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RESEARCH ARTICLE

# Quality and NUE of wheat (*Triticum aestivum* L.) under variable planting techniques and different nitrogen levels

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## Abstract

A research experiment was conducted between *Rabi* 2022-23 and 2023-24 on the research farm of Lovely Professional University, Phagwara (Punjab). The experiment employed a split plot design to evaluate the effects of three planting methods (2 rows per bed, cross and flat technique) and 5 nitrogen level treatments (0, 40, 80, 120 and 160 kg/ha nitrogen). Results indicated that 2 rows/bed and cross sowing technique significantly outperformed than flat sowing in terms of quality, uptake and nitrogen use efficiencies. Additionally, chlorophyll index, nitrogen content and uptake in grains and straw, total nitrogen uptake, protein content and nitrogen use efficiencies were more in 2 rows/bed and cross sowing technique as compared to flat sowing. Regarding nitrogen level treatments, 120 and 160 kg N/ha resulted in significantly higher quality attributes than all other treatments. The planting methods of 2 rows per bed and cross technique total nitrogen uptake by the crop increased by19.64 % and 14.71 %, 20.23 % and 15.64 % respectively during 2022-23 and 2023-24 as compared to flat sowing. Application of 160, 120, 80 and 40 kg N/ha increased total nitrogen uptake by 285.1, 246.7, 117.1 and 20.8 % in 2022-23 and by 376.7, 322.8, 174.6 and 51.1 % in 2023-24, respectively, compared to 0 kg N/ha. Agronomic efficiency and recovery efficiency were significantly more in 2 rows per bed and cross sowing technique, but physiological efficiency was significantly higher in flat sowing. Among nitrogen level treatments, agronomic efficiency and recovery efficiency were significantly higher in 120 and 160 kg N/ha but physiological efficiency was significantly higher in 40 kg N/ha than all other N levels.

**Keywords:** nitrogen; planting patterns; quality; split plot design; wheat

## Introduction

India is the largest producer of food grains. Among the different type of grains, wheat is World's important staple food. Its yield is being severely impacted by major biotic and abiotic factors such as infestation of weeds, insects, rodents, cold, salinity, flood, heat, drought and nutrients (1). After China, India is the second biggest producer of wheat (2). India produced 109.53 million tons of wheat over an area of 31.61 million ha, with a productivity of 3,464 kg/ha (3). After rice, wheat is the second most significant cereal in terms of acreage and production. Punjab has the highest productivity per unit area in India, although Uttar Pradesh leads in total wheat output, producing 35.9 million metric tons. The yield of crops can be increased by using proper planting pattern techniques which include bed method, cross sowing, flat sowing etc. Every method has its own advantages and disadvantages. Raised-bed farming has historically been used to manage water efficiently, either by reducing excess water in rainfed conditions or by optimizing irrigation in high-production systems (4). The bed method is more efficient than flat sowing as it provides mechanical support to plants, conserves water, enhances fertilizer use efficiency, reduces crop-weed competition, mitigates water logging and minimizes soil erosion. Raised-bed farming has been linked historically to problems with water management, either by offering ways to lessen the effects of excess water in rainfed environments or by more effectively delivering irrigation water in high-production irrigated systems under normal sowing. Raised bed sowing conserves approximately 25-30 % irrigation water (5).

Cross sowing, also known as bidirectional sowing, increases wheat grain yield by smothering weeds through optimal plant-to-plant spacing. This method enhances resource use efficiency and mitigates risks associated with climate variability and extreme weather events. In an earlier study, it was observed that the N content, grain and straw uptake, total uptake, protein content, chlorophyll index and nutrient use efficiency was higher under the 2 rows per bed and cross method than flat technique (6).

Nitrogen is the most important nutrient for crop growth and is equally essential for cereals. Nitrogen is the first most important macronutrient as it is continuously used by farmers. N is essential for both plants and animals because it has large amounts of vitamins, protein, hormones and other compounds. Since nitrogen is a key component of proteins, vitamins, hormones and other substances, it is necessary for both plants and animals. It plays a crucial role in energy-transfer compounds, such as ATP (adenosine triphosphate). ATP allows cells to conserve and use the energy released in metabolism. Significant components of nucleic acids such as DNA, the genetic material that allows cells (and eventually whole plants) to grow and reproduce. Without nitrogen, there would be no life as we know it. Life of crop plants depends critically on the element nitrogen. Nitrogen use efficiency can be improved with the adoption of different planting patterns. The use of optimum nitrogen does not only increase nitrogen use efficiency but also reduces environment pollution. The highest nitrogen use efficiency (NUE) was recorded at 62 kg/ha in bed sowing, which was statistically at par with 80 kg/ha in flat sowing (7). The purpose and significance of this study is maximized yield, efficient use of resources, soil fertility management, control pest and diseases, promote plant growth and development.

## Materials and Methods

The wheat variety PBW- 824 was sown at the research farm of Lovely Professional University, Phagwara, during the *rabi* seasons of 2022-2023 and 2023-24. The wheat was sown in sandy loam soil with a pH 6.9 in 2022-2023 and 6.3 in 2023-2024. The available nitrogen contents in the soil were 312.3 kg/ha in 2022-23 and 308.6 kg/ha in 2023-24. The experiment followed a split-plot design with three planting techniques assigned to the main plots and five nitrogen levels in the subplots. Each treatment was replicated four times during both years.

### Treatment details

| Main plot | Planting patterns |
|---|---|
| $M_1$ | Bed planting (2 rows/bed) |
| $M_2$ | Cross sowing (22.5 × 22.5 cm) |
| $M_3$ | Flat sowing (22.5 cm) |
| **Sub plot** | **N level treatments (kg/ha)** |
| $T_1$ | 0 |
| $T_2$ | 40 |
| $T_3$ | 80 |
| $T_4$ | 120 |
| $T_5$ | 160 |

The sowing. In both years, the size was the main plots 64 sq.m and 5×3.2 m measured for sub plots. The raised beds had a top width of 37.5 cm, a furrow width of 30 cm and a total width of 67.5 cm. Two rows were shown on the top of each bed. The herbicide spray of ACM-9 (clodinafop-propargyl 9 % + metribuzin 20 %) at 240 g/ha were sprayed on crop to avoid the infestation of BLW, *Phalaris minor* and both. According to protocols, the herbicide spray was completed (POE) after 35 days of seeding. According to treatments, at the time of sowing the 1st N dose was applied, 35 days of sowing the 2nd half dose was supplied and 48 days after sowing, 3rd N dose was applied. The first irrigation was applied at the CRI stage (21 DAS), the 2nd at starting of tillers, the 3rd at boot phase and 4th at milking phase.

To stop aphid and jassid damage, Malathion was spritzed on the plot @ of 1.0 litre/ha. The crop was sickled at 142 DAS during 1st season and 146 DAS during second, after accounting for the symbols of maturity. From the center of each plot, 2 sq.m of net plot were removed. Crops were banded after cutting and let to dry fully in the sunlight. Then crops were staked, the seeds were distinguished and a balancing machine was used to inspect the plot. The nitrogen uptake comes from nitrogen content multiplied with yield and for protein content nitrogen content multiplied with factor 6.25. Data collected from experimental fields like for chlorophyll index (with SPAD), N content in grains and straw (digestion, distillation and titration), N uptake by grains and straw, total nitrogen uptake (grains+straw), protein content and nitrogen use efficiencies. Data analysis was performed using OPSTAT software with a two-factorial design (OP sheoran, CCSHAU, Hisar, Haryana) (8).

## Results and Discussion

### Chlorophyll index

Data on chlorophyll index was observed at 60 and 90 DAS during 2022-23 and 2023-24 is presented in Table 1.

The difference in chlorophyll index was found to be significant both for planting methods and N treatments when recorded at 60 DAS during 2022-23. Chlorophyll index was statistically at par in two rows per bed and cross sowing than flat sowing technique. Among nitrogen levels, significantly more chlorophyll index was observed in 160 nitrogen kg/ha than other N treatments during 2022-23. During 2023-24, data revealed that chlorophyll index was significantly high in 2 rows per bed and bidirectional method as compared to flat sown crop. Among nitrogen levels, significantly higher chlorophyll index was examined in 160 nitrogen kg/ha than another N treatments. During both years there was a significant increase in chlorophyll index from each gaining of N level from zero to 160 kg N/ha.

At 90 DAS during 2022-23, the chlorophyll index was statistically at par in 2 rows per bed and bidirectional methods and it was significantly higher than in flat-sown method. Among nitrogen levels, significantly higher chlorophyll index was observed in 160 kg /ha nitrogen than

**Table 1.** Role of planting techniques and N levels on chlorophyll index of wheat

| Treatments | Chlorophyll index | | | |
|---|---|---|---|---|
| | 60 DAS | | 90 DAS | |
| | 2022-23 | 2023-24 | 2022-23 | 2023-24 |
| | Main plots- Planting patterns | | | |
| **Two rows/bed** | 42.21 | 39.02 | 38.66 | 38.60 |
| **Cross sowing** | 41.72 | 38.41 | 37.41 | 38.34 |
| **Flat sowing** | 39.96 | 36.53 | 37.38 | 37.68 |
| **SE(m) ±** | 0.45 | 0.28 | 0.47 | 0.61 |
| **CD at 5 % (P= 0.05 %)** | **1.60** | **0.87** | **1.64** | **1.82** |
| | Sub plots- Nitrogen level treatments | | | |
| **0 kg/ha** | 31.70 | 29.65 | 28.18 | 28.92 |
| **40 kg/ha** | 39.92 | 36.01 | 36.46 | 36.95 |
| **80 kg/ha** | 42.34 | 38.6 | 38.84 | 39.18 |
| **120 kg/ha** | 45.68 | 42.14 | 42.15 | 42.09 |
| **160 kg/ha** | 46.81 | 43.54 | 43.31 | 43.88 |
| **SE(m) ±** | 0.35 | 0.27 | 0.34 | 0.34 |
| **CD at 5 % (P= 0.05 %)** | **1.01** | **0.85** | **0.97** | **1.04** |
| **CD for interaction at 5%** | NS | NS | NS | NS |

another N levels. 120 kg/ha nitrogen observed significantly more chlorophyll content than 80 kg N/ha. 0 kg/ha N examined significantly less chlorophyll content than all another N treatments. During 2023-24, among planting patterns, the chlorophyll index was statistically par in 2 rows/ bed and cross technique and it was higher than flat technique. Among nitrogen levels, significantly higher chlorophyll index was observed at 160 kg/ha N than all another N methods. During both years there was a significant increase in chlorophyll index from each level of increment of N from 0 kg to 160 kg/ha nitrogen. Noor and Yang also reported higher chlorophyll index recorded in bed method and increased with higher nitrogen doses (9-11).

The interaction effects of planting methods and nitrogen treatments on the chlorophyll index were found to be non-significant at all growth stages in both years.

## Nitrogen content in grains and straw (%)

Data on nitrogen content in grains and straw was recorded after harvest during 2022-23 and 2023-24 is presented in Table 2.

Among planting patterns, nitrogen content in grains was significant when recorded during 2022-23 and nitrogen content in grains was significantly more in 2 rows per bed and cross method than flat sown method. 2 rows per bed and cross technique at par among each other. Among nitrogen levels, N content in grains was significantly more in 160 kg N/ ha as compared to other nitrogen levels. Nitrogen content in grains under 120 kg N/ha was significantly higher than 0, 40 and 80 kg N/ha. During 2023-24 nitrogen content in grains was significantly more in 2 rows per bed and cross method than flat sown. Among nitrogen levels, the nitrogen content in grains was significantly more in 160 kg N/ha as compared to other nitrogen levels. Nitrogen content in 120 and 160 kg N/ha was found at par.

The nitrogen content in straw was statistically at par in cross sowing and two rows/bed during 2022-23 and both these methods produced significantly more nitrogen content than flat sown crops. Among nitrogen level treatments, significantly more straw nitrogen was observed in 160 kg N/ ha than other nitrogen level treatments. Among planting patterns, nitrogen content in straw was significantly more in 2 rows per bed and cross technique than flat technique during 2023-24. Among nitrogen level treatments, significantly more N content was obtained in straw with 160 kg N/ha than other N levels. N content in grains and straw during both years was significantly more in 80 kg N/ha compared to 40 kg N/ha but it was significantly less than 120 kg N/ha. These results showed similarity with the findings of Hussain, Zhao, Hahimi reported higher nitrogen content in grains in bed technique (12-14).

The interaction effects of planting techniques and nitrogen level treatments for nitrogen content in grains and straw was found to be non-significant during both years.

**Table 2.** Influence of planting patterns and nitrogen levels on content in grain and straw (%) of wheat

| Treatments | N content in grain (%) | | N content in straw (%) | |
|---|---|---|---|---|
| | 2022-23 | 2023-24 | 2022-23 | 2023-24 |
| | **Main plots- Planting patterns** | | | |
| **Two rows/bed** | 1.06 | 0.98 | 0.55 | 0.55 |
| **Cross sowing** | 1.02 | 0.98 | 0.54 | 0.54 |
| **Flat sowing** | 0.88 | 0.82 | 0.48 | 0.46 |
| **SE(m) ±** | 0.03 | 0.01 | 0.01 | 0.02 |
| **CD at 5 % (P= 0.05 %)** | **0.09** | **0.04** | **0.03** | **0.06** |
| | **Sub plots- Nitrogen level treatments** | | | |
| **0 kg/ha** | 0.68 | 0.57 | 0.25 | 0.23 |
| **40 kg/ha** | 0.72 | 0.61 | 0.33 | 0.32 |
| **80 kg/ha** | 0.92 | 0.89 | 0.53 | 0.56 |
| **120 kg/ha** | 1.26 | 1.27 | 0.73 | 0.67 |
| **160 kg/ha** | 1.35 | 1.30 | 0.79 | 0.82 |
| **SE(m) ±** | 0.04 | 0.03 | 0.01 | 0.01 |
| **CD at 5 % (P= 0.05 %)** | **0.12** | **0.08** | **0.04** | **0.03** |
| **CD for interaction at 5 %** | NS | NS | NS | NS |

## Nitrogen uptake by grain and straw (kg/ha)

Data on N uptake by grain and straw (kg/ha) was recorded during 2022-23 and 2023-24 is presented in Table 3.

Among planting patterns, the difference for nitrogen uptake in grains was significant when recorded during 2022-23 and N uptake in grains in 2 rows per bed and cross sowing was significantly higher than flat technique whereas the former planting methods were at par. Among nitrogen levels, nitrogen uptake by grains in 120 and 160 kg/ha nitrogen was at par and significantly higher than all another N methods. Also 80 kg N/ha recorded significantly higher nitrogen uptake by grains as compared to 40 kg N/ha. During 2023-24, the uptake of nitrogen by grains was significantly less in flat sowing than other planting methods. Also, nitrogen uptake by grains was statistically at par in 2 rows per bed as compared to cross sown method. Among nitrogen levels, significantly more N uptake in grains was noticed in 160 kg N/ ha than another N level treatments. Supply of 120 kg nitrogen/ha examined seriously higher nitrogen uptake by grains as compared to 80 kg N/ha. Significantly less nitrogen in grains was recorded in 0, 40 and 80 kg N/ha compared to other nitrogen levels.

Among planting patterns, nitrogen uptake in straw was statistically at par in cross sowing and two rows/bed during 2022-23 which was significantly higher than flat technique. Among N levels, crucially more nitrogen uptake by straw was noticed in 160 kg N/ha than another N doses. There was a significant progressive in N uptake by straw with each increase of N from 0 to 160 nitrogen kg/ha. Among planting patterns, nitrogen uptake in straw was significantly less in flat

**Table 3.** Influence of planting patterns and nitrogen levels on N uptake grain and straw (kg/ha) of wheat

| Treatments | N uptake by grains (kg/ha) | | N uptake by straw (kg/ha) | |
|---|---|---|---|---|
| | 2022-23 | 2023-24 | 2022-23 | 2023-24 |
| | **Main plots- Planting patterns** | | | |
| **Two rows/bed** | 48.65 | 43.90 | 33.82 | 33.33 |
| **Cross sowing** | 46.21 | 43.25 | 32.88 | 30.99 |
| **Flat sowing** | 38.48 | 36.21 | 28.66 | 28.02 |
| **SE(m) ±** | 1.23 | 0.42 | 0.52 | 0.60 |
| **C.D. at 5 % (P= 0.05 %)** | **3.68** | **1.27** | **1.83** | **2.11** |
| | **Sub plots- Nitrogen level treatments** | | | |
| **0 kg/ha** | 20.19 | 15.02 | 12.40 | 11.11 |
| **40 kg/ha** | 22.17 | 23.11 | 17.18 | 16.37 |
| **80 kg/ha** | 40.61 | 40.44 | 30.15 | 31.30 |
| **120 kg/ha** | 66.28 | 68.16 | 46.71 | 42.31 |
| **160 kg/ha** | 72.96 | 71.68 | 52.55 | 52.89 |
| **SE(m) ±** | 2.96 | 1.07 | 0.73 | 0.75 |
| **C.D. at 5% (P= 0.05 %)** | **8.53** | **3.18** | **2.11** | **2.16** |
| **CD for interaction at 5 %** | NS | NS | NS | NS |

sowing than other planting patterns during 2023-24. Two rows/bed recorded statistically at par nitrogen uptake by straw as compared to cross sowing method. Among nitrogen levels, significantly more nitrogen uptake in straw was noticed in 160 kg/ha N than another N doses and lowest recorded in 0 kg N/ha. There was a significant progressive in N uptake by straw with each increase of N from 0 to 160 nitrogen kg/ha.

It may be concluded that nitrogen uptake in grain & straw was more in 2 rows/bed and cross sowing due to better enhancement of crops on beds. Also, the uptake of N by grains and straw was significantly higher in cross sowing as compared to flat sowing due to superior crop stand because of uniform stand in cross sowing method. Biological yield of crops was more in 120 and 160 kg N/ha, hence the uptake of nitrogen was more in contrast to low level of N. Results of present data matched with Chaturvedi, Litke and Sharma (15-17).

The interactive effects of planting patterns & nitrogen doses for N uptake in grains & straw was found to be non-significant during both years.

## Total nitrogen uptake by crop (kg/ha) and protein content (%)

Data on total N uptake by grain & straw (kg/ha) and protein content (%) in grains, recorded during 2022-23 and 2023-24, is presented in Table 4.

Total nitrogen uptake (grains and straw) among planting patterns was statistically at par between cross sowing and the two-rows-per-bed method, both of which showed significantly higher uptake than the flat-sowing technique in 2022-23. Among nitrogen levels, the significantly highest uptake was observed in 160 kg /ha nitrogen than another N level treatments. Also 0 and 40 kg N/ha levels were found to be statistically at par. Total uptake of nitrogen by crop was significantly more in 120 kg N/ha in contrast to 80 kg N/ha. During 2023-24, among planting methods, significantly less total uptake by crop was recorded in flat sowing method than other planting techniques. 2 rows per bed and bidirectional method recorded statistically par uptake of nitrogen by crop. Among nitrogen levels, significantly more uptake of nitrogen was observed in 160 kg/ha nitrogen than another N level treatments.

**Table 4.** Influence of planting patterns and nitrogen levels on total N uptake by crop (kg/ha) and protein content (%) of wheat

| Treatments | Total N uptake by crop (kg/ha) | | Protein content (%) | |
|---|---|---|---|---|
| | 2022-23 | 2023-24 | 2022-23 | 2023-24 |
| | Main plots- Planting patterns | | | |
| **Two rows/bed** | 82.47 | 77.23 | 6.62 | 6.12 |
| **Cross sowing** | 79.09 | 74.24 | 6.37 | 6.12 |
| **Flat sowing** | 68.93 | 64.23 | 5.49 | 5.14 |
| **SE(m) ±** | 1.45 | 1.02 | 0.16 | 0.05 |
| **CD at 5 % (P= 0.05 %)** | **5.11** | **3.38** | **0.57** | **0.19** |
| | Sub plots- Nitrogen level treatments | | | |
| **0 kg/ha** | 32.59 | 26.13 | 4.25 | 3.56 |
| **40 kg/ha** | 39.36 | 39.48 | 4.51 | 3.84 |
| **80 kg/ha** | 70.76 | 71.74 | 5.75 | 5.58 |
| **120 kg/ha** | 112.99 | 110.47 | 7.85 | 7.91 |
| **160 kg/ha** | 125.51 | 124.57 | 8.49 | 8.10 |
| **SE(m) ±** | 3.09 | 1.82 | 0.26 | 0.17 |
| **CD at 5 % (P= 0.05 %)** | **8.92** | **5.34** | **0.74** | **0.49** |
| **CD for interaction at 5%** | NS | NS | NS | NS |

Among planting patterns, the protein content was statistically par in cross and 2 rows per bed during 2022-23 and these planting methods showed significantly more protein content than flat sowing method. Among nitrogen levels, the protein content was found to be significantly more in 120 and 160 kg N/ha as contrast to another N levels, however differences in former treatments were found to be non-significant. The protein content was observed significantly more in 2 rows per bed and cross sown method as compared to flat method during 2023-24 also. Among nitrogen levels, the protein content was found to be significantly more in 120 and 160 kg N/ha in contrast to another nitrogen levels, however differences in former treatments were found to be non-significant.

The total uptake of nitrogen in 2 rows per bed and cross sowing was significantly higher than flat crops during both years which may be due to better crop stand in these planting patterns. The planting technique of 2 rows per bed & cross technique increased total nitrogen uptake by crop 19.64 % and 14.71 % during 2022-23 and 20.23 % and 15.64 % during 2023-24 respectively as compared to flat sowing. The application of 160, 120, 80 and 40 kg N/ha increased total nitrogen uptake by 285.1, 246.7, 117.1 and 20.8 % during 2022 -23 and by 376.7, 322.8, 174.6 and 51.1 % during 2023-24, respectively, compared to 0 kg N/ha. Nitrogen uptake was also higher at 120 and 160 kg N/ha due to improved crop growth (higher biological yield) compared to lower nitrogen doses (18, 19).

The interaction effects of planting techniques and N doses for total nitrogen uptake by crop and protein content was found to be non-significant during both years.

## Nitrogen use efficiencies (%)

Data on agronomic efficiency, recovery efficiency and physiological efficiency were recorded during 2022-23 and 2023-24 and data is presented in Table 5.

During 2022-23 Agronomic efficiency was crucially more in 2 rows per bed and cross technique than flat method. AE in two rows/bed was at par with cross sowing method. Among nitrogen levels, the AE was statistically at par in 120 kg nitrogen/ha and 160 kg which was seriously higher than 40 kg and 80 kg/ha N. Throughout 2023-24 the AE was statistically par in 2 rows per bed and cross method and both these planting patterns recorded significantly more AE than flat sown crops. Among nitrogen levels, the AE was crucially more in 160 kg/ha nitrogen than all another N doses. There was a progressive increment in AE with every increase of N from 0 kg to 160 kg/ha N.

Data on Recovery efficiency was recorded during 2022-23 and 2023-24 has been presented in Table 5. During 2022-23 the RE was significantly more in 2 rows per bed and cross technique than flat method. RE was significantly higher in cross sown crop than flat sown crop. Among nitrogen levels, the RE was crucially more in 120 kg N/ha than another nitrogen levels. During 2023-24 the RE was crucially more in 2 rows per bed than cross technique and flat method. RE was significantly higher in cross sown crop than flat sown crop. Among nitrogen levels, the RE was seriously more in 120 kg/ ha N than all another N doses. RE in 160 kg N/ha was crucially higher than 80 kg N/ha during both years.

Data on Physiological Efficiencies was recorded during 2022-23 and 2023-24 has been presented in Table 5. During 2022-23 the PE was significantly higher in flat sowing than cross sowing and two rows/bed planting method. PE was significantly more in cross sown crops than two rows/bed. Among nitrogen levels, the PE was significantly more in 40 kg/ha N than another nitrogen levels. During 2023-24 the PE was significantly higher in flat sowing than cross sowing and two rows/bed planting method. PE was significantly more in cross sown crops than two rows/bed. Among nitrogen levels, the PE was significantly more in 40 kg/ha N in contrast to another N doses. PE reduced significantly with an increase in nitrogen dose from 0 to 160 kg N/ha during both years. These conclusions are also same with Du and Godebo (20, 21).

AE is significantly higher in 120 and 160 kg N/ha because it reflects kg grain per kg nitrogen applied i.e. how much grain yields with respect to applied nitrogen. RE significantly higher in 120 kg N/ha because it reflects total nitrogen uptake by crop with respect to how much nitrogen applied but PE significantly higher in 40 kg N/ha because it reflects grain yield with respect to total uptake by crop i.e. kg grain per kg nitrogen uptake. So, it is the trend and after calculations, they all will vary accordingly.

**Table 5.** Effect of planting patterns and nitrogen level treatments on different nitrogen use efficiencies viz. AE, RE (%), PE

| Treatments | Nitrogen use efficiencies | | | | | |
|---|---|---|---|---|---|---|
| | Agronomic efficiency (AE) | | Recovery efficiency (RE) | | Physiological efficiency (PE) | |
| | 2022-23 | 2023-24 | 2022-23 | 2023-24 | 2022-23 | 2023-24 |
| | Main plots- Planting patterns | | | | | |
| **Two rows/bed** | 37.24 | 37.13 | 47.88 | 50.12 | 32.27 | 33.83 |
| **Cross sowing** | 36.45 | 36.54 | 45.50 | 48.01 | 33.25 | 37.58 |
| **Flat sowing** | 35.35 | 35.68 | 35.34 | 38.10 | 37.32 | 39.93 |
| **SE(m) ±** | 0.18 | 0.25 | 0.21 | 0.23 | 0.17 | 0.19 |
| **CD at 5% (P= 0.05 %)** | **0.65** | **0.88** | **0.63** | **0.71** | **0.53** | **0.59** |
| | Sub plots- Nitrogen level treatments | | | | | |
| **0 kg/ha** | - | - | - | - | - | - |
| **40 kg/ha** | 32.08 | 33.97 | 18.91 | 33.38 | 76.28 | 75.65 |
| **80 kg/ha** | 43.52 | 42.93 | 48.72 | 57.91 | 41.71 | 40.92 |
| **120 kg/ha** | 52.59 | 51.87 | 67.01 | 70.32 | 30.48 | 33.72 |
| **160 kg/ha** | 53.54 | 53.48 | 58.07 | 61.52 | 28.19 | 30.56 |
| **SE(m) ±** | 0.34 | 0.44 | 0.36 | 0.42 | 0.33 | 0.34 |
| **CD at 5% (P= 0.05 %)** | **0.98** | **1.28** | **1.08** | **1.26** | **0.97** | **1.02** |
| **CD for interaction at 5%** | NS | NS | NS | NS | NS | NS |

## Conclusion

Among all the parameters, cross sowing and two rows/bed recorded higher chlorophyll index, more protein content and nitrogen uptake than other planting techniques due to more favorable crop pattern and plot geometry.

Among nitrogen level treatments, the quality attributes like chlorophyll index, nitrogen content and nitrogen uptake by straw and grains, protein content, nitrogen use efficiencies were significantly better in 120 and 160 kg/ha nitrogen than another doses of N.

Overall, it may be concluded that the two rows/bed and bidirectional method gave better quality and nitrogen uptake than flat sowing. Among nitrogen levels, wheat quality parameters were at par within 120 kg and 160 kg N/ha *viz.* protein content, chlorophyll index, nitrogen content and nitrogen uptake by crop.

The significance of this study is cropping productivity, weed management and sustainability. Future research should focus on optimizing planting techniques, integrating remote sensing for crop monitoring and breeding wheat varieties with enhanced nitrogen use efficiency and stress tolerance.

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## Authors' contributions

HKG prepared the main manuscript, writing and data analysis. PT, TM, MSB and SK helped in writing and formatting. USW reviewed and approved the manuscript.

## Compliance with ethical standards

**Conflict of interest:** Authors do not have any conflict of interest to declare.

**Ethical issues:** None

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