealed that the 160 Kg nitrogen treatment significantly outperformed all other nitrogen level treatments. However, the chlorophyll index was higher at 60 days after sowing than at 90 days after sowing because nitrogen application was ongoing until 58 days after sowing, resulting in increased greenness at 60 days after sowing, corresponding to the full vegetative stage of the crop. By 90 days after sowing, as the crop reached the heading stage, chlorophyll content decreased in leaves due to assimilation. Significant interactions were observed among main and sub-treatments at 60 days after sowing in 2023-24, while pooled means were non-significant at 90 days after sowing in both years. Sharma et al. (2022) concluded that the highest number of tillers (8.7%), straw yield (15.2%), total nitrogen uptake (25.1%), and chlorophyll readings (6.2%-10.4%) were recorded under 120 Kg N/ha compared to other doses (0, 80 Kg N/ha), which aligns with similar findings [9].

3.3. Protein Content, Nitrogen Content in Grains and Straws (%)

The difference in protein content (%) across different planting patterns was significant in both years [Table 5]. Protein content in the two rows per bed planting pattern was notably higher than in other treatments during both the 2022-23 and 2023-24 periods. This higher protein content in the two-row-bed pattern can be attributed to better crop stand, looser conditions, reduced weed competition, and less waterlogged conditions. Additionally, other growth, yield, and quality parameters were also higher in this treatment. Regarding nitrogen levels, the highest protein content was consistently recorded at 160 Kg N/ha compared to other nitrogen treatments. The interaction effects of main and sub-plot treatments on protein percentage were found to be significant. The highest nitrogen content in grains and straw was also significantly observed in the two-row-bed planting pattern due to better urea utilization in loose conditions and better solubilization compared to bidirectional and flat sowing methods during both years. Across nitrogen level treatments, nitrogen content in grains and straw was notably higher with 160 Kg nitrogen per hectare compared to other treatments. Yousaf (2014) revealed that across various nitrogen treatments (0, 70, 110, 130, and 160 Kg N/ha), higher production and protein content were observed with increased nitrogen levels. All maturity attributes, productivity, and standard parameters were enhanced with the increase in nitrogen doses. Similar results were also reported by [10,11].

3.4. Nitrogen Uptake by Grains and Straw (Kg/ha)

Planting techniques and nitrogen (N) level treatments significantly impacted N uptake by grains and straw in wheat [Table 4]. The planting technique using two rows per bed resulted in significantly higher N uptake by grains and straw during both years compared to bidirectional sowing and flat sowing methods, demonstrating its superiority over these techniques. The highest uptake by grains (53.07 and 63.88 Kg/ha) was observed in the two rows per bed method, followed by bidirectional sowing (43.75 and 53.81 Kg/ha) and flat planting techniques (37.91 and 47.68 Kg/ha) during both years. The two rows per bed treatments increased nitrogen uptake by grains by 39.98% and 15.40% in 2022-23 and 33.97% and 12.85% in 2023-24 compared to bidirectional sowing and flat planting patterns, respectively. The higher uptake recorded in the two rows per bed method may be attributed to superior maturity attributes and yield parameters. In terms of nitrogen treatments, significantly higher uptake by grains and straw in wheat was observed with 160 Kg N/ha compared to 0, 40, 80, and 120 Kg N/ha. The uptake by grains increased by 22.93% in 2022-23 and 19.70% in 2023-24 with the application of 160 Kg N per ha compared to 120 Kg N/ha. Similarly, the uptake by straw increased by 23.96% in 2022-23 and 25.53% in 2023-24 with the application of 160 Kg N/ha compared to 120 Kg nitrogen. Godebo et al. (2021) conducted a study in the Kembata Tembaro Zone, Southern Ethiopia, which revealed that most parameters, including yield, yield components, N uptake, and use efficiency, were significantly higher under 30 and 46 Kg N/ha compared to 0 and 23 N/ha [12,13] also reported similar results.

4. CONCLUSION

Among all the parameters, quality parameters such as leaf area index, chlorophyll index, and protein content were significantly higher in the two rows per bed method. The uptake and nitrogen content of grains and straw were notably higher in the two rows per bed method than in other planting techniques. This was because the growth was better with the bed method due to improved crop growth, loose soil, a smothering effect, and less weed infestation. Among nitrogen level treatments, the uptake of nitrogen by grains and straw, nitrogen content, protein content, and chlorophyll index were significantly higher with 160 Kg N/ha compared to other nitrogen levels.

5. ACKNOWLEDGMENTS

I am thankful to my advisor Dr. U.S. Walia, Department of Agronomy who helped me in gathering various information, ideas from their life experiences and provide guidance in difficult situations that I faced while pursuing my degree, despite their busy schedules.

6. AUTHOR CONTRIBUTIONS

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agree to be accountable for all aspects of the work. All the authors are eligible to be an author as per the international committee of medical journal editors (ICMJE) requirements/guidelines.

7. FUNDING

There is no funding to report.

8. CONFLICTS OF INTEREST

The authors report no financial or any other conflicts of interest in this work.

9. ETHICAL APPROVALS

This study does not involve experiments on animals or human subjects.

10. DATA AVAILABILITY

The authors confirmed that, the data supporting the finding of the present study are available within the article.

11. USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

12. PUBLISHER'S NOTE

This journal remains neutral with regard to jurisdictional claims in published institutional affiliation.

REFERENCES

1. Feldman M, Kislev ME. Domestication of emmer wheat and evolution of free-threshing tetraploid wheat in A century of wheat research-from wild emmer discovery to genome analysis. Isr J of Plant Sci. 2008;55(3, 7):207-21. http://doi.org/10.1560/IJPS.55.3-4.207
2. Statistical Report. Directorate of Economics and Statistics and International Wheat Production Statistics. Ministry of Agriculture and Farmer Welfare; 2023-24.
3. Annual Report. Directorate of Economics and Statistics and International Wheat Production Statistics. Ministry of Agriculture and Farmer Welfare; 2020-21.
4. Singh CB, Rishi R, Kumar A, Hashim M, Pandey UC. Performance of improved varieties under various planting techniques in N-E plain zone of India. J Comm Mob Sus Dev. 2016;11:145-9.
5. Anjum SA, Saleem MF, Bilal MF, Cheema MA, Ghaffar A. Effect of nitrogen on growth and yield of Sugarcane. J Ame Soc Sug. 2012;32:75-86.
6. Rafiq MA, Ali A, Malik MA, and Hussain M. Effect of fertilizer levels and plant densities on yield and protein contents of autumn planted maize. Pak J Agri Sci. 2010;47:201-8.
7. Ullah I, Rehman A, Shabaz MA, Waheed A, Hafeez A, Ishfaq M, et al. Effect of different nitrogen levels on growth, yield and yield contributing attributes of wheat. Inter J Sci Engi Res. 2018;9(9):595-602. http://doi.org/10.14299/ijser.2018.09.01
8. Majeed A, Hussain AS. Bed planting of wheat improves nitrogen use efficiency and grain yield compared to flat planting. Crop J. 2015;3(2):118-24. https://doi.org/10.1016/j.cj.2015.01.003
9. Kumar S, Rawat P, Sasi M, Gusain P, Gupta P. Effect of different nitrogen levels on growth and yield of wheat. Pha Inno. 2023;12(7):3348-51.
10. Litke L, Gaile Z, Ruza A. Effect of nitrogen fertilization on winter wheat yield and yield quality. Agr Res. 2018;16(2):500-9. http://doi.org/10.15159/AR.18.064
11. Chaturvedi I. Effect of different nitrogen levels on growth, yield and nutrient uptake of wheat (*Triticum aestivum* L.). Inter J Agri Sci. 2006;2(2):372-4. http://doi.org/10.14299/ijser.2018.09.01
12. Qazizadah NA, Prakash R, Mor VS, Kumar A, Satyavan. Effect of nitrogen levels on performance of wheat varieties under saline water irrigation in semiarid regions. J Soi Sali Water Qua. 2022;14(1):15-21. https://epubs.icar.org.in/index.php/JoSSWQ/article/view/136520
13. Yang T, Wang X, Zhou Q, Wang Q, Jiang D, Huang M, Cai J. Effects of nitrogen fertilizer on quality characteristics of wheat with absence of different individual high-molecular weight glutenin sub-units. Inter J Mole Sci. 2002;23(4): 2178. https://doi.org/10.3390%2Fijms23042178

How to cite this article:
Gill HK, Walia US. Leaf area index, quality, and nutrient uptake in wheat (*Triticum aestivum* L.) affected by different planting patterns and nitrogen levels. J App Biol Biotech. 2025;13(1):46-50.
DOI: 10.7324/JABB.2024.200916