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EFFECT OF CROP RESIDUE AND NITROGEN MANAGEMENT ON NUTRIENT CONTENT AND QUALITY OF RICE IN RICE-WHEAT CROPPING SYSTEM

Paramjit Kaur Sraw, Jasjit Singh Kang and Jagroop Kaur*
Department of Agronomy, Punjab Agricultural University, Ludhiana-141 004, India

ABSTRACT

Field experiments were conducted during the *kharif* seasons of 2019 and 2020 to assess the effects of crop residue management practices and nitrogen levels on the nutrient content and quality of rice in a rice-wheat system. The experiments were carried out using a split-plot design and replicated thrice. The experiment involved six crop residue management practices as main plots and three nitrogen levels as subplots. The results revealed that both crop residue management practices and nitrogen levels significantly affected the grain nutrient content, protein content, and head rice recovery. However, milling parameters (brown and milled rice) and cooking parameters (minimum cooking time, elongation ratio, water uptake, and gruel solid loss) remained unaffected by crop residue management practices. Graded doses of nitrogen significantly affected the milling and cooking parameters. Notably, a significant improvement in quality parameters was observed with 125 kg N ha^{-1} compared to 75 kg N ha^{-1}.

Keywords: Crop residue, Milling quality, Nitrogen, Nutrient content, Rice

Rice and wheat are important crops for ensuring global food security and livelihoods. India, ranking second in the world after China, produces annually 106.8 million tons of wheat and 130.3 million tons of rice (FAOSTAT, 2022). The rice-wheat cropping system (RWCS) covers approximately 9.2 million hectares in India (Jat *et al.*, 2020). However, the sustainability of RWCS faces challenges due to second-generation technology issues and overexploitation of natural resources. Most RWCS areas are combine harvested, generating substantial crop residue. While wheat straw is commonly utilized as cattle feed, the incorporation or removal of rice straw poses difficulties due to its high silica content and the tight window between rice harvest and wheat sowing, often resulting in on-farm burning (Datta *et al.*, 2020). This burning has adverse effects on the environment, soil, and human health. To mitigate this, crop residue management technologies such as *in-situ* retention of rice residue in wheat, development of low-silica rice varieties, and *ex-situ* utilization of rice straw in various applications like mushroom cultivation and biomass energy production are being explored (Dutta *et al.*, 2022). Long-term management involving conservation tillage offers numerous benefits including improved soil organic carbon, nutrient availability, and better soil physical properties (Gupta *et al.*, 2023). Studies have shown significant increases in soil organic matter (10.7%), total nitrogen (6.1%), available nitrogen (22.0%), phosphorus (8.6%), and potassium (40.1%) over nine years with straw incorporation (Zhang *et al.*, 2021).

*Corresponding author: jagroopsekhon@pau.edu
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Nitrogen is an essential macronutrient required for the growth and metabolic processes of plants. It is an important nutrient that significantly affects the growth, dry matter production, yield, and quality of rice (Mondal *et al.*, 2023). Nitrogen is the main component of amino acids in proteins and is also necessary for the synthesis of chlorophyll, playing a crucial role in photosynthesis. Plants take up nitrogen mostly in the form of nitrate (NO_3^-) or ammonium (NH_4^+). Nitrogen influences leaf area by affecting cell division and increasing auxin content (Bojovic and Markovic, 2009). The long-term use of chemical fertilizers leads to the absorption and accumulation of heavy metals in plant tissue, subsequently decreasing the quality of grain and nutritional value (Maqbool *et al.*, 2020). Therefore, considering the aforementioned facts, the experiment was planned to assess the interactive effect of crop residue management practices and nitrogen levels on the quality parameters of rice in the rice-wheat cropping system.

MATERIALS AND METHODS

A field experiment was conducted at Students' Research Farm, Department of Agronomy (30° 54' North, 75° 48' East, and 247m above mean sea level), Punjab Agricultural University, Ludhiana, Punjab, during *kharif* 2019 and 2020 to determine the effect of crop residue management practices and nitrogen levels on the quality of rice in the rice-wheat system. The climate of the experimental area is subtropical, with an average annual rainfall of 650 mm, 75% of which is received in the monsoon season. Meteorological data recorded during the growth period of the crop showed that the mean weekly maximum and minimum temperatures during *kharif* 2019 ranged from 30.2 to 43.0°C and 19.2 to 28.5°C, respectively. In *kharif* 2020, corresponding values ranged from 29.6 to 42.1°C and 14.9 to 28.0°C, respectively. The maximum and minimum mean weekly temperatures of 43.0°C and 19.2°C were recorded during the 21st and 41st standard meteorological week (SMW), respectively, during *kharif* 2019, whereas in *kharif* 2020, maximum and minimum mean weekly temperatures of 42.1°C and 14.9°C were recorded in the 21st and 42nd SMW, respectively.

The experiment was conducted in a split-plot design and replicated thrice. The treatments consisted of six crop residue management practices, namely: T_1 - Transplanted rice without wheat straw - ZT wheat without rice straw [TPR(-WS)-ZTW(-RS)], T_2 - Transplanted rice without wheat straw - CT wheat without rice straw [TPR(-WS)-CTW(-RS)], T_3 - Transplanted rice without wheat straw - CT wheat with rice straw [TPR(-WS)-CTW(+RS)], T_4 - Transplanted rice without wheat straw - ZT wheat with rice straw [TPR(-WS)-ZTW(+RS)], T_5 - Transplanted rice with wheat straw - ZT wheat with rice straw [TPR(+WS)-ZTW(+RS)], T_6 - Transplanted rice after partial burning of wheat straw - ZT wheat after partial burning of rice straw as main plots and three nitrogen levels, namely, 75, 100, and 125 kg N/ha in subplots. The experimental plot size was 10 m^2. Seedlings of 'PR 127' were transplanted under puddled conditions at a spacing of 20 cm × 15 cm. A full dose of phosphorus (30 kg P_2O_5/ha), potassium (30 kg K_2O/ha), and zinc sulfate (21%, 62.5 kg/ha), along with one-third of nitrogen as per treatments, were applied as a basal dose at the time of transplanting, and the remaining two-thirds of nitrogen were applied in two equal splits at three and six weeks after transplanting. The experiment was harvested in the second fortnight of October in both years.

Quality analysis

To calculate the brown rice recovery, 100 g of clean paddy samples at 14% moisture were dehusked in a laboratory sheller (Satake Rice Sheller, Satake Engg. Co., Japan). The resulting product after shelling (brown rice) was weighed and expressed as a percentage. Additionally, to determine milled rice recovery, the samples of brown rice were polished in a Mc Gill Miller No. 2 (USA) to remove the bran and then expressed as a percentage.

To separate broken rice from milled rice samples, a Rice grading device (Burrows make, USA) was utilized. Kernels with more than 3/4th length were considered as head rice and presented as head rice recovery in percentage. The protein content of grains was measured using a whole grain analyzer (Infratec 1241, FOSS, Sweden).

The elongation ratio was calculated following the procedure outlined by Azeez and Shafi (1966). Water soaking was initiated by submerging 25 whole milled kernels in 20 ml of distilled water for a duration of 30 minutes. Subsequently, the samples were cooked by immersing them in a boiling water bath for an additional 10 minutes. After draining excess water, the cooked rice was transferred to a Petri dish lined with filter paper. Ten randomly selected cooked whole grains were then measured using a millimeter scale.

For estimation of cooking quality parameters (gruel solid loss, minimum cooking time, and water uptake ratio), dehusked samples (2 g in 20 ml of distilled water) were cooked according to the procedures outlined by Bhattacharya and Sowbhagya (1971) and Sidhu *et al.* (1975).

The nitrogen content in grain and straw was determined using a modified Kjeldahl method (Piper, 1966), while phosphorus content was determined using the Vanado-molybdate phosphoric acid colorimetric method in the nitric acid system (Jackson, 1967). The K content in grain and straw was determined using Lange's Flame photometer (Jackson, 1967).

The total uptake of nutrients (N, P, and K) by the plant was calculated by multiplying the percentage of N, P, and K content in grain and straw by the respective grain and straw yields. The total uptake of nutrients was then expressed in kg/ha.

Statistical analysis

The data obtained on various parameters were tabulated and subjected to analysis of variance (ANOVA) with significance determined at 5 per cent level.

RESULTS AND DISCUSSION

Effect on milling quality

Brown rice recovery

The brown rice recovery (Table 1) exhibited an increase with crop residue retention or incorporation compared to treatments without residue removal or burning. However, differences among various crop residue management treatments were not statistically significant. Notably, nitrogen levels exerted a significant influence on brown rice recovery. Application of 125 kg N/ha resulted in significantly higher brown rice recovery (82.2%) compared to 75 kg N/ha (79.0%), although the latter was comparable to 100 kg N/ha (81.0%). The increase in nitrogen levels is associated with enhanced protein content in grains, leading to improved milling quality of rice. These findings align with previous studies by Li *et al.* (2007), Gautam *et al.* (2008), Ma *et al.* (2009), and Zhu *et al.* (2017).

Milled rice recovery

While crop residue management practices did not yield statistically significant effects on milled rice recovery (Table 1), treatments involving residue retention or incorporation tended to exhibit numerically higher values compared to those involving residue removal or burning. Among nitrogen levels, the application of 125 kg N/ha recorded the highest milled rice recovery (71.6%), followed by 100 kg N/ha (70.6%) and 75 kg N/ha (68.9%). Gautam *et al.* (2008) similarly observed improved milled rice recovery with increasing nitrogen levels from 0 to 160 kg/ha. The addition of nitrogen fertilizers enhances nitrogen uptake and protein content in plants, thereby increasing resistance to the abrasive milling process (Cagampang *et al.*, 1966). The observed enhancement in grain quality may be attributed to increased nutrient availability, coupled with enhanced uptake and assimilation by plants (Kaur *et al.*, 2022).

Table 1. Effect of crop residue management practices and nitrogen levels on brown rice and milled rice recovery (pooled data of 2 years)

Treatments	Brown rice recovery (%)	Milled rice recovery (%)
Crop residue management practices (CRM)		
TPR (-WS) -ZTW (-RS)	80.0	70.0
TPR (-WS) -CTW (-RS)	79.6	69.0
TPR (-WS) -CTW (+RS)	81.5	70.5
TPR (-WS) -ZTW (+RS)	81.4	70.9
TPR (+WS) -ZTW (+RS)	82.1	70.8
TPR after brn-ZTW after brn	80.6	70.6
CD (p≤5%)	NS	NS
Nitrogen Levels (N)		
75 kg N/ha	79.0	68.5
100 kg N/ha	81.0	70.6
125 kg N/ha	82.2	71.6
CD (p≤5%)	1.2	1.3
CRM x N	NS	NS

Head rice recovery

Crop residue management practices and nitrogen levels exhibited a significant interaction effect on head rice recovery (Table 2). The maximum head rice recovery in transplanted rice with single or both crop residues was achieved with 125 kg N/ha, although it was comparable to values obtained with 75 and 100 kg N/ha. In treatments without residue, head rice recovery was highest with 125 kg N/ha, significantly surpassing values obtained with 75 kg N/ha. The application of nitrogen enhanced the protein content of rice, thereby improving head rice recovery (Zhu *et al.*, 2017; Ishfaq *et al.*, 2020).

Protein content

Crop residue management practices and nitrogen levels significantly influenced the protein content in rice grains (Table 2). Among the crop residue management practices, the highest protein content was observed in treatments involving the retention or incorporation of both rice and wheat residues in the rice-wheat system. In treatments where both rice and wheat residues were retained or incorporated, the protein content in rice grains did not show a significant response to increasing nitrogen levels. However, a higher protein content was observed at a higher level of nitrogen (125 kg N/ha) compared to a nitrogen level of 75 kg N/ha where no residue was retained or incorporated (Table 2). These findings are consistent with the observations of Zhou *et al.* (2022) and Zhu *et al.* (2017). The improvement in protein content with nitrogen application can be attributed to nitrogen being a primary constituent of all amino acids and proteins. Nitrogen application increases the nitrogen content in grains, leading to an increase in protein content. The increase in protein content under crop residue management treatments may be due to an increase in nitrogen content in grains. The improvement in milling quality (head rice recovery), cooking quality, and protein content in grains under residue management practices may be attributed to the long-term availability and absorption of nutrients.

Effect on cooking quality

Elongation ratio

It is evident from the data (Table 3) that the elongation ratio of rice grains was not significantly affected by various residue management treatments. However, nitrogen levels had a significant effect on the elongation ratio of milled rice grains. The maximum elongation ratio was observed with the application of 75 kg N/ha (1.45), which was significantly higher than that of 100 kg N/ha (1.43) and 125 kg N/ha (1.39).

The higher elongation ratio at the lowest nitrogen level may be attributed to a higher carbohydrate content at a lower nitrogen rate. Carbohydrates absorb water during cooking and swell, ultimately affecting the elongation of grains. These findings are supported by the results of Zhu *et al.* (2017).

Minimum cooking time

Crop residue management practices and nitrogen treatments significantly influenced the minimum cooking time. The maximum cooking time was recorded in treatments where residue was retained or incorporated, which were significantly higher than treatments without residue. Additionally, the maximum value of minimum cooking time was observed with the application of 125

Table 2. Interactive effect of crop residue management practices and nitrogen levels on head rice recovery and grain protein content in rice (pooled data of 2 years)

Treatments	Head rice recovery (%)			Protein content (%)		
Crop residue management practices (CRM)	N (kg/ha)			N (kg/ha)		
	75	100	125	75	100	125
TPR (-WS) -ZTW (-RS)	51.1	53.9	55.2	6.89	7.45	7.76
TPR (-WS) -CTW (-RS)	51.2	53.4	54.9	6.89	7.44	7.82
TPR (-WS) -CTW (+RS)	54.0	55.4	56.6	8.01	8.44	8.85
TPR (-WS) -ZTW (+RS)	54.6	55.7	56.9	7.90	8.27	8.62
TPR (+WS) -ZTW (+RS)	56.0	55.8	56.4	8.95	8.90	8.97
TPR after brn-ZTW after brn	52.4	54.3	56.4	7.26	7.74	8.13
CD (p≤5%)	CRM x N =1.9			CRM x N =0.42		

kg N/ha, significantly exceeding that of 100 and 75 kg N/ha.

The increase in cooking time with an increase in nitrogen amount may be attributed to the increase in protein concentration with higher nitrogen rates. Protein provides hardness to grains (Leesawatwong *et al.*, 2005; Kaur *et al.*, 2016), and harder grains may require more time for cooking.

Water uptake ratio

Water uptake ratio did not differ significantly with various crop residue management practices and nitrogen levels.

Gruel solid loss

The solids dissolved in water from rice kernels represents gruel solid loss, typically discarded after cooking rice grains. Crop residue management techniques did not reach a significant level for gruel solid loss, but nitrogen management practices did exhibit a significant effect. The highest percentage of gruel solid loss was observed with 75 kg N/ha, significantly exceeding that of 100 and 125 kg N/ha. These findings are consistent with those of Singh *et al.* (2011) in rice, who reported lower gruel solid loss from milled rice obtained from paddy grown with higher nitrogen application.

N, P and K content in rice grain and straw

The nutrient content (N, P, and K) in grain and straw was significantly higher under residue-treated plots. Specifically, nutrient content in grains and straw

Table 3. Effect of crop residue management practices and nitrogen levels on cooking quality of rice in rice-wheat system (Pooled data of 2 years)

Treatments	Elongation ratio	Minimum cooking time (minutes)	Water uptake ratio	Gruel solid loss (%)
Crop residue management practices (CRM)				
TPR (-WS) -ZTW (-RS)	1.44	13.3	2.58	5.29
TPR (-WS) -CTW (-RS)	1.45	13.2	2.60	5.26
TPR (-WS) -CTW (+RS)	1.40	14.0	2.55	5.34
TPR (-WS) -ZTW (+RS)	1.40	13.9	2.55	5.33
TPR (+WS) -ZTW (+RS)	1.39	14.1	2.53	5.35
TPR after brn-ZTW after brn	1.45	13.8	2.59	5.32
CD (p≤5%)	NS	0.5	NS	NS
Nitrogen levels (N)				
75 kg N/ha	1.45	13.4	2.59	5.41
100 kg N/ha	1.43	13.7	2.55	5.31
125 kg N/ha	1.39	14.0	2.53	5.21
CD (p≤5%)	0.02	0.2	NS	0.09
CRM x N	NS	NS	NS	NS

Table 4. Effect of crop residue management practices and nitrogen levels on nutrient content and total nutrient uptake by rice in rice-wheat system (pooled data of 2 years)

Treatments	Nutrient content (%)						Total nutrient uptake (kg/ha)		
	Grain			Straw					
	N	P	K	N	P	K	N	P	K
Crop residue management practices (CRM)									
TPR (-WS) -ZTW (-RS)	1.24	0.30	0.28	0.41	0.15	0.91	104.7	28.5	84.0
TPR (-WS) -CTW (-RS)	1.25	0.30	0.27	0.42	0.15	0.93	108.2	29.8	87.9
TPR (-WS) -CTW (+RS)	1.42	0.33	0.34	0.47	0.16	0.95	132.6	35.6	107.2
TPR (-WS) -ZTW (+RS)	1.38	0.33	0.33	0.47	0.17	0.99	130.6	35.8	109.8
TPR (+WS) -ZTW (+RS)	1.44	0.34	0.36	0.50	0.18	1.06	145.8	40.3	121.8
TPR after brn-ZTW after brn	1.30	0.29	0.29	0.45	0.15	0.91	116.2	30.9	90.8
CD (p≤5%)	0.07	0.02	0.02	0.02	0.01	0.04	5.7	2.0	6.1
Nitrogen levels (N)									
75 kg N/ha	1.30	0.31	0.30	0.43	0.15	0.95	112.9	30.0	93.9
100 kg N/ha	1.34	0.31	0.31	0.44	0.16	0.95	124.8	34.1	100.5
125 kg N/ha	1.37	0.32	0.31	0.45	0.16	0.97	131.4	36.5	106.3
CD (p≤5%)	0.02	NS	NS	0.01	NS	NS	3.7	1.41	4.5
CRM x N	NS	NS	NS	NS	NS	NS	NS	NS	NS

was significantly higher in treatments where single or both crop residues were incorporated or retained, compared to residue removal or burning treatments. The highest N, P, and K content in grain (1.44%, 0.34%, and 0.36%, respectively) and straw (0.50%, 0.18%, and 1.06%, respectively) was observed in treatments comprising both rice and wheat crop residue retention/ incorporation, which was comparable to treatments where only rice residue was incorporated and retained. While graded doses of nitrogen significantly affected the N content in grain and straw, P and K content in grain and straw remained unaffected. Specifically, the highest N content in grain (1.37%) and straw (0.45%) was observed with N level of 125 kg/ha, significantly exceeding that of 75 kg N/ha.

Total N, P and K uptake by rice

The maximum uptake of nutrients by rice occurred in plots where both rice and wheat crop residue retention/ incorporation were practiced, significantly surpassing the residue removal and burning treatments. Nutrient cycling in residue-treated plots enhanced nutrient availability to plants.

An increase in nitrogen level from 75 to 125 kg/ ha significantly increased the uptake of N, P, and K. Mondal *et al.* (2023) also observed 85%, 49%, and 26% higher rice grain N uptake with 240 kg N/ha application compared to 0, 40, and 120 kg N/ha, respectively.

The results of this study demonstrate a significant improvement in milling quality (head rice recovery) and protein content when crop residue was retained or incorporated with the application of 75 kg N/ha, compared to residue removal or burning at the same nitrogen level. However, cooking quality decreased with an increase in nitrogen level from 75 to 125 kg/ha, regardless of the crop residue management practice.

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