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Impact of Different Rice Straw Management Techniques and Nitrogen Levels on Yield and Nutrient Uptake in Wheat (*Triticum aestivum* L.)

Anurag Yadav[1], Rajesh Kumar[1], Gumpi Kabak[1], Sandeep Menon[1], Rohit Saral[1], Swati Mehta[1], Pankaj Dahiya[1]

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ABSTRACT

Background: The combined application of nitrogen and the incorporation of rice straw play a vital role in enhancing wheat productivity. Rice straw contributes to the enrichment of soil organic matter and supports nutrient cycling, while nitrogen is essential for promoting plant growth and grain development. Understanding the synergistic effects of these two inputs is critical for optimizing wheat yield and improving grain quality within sustainable agricultural systems.

Methods: The study was conducted at Research Farm, Division of Agronomy, Lovely Professional University During *rabi* 2022-2023 and 2023-2024 and focused on the impact of various rice straw management practices and nitrogen levels on the yield and quality of wheat that emphasizing the importance of sustainable agricultural practices. The experimental field had sandy loam soil with slightly alkaline pH (7.6), medium in organic carbon, phosphorus and potassium alongside low concentrations of nitrogen. It comprised 12 treatments combinations arranged in Split plot Design and replicated three times to evaluate two factors in main plot (1) Rice Straw management: S0(without straw), S_1 (Super Seeder) and S_2 (Pusa Bio Decomposer) and (2) Subplot Nitrogen levels N_0: (Control), N_1: (75% RDN), N_2: (100% RDN) N_3: (125% RDN).

Result: The results indicated that among the different straw management practices, S, (Straw decomposed by Pusa decomposer) significantly enhanced wheat grain yield (49.75 q/ha), straw yield (69.87 q/ha), biological yield (120.00 q/ha) and test weight (43.30 g) compared to other treatments. Similarly, nitrogen levels had a significant impact on wheat performance. The highest grain yield (51.26 q/ha), straw yield (67.71 q/ha), biological yield (118.97 q/ha) and test weight (42.23 g) were recorded under N_3 (125% RDN). However, these values were statistically at par with N, (100% RDN). The harvest index was found to be non-significant for both main plot and subplot treatments. Nutrient uptake in grain (103.60 kg N/ha, 19.89 kg P/ha and 24.40 kg K/ha) and straw (36.09 kg N/ha, 9.77 kg P/ha and 125.37 kg K/ha) was significantly enhanced under S, (Straw decomposed by Pusa decomposer). Among nitrogen levels, the highest nutrient uptake in grain was recorded under Nƒ (125% RDN) with 103.64 kg N/ha, 19.71 kg P/ha and 24.74 kg K/ha, while in straw, it was 34.07 kg N/ha, 9.28 kg P/ha and 117.70 kg K/ha. These values were statistically at par with those under N, (100% RDN).

Key words: Grain yield, Nitrogen levels, Nutrient uptake, Rice straw, Straw yield, Wheat.

INTRODUCTION

Wheat is one of the world's most important staple food crops that has been labelled as King of Cereals It contributes 24% in the total foodgrain production in the country, next to rice. It is grown in 31.8 million ha in India with the production of 113.9 million tonnes and productivity of 3.6 tonnes/ha (MOAFW, 2024).

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 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.,* 2021).

Rice straw, a widely available agricultural by product, represents one of the most abundant lignocellulosic wastes in the world (Saini *et al.,* 2013). 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

[1]Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara-144 401, Punjab, India.

Corresponding Author: Rajesh Kumar, Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara-144 401, Punjab, India. Email: rajesh.26029@lpu.co.in

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use as animal feed (Vaswani *et. al.,* 2013). Unfortunately, ineffective management leads to these residues being burned in fields, causing environmental pollution and depleting essential soil nutrients (Goyal *et al.,* 2009).

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

Experimental site

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. Most of the annual rainfall (500-800 mm) occurred during the monsoon season, between July to September, with groundwater found at depths of 90-100 meters.

Experimental details and crop management

The study conducted during *rabi* 2022-2023 and 2023-2024 assessed the impact of different rice straw management techniques and nitrogen levels on wheat yield and quality. 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: in main plot Rice Straw Management: S_0: (conventional sowing) S_1: (Sowing with super seeder) S_2: (Straw decomposed using Pusa bio decomposer) in sub plot Nitrogen levels: N_0: (Control) N_1: (75% RDN), N_2:(100% RDN), N_3: (125% 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.

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 analysed for nitrogen, phosphorus and potassium levels.

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).

Data collection and analysis

After the harvesting biological yield (q/ha), straw yield (q/ha), grain yield (q/h) and harvest index (%) are calculated along with samples of grain and straw were taken for further analysis of NPK uptake in grain and straw using appropriate procedures. Grain and straw samples were taken at maturity and dried at 65°C until a consistent weight was reached to assess NPK absorption. The dried samples were pulverized and digested to measure the N content using the wet digestion technique (Keeney and Nelson, 1982). The colorimetric method (Olsen *et al.,* 1954) and flame photometry (Brown, 1963) were used to estimate the P and K contents, respectively. The nutrient content in the tissue was multiplied by the dry matter yield of grain and straw to determine the absorption of N, P and K.

$$N\% = \frac{\text{Nitrogen detected (mg)}}{\text{Sample weight (mg)}} \times 100$$

$$\text{N uptake} = \text{N content (\%)} \times \text{Yield (kg/ha)}$$

$$P\% = \frac{\text{Phosphorus detected (mg)}}{\text{Sample weight (mg)}} \times 100$$

$$\text{P uptake} = \text{P content (\%)} \times \text{Yield (kg/ha)}$$

$$K\% = \frac{\text{Potassium detected (mg)}}{\text{Sample weight (mg)}} \times 100$$

$$\text{K uptake} = \text{K content (\%)} \times \text{Yield (kg/ha)}$$

Statistical analysis

Data was analysed in OPSTAT (Operational Statistics). The least significant difference (LSD) at $p<0.05$ was used to compare the treatment means. Data were combined for two years as the trend of findings in the two years did not differ significantly.

RESULTS AND DISCUSSION

Yield attributes

Grain yield

According to Table 1, it was observed that Rice straw and nitrogen management had a significant effect on grain yield. The highest grain yield was recorded under straw decomposition with Pusa decomposer (S2 at 49.75 q/ha) which was 31.12% higher than the control (S0, 37.94 q/ha). Sowing with a Super seeder (S1) also improved grain yield (44.96 q/ha, 18.50% higher than S0). The increased grain yield in S2 could be attributed to better nutrient recycling, improved soil health and enhanced microbial activity (Prem *et al.,* 2024). Whereas, in N application increasing nitrogen application significantly boosted grain yield. The highest yield (51.26 q/ha) was observed at 125% RDN (N3), which was significantly 53.93% higher than the control (N0, 33.30 q/ha). These findings are similar to Kumar and Pareek (2022) and Yan *et al.,* (2023).

Straw yield

It was revealed by the data presented in Table 1 that straw yield followed a similar trend as grain yield, with the highest yield recorded in the Pusa decomposer (S_2) treatment at 69.87 q/ha, which was 27.29% higher than the control (S_0, 54.89 q/ha). Sowing with a super seeder (S_1) also increased straw yield (63.09 q/ha, 14.94% higher than S0). The improvement in straw yield can be attributed to better decomposition, enhanced soil organic matter and improved crop growth conditions (Ouyang *et. al.,* 2021). Among nitrogen levels, the highest straw yield (67.71 q/ha) was obtained with 125% RDN (N_3), which was 25.22% higher than N_0 (54.07 q/ha). The difference between 100% RDN (N_2) and 125% RDN (N_3) was minimal (only 0.47%), suggesting that 100% RDN was sufficient for optimizing straw yield. These findings were supported by Maarastawi *et al.,* (2018), Chen *et al.,* (2018), Yang *et al.,* (2024) and Guan *et al.,* (2020).

Biological yield

Biological yield, which is the sum of grain and straw yield, which was also significantly influenced by treatments. The highest biological yield was observed in S_2 (119.62 q/ha), which was 28.85% higher than the control (S_0, 92.83q/ha). The S_1 treatment also showed an improvement (108.06 q/ha, 16.40% higher than S_0). The increase in biological yield under S_2 might be due to the enhanced decomposition of rice straw, leading to better nutrient availability and plant growth (Ling *et al.,* 2024). Regarding nitrogen levels, biological yield increased with increasing nitrogen application, with N_3 (118.97 q/ha) being 36.16% higher than N_0 (87.37 q/ha). Similar findings were supported by Yang *et al.,* (2024) and Guan *et al.,* (2020).

Harvest index

The harvest index (HI) was statistically non-significant across treatments, though slight improvements were

Table 1: Impact of rice straw management and nitrogen levels on grain yield, straw yield, biological yield and Harvest index (pooled data of 2 years).

Treatments	Grain yield (q/ha)	Straw yield (q/ha)	Biological yield (q/ha)	Harvest index (%)
Rice straw				
S_0-Control	37.94	54.89	92.83	40.65
S_1-Sowing with super seeder	44.96	63.09	108.28	41.39
S_2-Straw decomposed by Pusa decomposer	49.75	69.87	119.62	41.37
SEm$\pm$	0.72	1.17	1.76	0.67
CD (P=0.05)	2.12	3.46	5.19	NS
Nitrogen levels				
N_0-Control	33.30	54.07	87.37	38.08
N_1-75% RDN	42.76	61.30	104.06	41.06
N_2-100% RDN	49.56	67.39	116.94	42.34
N_3-125% RDN	51.26	67.71	118.97	43.05
SEm$\pm$	0.70	0.90	1.62	0.72
CD (P=0.05)	1.97	2.53	4.55	NS

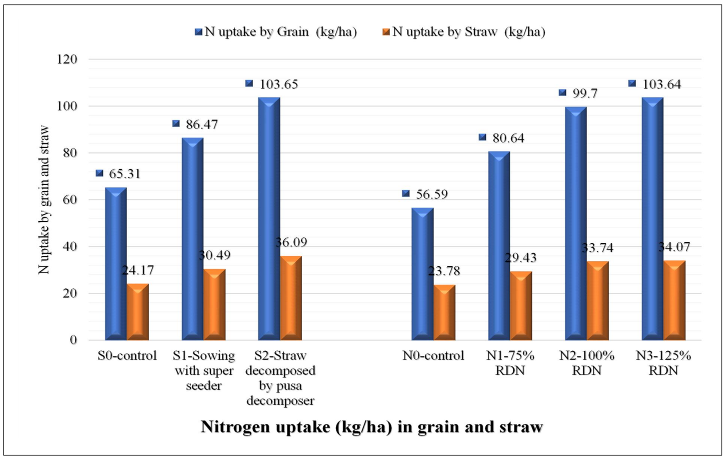

Fig 1: Effect of rice straw management and nitrogen levels on N uptake (Kg/ha) by grain and straw of wheat (pooled data of 2 years).

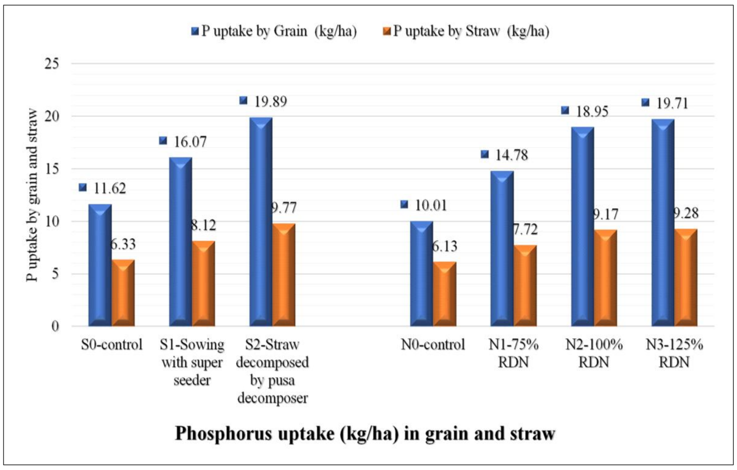

Fig 2: Impact of rice straw management and nitrogen levels on P uptake (Kg/ha) by grain and straw of wheat (pooled data of 2 years).

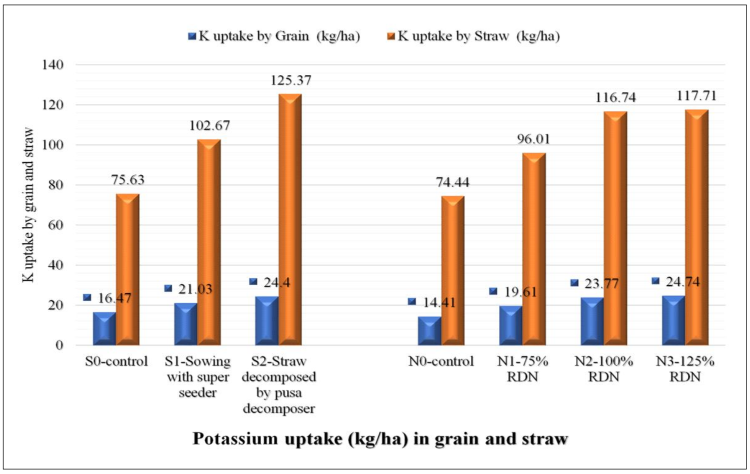

Fig 3: Impact of rice straw management and nitrogen levels on K uptake (Kg/ha) by grain and straw of wheat (pooled data of 2 years).

observed. The highest HI was recorded in S_2 (41.39%), which was slightly higher than S1 (41.37) and S_0 (40.65%). Similarly, N_3 showed highest (43.05%) HI which was slightly highest compared to N_0 (38.08%). The slight improvement in HI under S_2 and N_3 indicates better partitioning of biomass toward grain yield. However, since the differences were non-significant, it suggests that while nutrient management influences overall yield, the proportional distribution of biomass between grain and straw remains relatively stable.

Nutrient uptake in grain and straw

According to Fig 1, 2 and 3, it was revealed that rice straw management and nitrogen application significantly influenced nutrient uptake. The highest N uptake was recorded in Pusa decomposer (S_2), with 103.6 kg/ha in grains and 36.09 kg/ha in straw, followed by super seeder (S_1), while the lowest was in control (S_0). Similarly, 125% RDN (N_3) had the highest nitrogen uptake (103.64 kg/ha in grains, 34.07 kg/ha in straw), followed closely by 100% RDN (N_2). For phosphorus uptake, S_2 recorded the highest values (19.89 kg/ha in grains, 9.77 kg/ha in straw), while N_3 had the maximum uptake among nitrogen levels (19.71 kg/ha in grains, 9.28 kg/ha in straw). Likewise, potassium uptake was highest in S2 (24.40 kg/ha in grains, 125.37 kg/ha in straw), with N3 (24.74 kg/ha in grains, 117.71 kg/ha in straw), showing the highest uptake among nitrogen levels. This result was supported by Akwakwa *et al.* (2023); Cui *et al.* (2022) and Ramteke *et al.* (2022).

CONCLUSION

It was concluded by the above results that managing rice straw leads to increased absorption of essential nutrients such as nitrogen, phosphorus and potassium in both wheat grain and straw, with elevated nitrogen levels further enhancing nutrient content in both grain and straw. Moreover, the incorporation of rice straw and higher nitrogen applications resulted in a more fertile and productive soil environment. Enhanced yield and yield attributing parameters including grain yield, straw yield, biological yield and harvest index. In summary, the study highlights the importance of integrating organic amendments like rice straw with effective nitrogen management to promote sustainable agriculture, enhance nutrient cycling and preserve long-term soil fertility. These practices are crucial for increasing crop yields and and improving overall farm productivity while minimizing the environmental footprint of intensive farming systems.

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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, 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 the design of the study, data collection, analysis, decision to publish or preparation of the manuscript.

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