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Impact of Rice Straw and Nitrogen Levels on Yield and Quality of Wheat (*Triticum aestivum* L.)

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ABSTRACT

Background: The incorporation of rice straw and the application of nitrogen are key factors influencing wheat production. Rice straw, as a residue, contributes to soil organic matter and nutrient cycling while nitrogen is crucial for plant growth and grain development. Understanding their combined impact is essential for optimizing wheat yield and improving grain quality in sustainable agricultural systems.

Methods: The study was conducted at Research Farm, Division of Agronomy, Lovely Professional University during *rabi* 2022-2023 and 2023-2024 focused on the impact of various rice straw management practices and nitrogen levels on the yield and quality of wheat emphasizing the importance of sustainable agricultural practices. The experimental field had sandy loam soil with slightly alkaline pH (7.6), moderate organic carbon content alongside low concentrations of essential nutrients *viz*, nitrogen, phosphorus and potassium. It comprised 12 treatments arranged in split plot design and replicated three times to evaluate two main factors Rice Straw management: S_0: Control, S_1: Super seeder and S_2: Pusa bio decomposer and nitrogen levels: N_0 : Control (no nitrogen), N_1: 75% of the recommended dose (RDN), N_2: 100% of RDN, N_3: 125% of RDN.

Result: The results demonstrated that the S_2 and N_3 treatments significantly improved wheat performance, with the highest values for effective tillers (93.58, 91.74/m row), grains per spike (43.71, 42.20) and test weight (43.30, 42.23 g). Grain yield peaked at 49.75 q/ha (S_2) and 51.26 q/ha (N_3), while straw yield and biological yield also showed corresponding increases. The harvest index, although non-significant, reflects trends consistent with these yield improvements. Quality attributes were enhanced under S_2 and N_3 treatments, with maximum protein content (12.88%, 12.53%), protein yield (905.44 kg/ha, 854.94 kg/ha) and levels of essential amino acids (lysine, tryptophan, phenylalanine).

Key words: Nitrogen levels, Rice straw management, Soil health, Sustainable agriculture, Wheat.

INTRODUCTION

As a foundation of global agriculture, wheat (*Triticum aestivum* L.) stands as India's second-most vital crop, right after rice. Known for its adaptability, wheat flourishes in a variety of soils and climates. Around 80-85% of wheat is milled into atta, the key ingredient in staples like chapattis. Soft wheat is prized for bakery items, while hard wheat is used to make semolina and sewaiya. Nutritionally, wheat is packed with 78% carbohydrates, 12% protein, and 2% fat, alongside essential vitamins and minerals (Kumar *et al*., 2011). Its straw further supports agricultural sustainability as essential livestock fodder.

Once dismissed as "wastes," crop residues are now valued as "potential black gold" for their nutrient-rich content that boosts agricultural productivity (Reicosky and Wilts, 2005). In India, significant crops like rice, wheat, maize, and sugarcane generate around 686 million tonnes of residues annually, with cereals (364MT) being the largest contributors followed by sugarcane (56 MT) and others (47 MT) (Ministry of Agriculture and Farmers Welfare, 2020). Effective management of these residues is becoming increasingly important amid rising environmental concerns about chemical inputs in agriculture (Dadhich *et al*., 2012).

Rice straw, a widely available agricultural byproduct, represents one of the most abundant lignocellulosic wastes in the world. Given that rice is a staple food for over half of the global population, particularly in Asia, this resource is particularly significant (Singh and Arya, 2021). Other crop residues, such as pearl millet husk, groundnut shell, and sesame stover, often go to waste due to their high carbon-to-nitrogen (C/N) ratios and lack of use as animal feed. Unfortunately, ineffective management leads to these residues being burned in fields, causing environmental pollution and depleting essential soil nutrients.

Therefore, integrating crop residues with inorganic fertilizers represents a powerful strategy for enhancing soil

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health and boosting long-term crop productivity. This holistic approach not only maintains crop yields but also improves nutrient use efficiency and enriches soil fertility. By leveraging the synergy between these resources, we pave the way for a more sustainable agricultural future that maximizes the benefits of our natural assets.

MATERIALS AND METHODS

Location and climate

The research trial was conducted during *Rabi* season of 2022-23 and 2023-2024 at the experimental farm of Department of Agronomy, School of Agriculture, Lovely Professional University in Phagwara, Punjab, India. The farm is situated at 31°14′35.2″ North latitude and 75°41′48.2″ East longitude in a semi-arid, subtropical climate with 245 m average elevation from above mean sea level (Fig 1). Most of the annual rainfall (500-800 mm) occurred during the monsoon season, between July and September, with groundwater found at depths of 90-100 meters.

Experimental design and crop management

The study conducted from 2022-23 to 2023-24 assessed the impact of different rice straw management techniques and nitrogen levels on wheat yield and soil health. A split-plot design with 12 treatment combinations, replicated three times across 36 plots, was used to evaluate two main factors: The two key factors tested were: Rice Straw Management: S_0 : Control (no straw) S_1: Sowing with Super Seeder (incorporating straw directly into the soil) S_2: Straw decomposed using Pusa Bio Decomposer (decomposed 20 days before application) and Nitrogen Levels: N_0: Control (no nitrogen), N_1: 75% of the recommended dose (RDN), N_2: 100% of RDN, N_3: 125% of RDN. Rice straw decomposed with the Pusa Bio Decomposer was incorporated into designated plots before sowing. The straw underwent microbial decomposition for 20 days to enhance nutrient availability (Kumar and Pareek, 2022).

The wheat variety PBW 824 was sown using the drilling method. Data collection included measurements of crop growth, biomass, grain yield and nutrient uptake along with soil nutrient content and organic carbon levels. Pre and post-treatment soil samples were analyzed for nitrogen, phosphorus and potassium levels. This combination of innovative rice straw management and nitrogen application provided valuable insights into sustainable practices that enhance wheat productivity and improve soil health over the long term.

The soil, characterized as sandy loam from the Central alluvial plain, exhibited a pH of 7.6 and an electrical conductivity (EC) of 0.47ds/m. Initial tests conducted in October 2022 revealed moderate organic carbon content (0.57%) alongside low concentrations of essential nutrients, including nitrogen (183.7 Kg/ha), phosphorus (26.4 Kg/ha) and potassium (192.3 Kg/ha).

Estimation of yield attributes of wheat

The total numbers of ear bearing tillers/meter row length from the two sampling rows were recorded from each plot at harvest. Average of both the counts was taken for statistical analysis. Length of ear from the point of attachment of the lower most primary rachis to the tip of the panicle of ten spikes collected randomly from the tagged plants from the sampling rows. Length of the ear from each plot was measured and the average length of ear was calculated (cm). One thousand grains were randomly taken from the bulk produce of each net plot and were counted and weighed manually and their weight was recorded in grams.

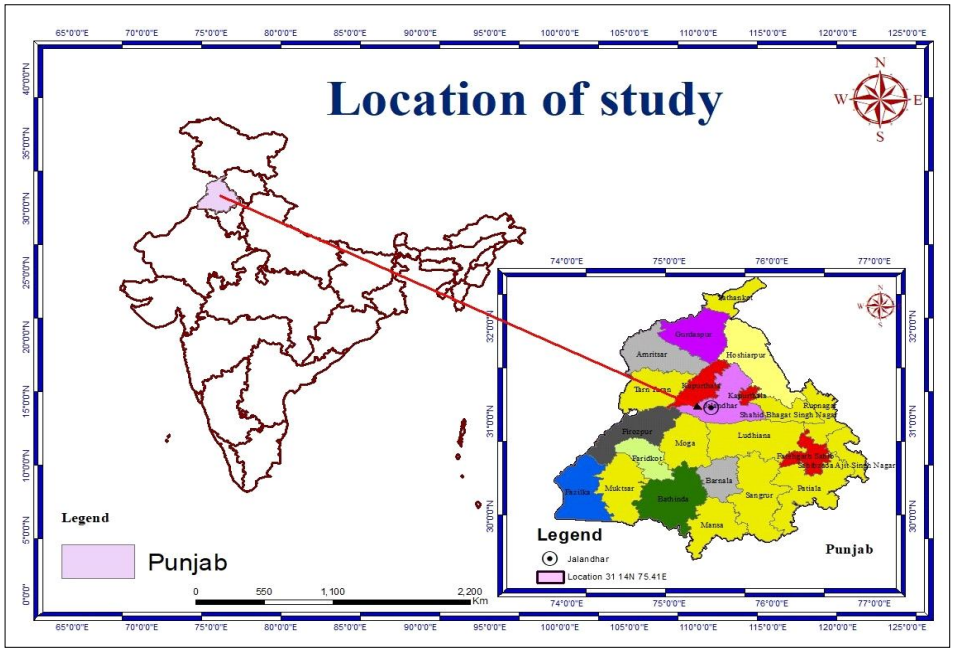


Fig 1: Description of study site.

Estimation of yield

Grain yield and straw yield (q/ha)

From the individual plot, net plot area was harvested; sun dried for 3-4 days and was subsequently threshed (through thresher) and cleaned. The grain thus obtained, were weighed and expressed in quintals per hectare (q/ha). The total biological yield (grain + straw) from the net plot was recorded and straw yield was worked out by subtracting the grain yield from the biological yield and expressed in q/ha.

Harvest index (per cent)

The ratio of economic yield to the biological yield (harvest index) was computed using the following formula as given by Donald and Hamblin (1976).

$$\text{Harvest index (per cent)} = \frac{\text{Economic yield (q/ha)}}{\text{Biological yield (q/ha)}} \times 100$$

Estimation of quality parameters

Protein content (per cent)

Protein content of wheat grain was determined by multiplying respective nitrogen content in wheat grain with a factor 6.25 (AOAC International, 1970).

Tryptophan (per cent)

Alkaline hydrolysis (commonly with barium hydroxide or sodium hydroxide) is used to release tryptophan, as acid hydrolysis can degrade tryptophan. The percentage of tryptophan is calculated using the formula:

$$\text{Tryptophan (per cent)} = \frac{\text{Tryptophan content (mg)}}{\text{Total sample weight (mg)}} \times 100$$

Lysine (per cent)

The protein in the sample is hydrolyzed using acid hydrolysis (*e.g.*, 6N HCl at high temperature for several hours). This breaks down proteins into their constituent amino acids, including lysine. Then high-performance liquid chromatography (HPLC) was used to separate and quantify lysine.

$$\text{Lysine (per cent)} = \frac{\text{Lysine content (mg)}}{\text{Total sample weight (mg)}} \times 100$$

RESULTS AND DISCUSSION

Yield parameters

The application of different rice straw treatments and nitrogen levels significantly influenced various yield parameters of wheat. Among the rice straw treatments, S_2 (straw decomposed by Pusa decomposer) consistently resulted in the highest values for yield parameters. Specifically, effective tillers per meter row length for S_2 were 93.58, compared to 84.57 for S1 and 74.35 for S_0. Similarly, increasing nitrogen levels, particularly N_3 (125% RDN), significantly improved all yield components, with effective tillers reaching 91.74 at N_3, compared to 81.74 at N_1 and 73.64 at N_0 (Table 1). The rise in tiller numbers associated with higher nitrogen levels can be linked to the well-established role of nitrogen in promoting vigorous vegetative growth in plants. This enhancement not only supports tiller development but also contributes to the overall productivity of the crop. Results are in conformity with the study done by Iqbal *et al.* (2012).

For the number of grains per spike, the S_2 treatment had 43.71 grains, outperforming both the control (S_0) at 30.67 grains and the super seeder (S_1) at 37.11 grains. In parallel, increasing nitrogen levels, especially at N_3, contributed to higher grain numbers, with 42.20 grains (Table 1). These findings are in agreement with the work of Ashish and Tiwana (2023), Iqbal *et al.* (2012) who reported that the enhanced allocation of assimilates, driven by the progressive increase in nitrogen levels, fostering greater photosynthetic efficiency (Ouyang *et al.,* 2021).

The test weight (in grams) also followed a similar trend, with S_2 achieving 43.30 g and N_3 recording 42.23 g, both reflecting improved grain filling under optimal straw decomposition and nitrogen supply (Table 1). Results are in conformity with the study done by Ali *et al*. (2011).

Table 1: Effect of rice straw management and nitrogen levels on effective tillers, number of grains per spike and test weight of wheat.

Treatments	Effective tillers/m row length	Number of grains per spike	Test weight (g)
	Pooled data (2022-24)		
Rice straw			
S_0- Control	74.35	30.67	36.40
S_1- Sowing with super seeder	84.57	37.11	39.78
S_2- Straw decomposed by pusa decomposer	93.58	43.71	43.30
SEm±	1.72	0.67	0.62
CD (P=0.05)	5.08	1.97	1.82
Nitrogen levels			
N_0- Control	73.64	30.05	36.30
N_1- 75% RDN	81.74	36.04	39.06
N_2- 100% RDN	89.54	40.37	41.72
N_3- 125% RDN	91.74	42.20	42.23
SEm±	1.31	0.66	0.68
CD (P=0.05)	3.67	1.84	1.91

The organic matter from decomposed rice straw fosters optimal growth conditions, leading to heavier and denser wheat grains. These findings support the conclusions of previous research by Sharma *et al.* (2021).

Yield

In terms of grain yield (q/ha), the combined effects of rice straw management and nitrogen levels were evident, with S_2 producing 49.75 q/ha and N_3 yielding 51.26 q/ha (Fig 2). The decomposition of rice straw in S_2 likely enhanced soil health and microbial activity, leading to greater grain production. These findings support the conclusions of previous research done by Vashisht *et al.* (2021). While N_3 provided the necessary nitrogen for maximizing yield potential. These findings are in conformity with Kousar *et al.* (2015) state that the increased grain yield with sufficient nitrogen supply could potentially be attributed to delayed leaf senescence, allowing for prolonged photosynthetic activity and enhanced nutrient translocation to the grains (Prem *et al.,* 2024).

Straw yield also increased with both S_2 at 69.87 q/ha and higher nitrogen levels (N_3 at 67.71 q/ha) (Fig 2), indicating that both decomposed straw and sufficient nitrogen promote overall biomass production. The outcomes of this study corroborate earlier findings by Sharma *et al.* (2021) that the incorporation of rice straw, improves soil organic matter, boosting microbial activity, and increases nutrient availability. This process enriches the soil environment, supporting greater wheat biomass production (Elhag *et al.,* 2017). The increase in straw yield can be attributed to improved soil moisture availability, which facilitated the uptake of essential nutrients during

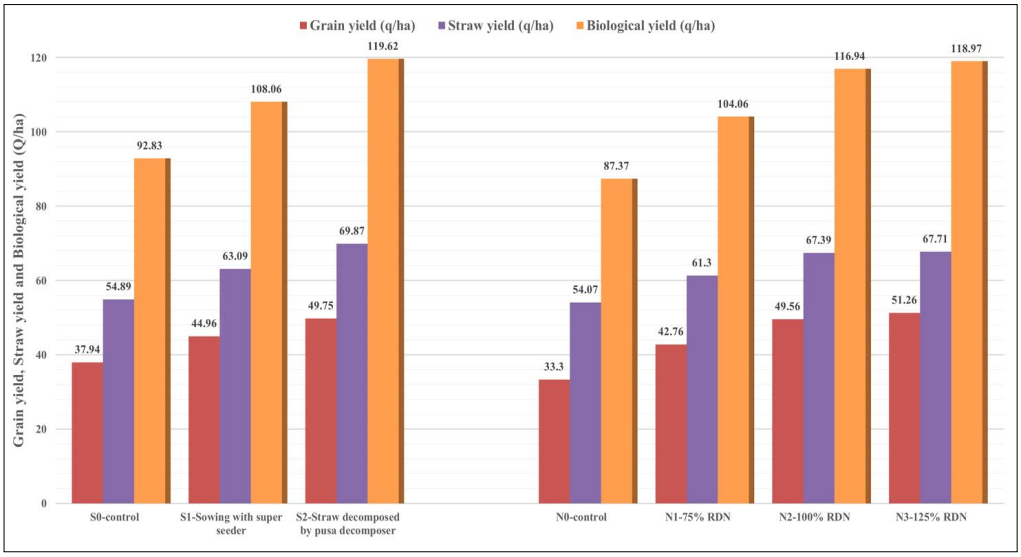


Fig 2: Effect of rice straw management and nitrogen levels on grain, straw, biological yield and harvest index of wheat.

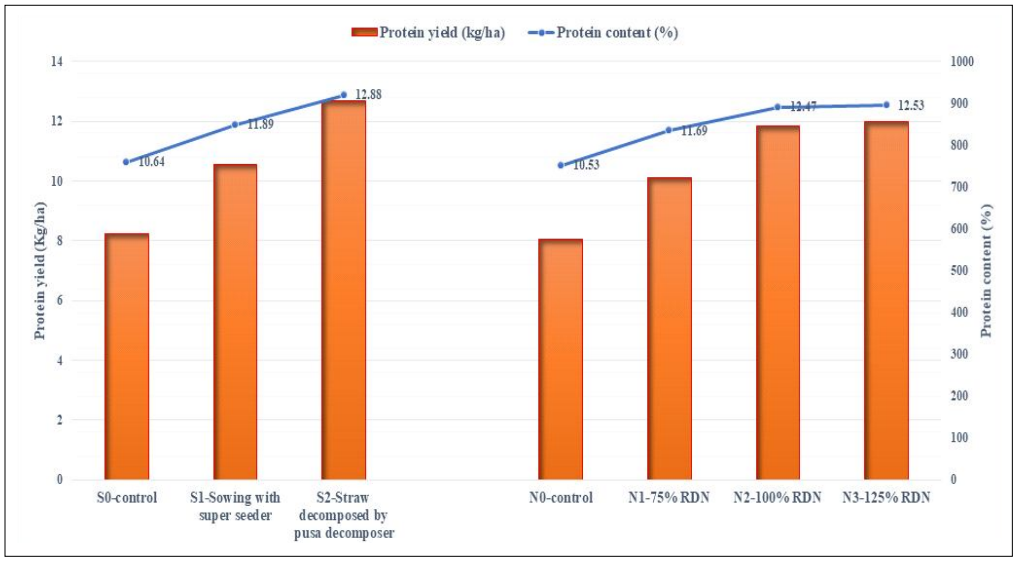


Fig 3: Effect of rice straw management and nitrogen levels on protein content and protein yield of wheat.

Table 2: Effect of rice straw management and nitrogen levels on amino acid (tryptophan, lysine and phenylaline) in wheat grain.

Treatments	Tryptophan (%)	Lysine (%)	Phenylaline
	Pooled data (2022-24)		
Rice straw			
S_0- Control	1.09	2.54	3.91
S_1- Sowing with super seeder	1.29	3.09	4.57
S_2- Straw decomposed by pusa decomposer	1.55	3.44	5.10
SEm±	0.01	0.04	0.06
CD (P=0.05)	0.04	0.11	0.18
Nitrogen levels			
N_0- Control	1.03	2.50	3.73
N_1- 75% RDN	1.27	2.93	4.30
N_2- 100% RDN	1.43	3.27	4.91
N_3- 125% RDN	1.51	3.41	5.18
SEm±	0.01	0.04	0.07
CD (P=0.05)	0.04	0.10	0.20

the growing season (Goyal *et al.,* 2009). This not only enhanced yield components but also contributed to the accumulation of greater dry matter in the plants. These findings are consistent with Sharma and Dhaliwal (2020) who also observed similar trends.

The biological yield, was highest in the S_2 treatment at 119.62 q/ha and N_3 at 118.97 q/ha (Fig 2), reflecting the combined benefits of straw decomposition and nitrogen application. The enhancement in biological yield with higher nitrogen levels is likely a result of nitrogen's role in promoting vigorous vegetative growth and stimulating a greater number of tillers, particularly at elevated nitrogen application rates. These outcomes of this research support earlier work by Shah *et al.* (2011).

However, the harvest index was found to be non-significant across all treatments, indicating that the proportion of grain to total biomass remained relatively stable, suggesting no substantial impact from the treatments on this parameter.

Quality parameters

The quality attributes of wheat were profoundly influenced by both rice straw treatments and nitrogen levels. In terms of protein content, the treatment S_2 (straw decomposed by Pusa decomposer) exhibited the highest percentage at 12.88%, surpassing S_1 (sowing with super seeder) at 11.89% and the control (S_0) at 10.64% (Fig 3). This enhancement in protein content likely resulted from the improved soil nutrient availability and microbial activity associated with straw decomposition (Saini *et al*., 2013). These finding are in conformity with Zhang *et al.* (2019). Similarly, nitrogen application levels positively impacted protein content, with N_3 (125% RDN) achieving 12.53%, compared to 10.53% at N_0. Similar conclusions were drawn by Sharma and Dhaliwal (2020), Vaswani *et al*. (2013).

Regarding protein yield (kg/ha), the S_2 treatment produced 905.44 kg/ha, significantly outperforming S_1 at 754.71 kg/ha and S_0 at 587.72 kg/ha. This increase in protein yield can be attributed to both higher protein content and greater biomass production under effective straw management. The results of this research align well with insights documented in existing literature by Zhang *et al.* (2019). Nitrogen levels also played a crucial role, with N_3 yielding 854.94 kg/ha, significantly higher than the control level of 573.75 kg/ha (Fig 3).

Finally, the concentrations of essential amino acids were influenced by both treatments and nitrogen levels. S_2 exhibited the highest levels of tryptophan (1.55%), lysine (3.44%) and phenylalanine (5.10%), showcasing the benefits of effective straw management on grain quality. Nitrogen treatments further enhanced amino acid profiles, with N_3 resulting in 1.51% tryptophan, 3.41% lysine and 5.18% phenylalanine (Table 2), emphasizing the positive impact of adequate nitrogen supply on the nutritional quality of rice grains.

CONCLUSION

In India, where sustainable farming is increasingly important, efficient rice straw management and optimized nitrogen application are crucial for boosting crop productivity. This study found that the use of Pusa decomposer (S_2) resulted in a grain yield of 49.75 q/ha and a protein content of 12.88%, significantly higher than the control. Similarly, the application of 125% RDN (N_3) produced a grain yield of 51.26 q/ha and a protein content of 12.53%, under scoring the benefits of proper nitrogen management. These results show that integrating straw decomposition with optimal nitrogen use leads to enhanced yield and improved grain quality, offering a pathway for sustainable wheat farming in India.

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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.

Informed consent

All experimental procedures and handling techniques were approved Lovely Professional University, Punjab.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced for conducting study, data collection, analysis, decision to publish, or preparation of the manuscript.

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