



Crop Residue Management and its Impact on Yield and Nutrient Uptake in Rice-Wheat Cropping Sequence in Tarai Belt of Shivalik Himalaya

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This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The rice-wheat cropping system is among the most extensively practised agricultural systems globally and is particularly prevalent in northwest India. The study emphasized that in situ crop residue management practices offer the most effective solution to mitigate the widespread issue of

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residue burning. Crop diversification in rice-based cropping systems has been recognised as an effective strategy for fulfilling the objectives of enhancing productivity for food security, judicious uses of resources and sustainable agriculture for the marginalised group of farmers. A two-year field study was conducted to evaluate the effects of inorganic and organic nutrient sources on the yield and nutrient uptake of rice and wheat crops. Detailed meteorological data for the cropping season—based on mean weekly observations recorded at the Meteorological Observatory of the Crop Research Centre during the experimental period. For the determination of available nutrients, the AB-DTPA (ammonium bicarbonate–diethylenetriaminepentaacetic acid) extractable concentrations of nitrate-nitrogen ($\text{NO}_3\text{-N}$), phosphorus (P_2O_5), and potassium (K_2O) were measured following the standard procedure. The results revealed that the application of inorganic fertilizers (T9) consistently produced the highest grain and straw yields in both rice (55.24 and 70.87 q ha^{-1}) and wheat (52.21 and 75.05 q ha^{-1}), primarily due to the rapid availability of nutrients that support optimal crop growth. In contrast, control treatments without nutrient inputs (T8) recorded the lowest yields across both crops. Treatments incorporating crop residues (T2–T7) generally resulted in lower yields compared to those receiving full inorganic inputs, likely due to the slower release of nutrients during residue decomposition. However, combinations involving crop residues, green manures, and Pusa Decomposer (notably T3 and T5) demonstrated improved performance among the organic treatments, indicating synergistic effects on nutrient cycling and soil health. Nutrient uptake followed similar patterns, with T9 showing the highest nitrogen, phosphorus, and potassium uptake in both crops. Integrated nutrient management, combining organic and inorganic sources, significantly enhanced nutrient uptake compared to the control and sole organic treatments. These findings underscore the importance of balanced and integrated fertilization strategies to optimize crop productivity and nutrient efficiency in rice-wheat cropping systems. Supporting literature further reinforces the benefits of combining organic amendments with recommended fertilizer doses for sustained soil fertility and crop yield improvement.

Keywords: Uptake; soil health; nutrient cycling; crop residue.

1. INTRODUCTION

Crop diversification through crop substitution or mixed cropping/intercropping may be a useful tool for mitigating the problems associated with aberrant weather conditions. The diverse agro-ecosystem of India is favourable for cultivating several pulses, oilseeds, vegetables, fodder and aromatic, as well as medicinal, crops. An increase in demand for oilseeds and pulses can be successfully met through crop diversification in the rice–wheat cropping system (Singh et al., 2020; Upadhaya et al., 2022). The rice–wheat cropping system is among the most extensively practised agricultural systems globally and is particularly prevalent in northwest India. This widespread adoption is attributed to the region's favorable agro-climatic conditions, ecological suitability, and ample availability of natural resources. The system plays a critical role in ensuring global food security by supplying staple food grains to a significant proportion of the world population (Banjara et al., 2021a). The rice–wheat cropping system significantly contributes to cereal production in South and East Asia, accounting for approximately 72%, 85%, 87%, 100%, and 71% of total cereal output in China, India, Pakistan, Bangladesh, and Nepal,

respectively (Singh and Paroda, 1994; Yadav et al., 1998; GoP, 2011). India has demonstrated substantial growth in cereal production, increasing from 87.4 million tons in 1961 to 324.3 million tons in 2019 FAOSTAT (Canton et al., 2021). Despite this progress, the annual system productivity in the Indo-Gangetic Plains remains relatively low, ranging from 3 to 5 Mg ha^{-1} , which is significantly below the region's climatic yield potential of 12.0 to 19.3 Mg ha^{-1} (Ladha et al., 2003; Pathak et al., 2003). Declining crop factor productivity and deteriorating resource base in the rice-wheat system have led to the promotion of conservation tillage-based agriculture (Thuy et al., 2008). Conservation tillage involves zero or minimal tillage for row seeding using a drill/planter. Zero or reduced tillage has had a significant positive impact on the environment, crop productivity, profitability, resource-use efficiency, and farmers' livelihood, especially in those areas where the rice harvest is normally delayed (Verma et al., 2025). Rice serves as the primary staple food for over 70% of the Indian population, while the remainder consumes rice in combination with wheat or other cereals (USDA, 2019). According to the Ministry of New and Renewable Energy (MNRE), India generates approximately 500 million tons (MT) of crop

residues annually (NPMCR, 2019). Cereal crops, primarily rice, wheat, and maize, account for nearly 70% of this total, with the rice–wheat cropping system alone contributing about one-fourth of the residues (Kumar et al., 2019). In northwest India, approximately 23 MT of rice residues are produced each year, much of which is burned in situ. Following forage harvest, an estimated 25% (1.5–2.0 t ha⁻¹, totalling approximately 16 MT) of wheat residues remain in the field and are often burned by farmers without agronomic justification. The rice–wheat system, which typically yields 4 t ha⁻¹ of rice and 3 t ha⁻¹ of wheat, has the potential to deplete over 280 kg of nitrogen, 26 kg of phosphorus, and 245 kg of potassium per hectare from the soil annually. Combined rice and wheat residue production can reach 6–11 t ha⁻¹ per year. Effective management of 4–6 t ha⁻¹ of rice residues is critical to facilitate timely sowing of the subsequent wheat crop. Available residue management strategies include open-field burning, in situ incorporation, surface retention and mulching, as well as baling and removal of straw (Whitbread et al., 2003). Singh et al. (2019) comprehensively reviewed crop residue management in the rice–wheat cropping system, highlighting its importance for resource conservation, environmental protection, and sustainable agriculture in northwest India. The study emphasized that in situ crop residue management practices offer the most effective solution to mitigate the widespread issue of residue burning.

2. MATERIALS AND METHODS

Experimental Site: The study was conducted as part of a long-term field experiment initiated in 2017 under the All India Coordinated Research Project on Rice (Soil Science). This experiment was established at the B-1 plot of the Norman E. Borlaug Crop Research Centre, located within Govind Ballabh Pant University of Agriculture and Technology, Pantnagar. The study site is situated in the Tarai region, a narrow strip of land at the base of the Shivalik range of the Himalayas, positioned at 28.97° N latitude, 79.29° E longitude, and an elevation of 244.8 meters above mean sea level.

Climate and Weather Conditions: Pantnagar is characterized by a sub-humid, subtropical climate with distinct seasonal variations, including hot, dry summers and cold winters. The region experiences a pronounced dry season from early October to mid-June, while the wet

season extends from mid-June to early October. The highest temperatures are typically recorded during May and June, ranging between 40°C and 45°C, whereas the lowest temperatures occur in December and January, fluctuating between 2°C and 5°C. Relative humidity peaks during July, while the driest conditions, with the lowest humidity levels, are observed in April and May. The area receives an average annual rainfall of approximately 1400 mm, the majority of which occurs during the southwest monsoon season, from June to September. Detailed meteorological data for the cropping season—based on mean weekly observations recorded at the Meteorological Observatory of the Crop Research Centre during the experimental period.

Soil Type: The soils exhibit a range of drainage conditions, from well-drained to poorly drained, and their color varies from light grey to ash grey, depending on the texture and maturity of the soil profile. They are typically loamy in texture, making them suitable for the cultivation of a wide variety of crops. Overall, the Mollisols at the experimental site are fertile, well-drained to poorly drained soils with a rich organic content, formed under specific climatic and vegetative conditions on alluvial plains derived from the Shivalik range.

Collection Soil Samples: Soil samples were systematically collected to evaluate their properties and distribution at various depths, both prior to the commencement of experimentation and following the harvest of rice and wheat crops. Sampling was conducted using an auger to extract soil cores from depths of 0–15 cm and 15–30 cm. To comprehensively assess soil characteristics, samples were gathered from different agricultural systems, including Agroforestry, Orchard, Medicinal Plants, Fodder, and Rice-Wheat systems. Sampling intervals were established at 0–15 cm, 15–30 cm, 30–60 cm, 60–90 cm, and 90–120 cm depths. This stratified approach facilitated a detailed examination of soil properties across multiple depths and land use systems.

Plant and Soil Analysis: Phosphorus (P) and potassium (K) concentrations in rice paddy, rice straw, wheat grain, and wheat straw were determined using standard laboratory procedures. Phosphorus was quantified calorimetrically following the method outlined by Ryan et al. (2001), while potassium was measured using flame photometry as described by Wright and Stuczynski (1996). Nitrogen (N)

List 1. Treatment Details

Treatment	Rice crop (Kharif)	Wheat crop (Rabi)
T1	100 % RDF (NPK)	100 % RDF (NPK)
T2	50% N from residue + 50 % RDF	50 % N from residue + 50 % RDF
T3	50 % N from residue + 50 % RDF + Pusa Decomposer	50 % N from residue + 50 % RDF + Pusa Decomposer
T4	50 % N from residue + 50 % GM	50 % N from residue
T5	50 % N from residue + 50 % GM + Pusa Decomposer	50 % N from residue + Pusa Decomposer
T6	Residue @ 2.5 t ha ⁻¹ + Pusa Decomposer	Residue @ 2.5 t ha ⁻¹ + Pusa Decomposer
T7	Residue @ 2.5 t ha ⁻¹ + No Pusa Decomposer	Residue @ 2.5 t ha ⁻¹ + No Pusa Decomposer
T8	Absolute control	Absolute control
T9	150 % RDF (NPK)	150 % RDF (NPK)
T10	100 % RDF +FYM @ 5 t ha ⁻¹ + Zn + B	100 % RDF +FYM @ 5 t ha ⁻¹ + Zn + B

Note: Wheat residue was used in rice crop and rice residue was used in wheat crop. Recommended dose N = 120 kg ha⁻¹, P₂O₅ = 60 kg ha⁻¹, K₂O = 30 kg ha⁻¹
ZnSO₄ @ 25 kg ha⁻¹, borax @ 5kg/ha

content was assessed using the Kjeldahl method, a widely accepted technique for determining total nitrogen in organic and inorganic substances. Nutrient uptake was calculated by multiplying the dry matter yields of straw and grain by their respective nutrient concentrations and summing the values. Soil samples were air-dried, and plant debris and stones were manually removed. The samples were then ground and sieved through a 2 mm stainless steel mesh. For the determination of available nutrients, the AB-DTPA (ammonium bicarbonate–diethylenetriaminepentaacetic acid) extractable concentrations of nitrate-nitrogen (NO₃-N), phosphorus (P₂O₅), and potassium (K₂O) were measured following the procedure described by Soltanpour and Workman (1979).

Statistical Analysis: The statistical analysis was conducted following the methodology outlined by Snedecor and Cochran (1962). All observations related to yield and analytical data collected during the study were subjected to statistical evaluation using a randomized block design (RBD) and analyzed with OPSTAT software. The relationship between two or more variables was examined using correlation coefficients, calculated through the least squares method.

3. RESULTS AND DISCUSSION

Grain yield of rice crop: The application of inorganic and organic nutrient sources significantly influenced rice grain yields, with values ranging from 30.25 to 55.24 q ha⁻¹.

Treatment T9, which utilized inorganic fertilizers, achieved the highest yield of 55.24 q ha⁻¹, surpassing all other treatments (Table 1). This increase is attributed to the rapid nutrient availability provided by inorganic fertilizers, which likely enhanced crop productivity during the growing season. Conversely, treatment T8, which received no fertilizers, recorded the lowest yield of 30.25 q ha⁻¹ due to limited nutrient availability. Treatments incorporating crop residues (T2–T7) yielded lower than those with inorganic fertilizers (T1, T9, T10). This disparity is likely due to the slower nutrient release from decomposing crop residues, which may not align with the crop's peak nutrient demands. Additionally, microbial decomposition of residues can compete with plants for nutrients, further limiting availability during critical growth stages. In contrast, inorganic fertilizers provide readily available nutrients, supporting higher yields. Among the treatments with crop residues, T5, which combined crop residue, green manure, and the Pusa Decomposer, demonstrated superior performance. This combination likely enhanced nutrient availability through synergistic effects, improving yield outcomes. Overall, treatments incorporating crop residues were more effective than T8, which lacked both organic and inorganic nutrient inputs. The second-year rice crop exhibited significant yield variations among treatments, following a trend similar to the first-year crop, indicating consistent effects of nutrient management strategies over time. Supporting studies have highlighted the benefits of integrating organic and inorganic fertilizers. For instance, research by Posha and

Reddy (2018) found that incorporating crop residues with fertilizers significantly increased maize yields compared to controls. Similarly, studies by Singh and Yadav (2006), Rajkhowa and Borah (2008), and Dhar et al. (2014) have reported enhanced crop yields through integrated nutrient management practices.

Straw yield of rice: The application of inorganic and organic nutrient sources significantly influenced rice straw yields, with values ranging from 44.12 to 70.87 q ha⁻¹. Treatment T9, which utilized inorganic fertilizers, achieved the highest straw yield of 70.87 q ha⁻¹, surpassing all other treatments (Table 1). This increase is attributed to the rapid nutrient availability provided by inorganic fertilizers, which likely enhanced crop productivity during the growing season. Conversely, treatment T8, which received no fertilizers, recorded the lowest straw yield of 44.12 q ha⁻¹ due to limited nutrient availability. Treatments incorporating crop residues (T4–T7) yielded lower than those with inorganic fertilizers (T9, T10, and T1). This disparity is likely due to the slower nutrient release from decomposing crop residues, which may not align with the crop's peak nutrient demands. Additionally, microbial decomposition of residues can compete with plants for nutrients, further limiting availability during critical growth stages. In contrast, inorganic fertilizers provide readily available nutrients, supporting higher yields. Among the treatments with crop residues, T3, which combined crop residue, green manure, and the Pusa Decomposer, demonstrated superior performance. This combination likely enhanced nutrient availability through synergistic effects, improving yield outcomes. Overall, treatments incorporating crop residues were more effective than T8, which lacked both organic and inorganic nutrient inputs. The second-year rice crop exhibited significant yield variations among treatments, following a trend similar to the first-year crop, indicating consistent effects of nutrient management strategies over time. Supporting studies have highlighted the benefits of integrating organic and inorganic fertilizers. For instance, research by Posha and Reddy (2018) found that incorporating crop residues with fertilizers significantly increased maize yields compared to controls. Similarly, studies by Singh and Yadav (2006), Rajkhowa and Borah (2008), and Dhar et al. (2014) have reported enhanced crop yields through integrated nutrient management practices.

Grain yield of wheat crop: The wheat grain yield data (Table 2) indicated a range from 32.45 to 52.21 q ha⁻¹ across different treatments. The highest yield of 52.21 q ha⁻¹ was observed in treatment T9, which involved the application of inorganic fertilizers, enhancing nutrient availability during the growing season. Conversely, treatment T8, which received no organic or inorganic fertilizers, recorded the lowest yield of 32.45 q ha⁻¹. Treatments incorporating crop residues (T2, T3, T4, T5, T6, and T7) exhibited lower grain yields compared to those receiving inorganic fertilizers (T9, T10, and T1). This difference is attributed to the gradual nutrient release from decomposing crop residues, which may not align with the crop's peak nutrient demands. Among the treatments with Pusa Decomposer, T3 demonstrated the highest grain yield, likely due to improved soil health, increased microbial activity, and enhanced enzymatic functions. The second trial mirrored these findings, with T9 yielding 54.61 q ha⁻¹ and T8 yielding 23.64 q ha⁻¹. Supporting studies have highlighted the benefits of integrating organic and inorganic fertilizers. For instance, Mandal et al. (2004) reported that incorporating rice straw with organic manure increased wheat grain yield due to improved soil physical conditions and enhanced microbial activity. Similarly, Dhaliwal and Walia (2008) found that applying 50% NPK through chemical fertilizers in combination with 50% N through farmyard manure or green manure resulted in higher wheat grain yield due to improved soil properties.

Straw yield of wheat crop: Wheat straw yield ranged from 41.25 to 75.05 q ha⁻¹ across treatments (Table 2). The highest yield was recorded in T9 (75.05 q ha⁻¹), attributed to the use of inorganic fertilizers, which enhanced nutrient availability. The lowest yield occurred in T8 (41.25 q ha⁻¹), which lacked nutrient inputs. Treatments incorporating crop residues (T2–T7) produced lower straw yields than those with inorganic fertilizers (T1, T9, T10), likely due to slower nutrient release. Among the treatments with Pusa Decomposer, T3 yielded the most straw, benefiting from improved decomposition and nutrient cycling under 50% RDF. Supporting studies by Singh et al. (2017) and Kumar & Singh (2010) reported increased straw yields with higher RDF and organic amendments due to enhanced biomass production, microbial activity, and nutrient uptake, contributing to greater photosynthetic efficiency and yield.

3.1 Uptake

Total nitrogen uptake by rice: Total nitrogen uptake by rice varied from 22.67 to 93.7 kg ha⁻¹ in the first year and from 30.91 to 102.03 kg ha⁻¹ in the second year (Table 3). The highest uptake was consistently recorded in treatment T9, attributed to the application of inorganic fertilizers, while the lowest was observed in T8, which received no nutrient inputs. All treatments showed improved nitrogen uptake compared to T8, with enhancements likely due to better soil physico-chemical properties from the incorporation of crop residues and green manure. Similar results were reported by Paul et al. (2014), Prasad et al. (2010), and Chesti et al. (2015), highlighting that integrated or full-dose fertilizer application significantly increases nutrient uptake in rice.

Total phosphorus uptake by rice: Total phosphorus uptake by rice varied from 6.49 to 37.07 kg ha⁻¹ in the first trial and from 7.48 to 35.47 kg ha⁻¹ in the second trial (Table 4). The highest uptake was observed in treatment T9, which received inorganic fertilizers, while the lowest was in T8, which received no nutrient inputs. Treatments T9, T10, T1, and T2 exhibited superior phosphorus uptake compared to T3, while treatments T4, T5, T6, T7, and T8 were inferior to T3. This suggests that integrated nutrient management practices, combining organic and inorganic fertilizers, can enhance phosphorus availability and uptake in rice. Kachroo et al. (2006) reported that incorporating rice residues increased phosphorus uptake by 3.6 kg ha⁻¹ compared to no residue incorporation. Virdia and Mehta (2009) found that combining organic manure with the recommended fertilizer dose resulted in higher phosphorus uptake in rice. These findings underscore the importance of integrated nutrient management in improving phosphorus availability and uptake in rice cultivation.

Total potassium uptake by rice: In the first year, total potassium uptake by rice ranged from 48.80 to 139.15 kg ha⁻¹, with the highest uptake observed in treatment T9 (139.15 kg ha⁻¹) and the lowest in T8 (48.80 kg ha⁻¹). A similar trend was noted in the second year, with uptake varying from 45.61 to 137.56 kg ha⁻¹, again highest in T9 and lowest in T8 (Table 5). The increased potassium uptake in T9 is attributed to the application of potassium-containing fertilizers, which enhanced soil potassium availability and facilitated greater uptake by rice plants.

Conversely, the low uptake in T8 is due to the absence of potassium inputs, leading to insufficient potassium availability for the plants. Studies have shown that integrating organic amendments with recommended fertilizer doses can enhance potassium uptake in rice. For instance, Virdia and Mehta (2009) reported that incorporating organic manure along with recommended fertilizer doses resulted in higher potassium uptake compared to using recommended fertilizer doses alone. These findings underscore the importance of balanced fertilization strategies, combining both organic and inorganic sources, to optimize potassium availability and uptake in rice cultivation.

Total uptake of nitrogen by wheat: In the first year of the study, total nitrogen uptake by wheat ranged from 24.23 to 97.76 kg ha⁻¹. The highest uptake was observed in treatment T9 (97.76 kg ha⁻¹), followed by T10 (88.2 kg ha⁻¹), T1 (86.17 kg ha⁻¹), and T3 (77.12 kg ha⁻¹), while the lowest was recorded in the control treatment T8 (24.23 kg ha⁻¹). A similar trend was noted in the second trial, with uptake varying from 23.72 to 102.34 kg ha⁻¹ (Table 3). The increased nitrogen uptake in treatments involving crop residues and green manuring can be attributed to the enhanced nitrogen availability from decomposing organic matter. For instance, green manuring with *Sesbania* species has been reported to add significant amounts of nitrogen to the soil, thereby improving nitrogen uptake in subsequent crops. Incorporating green manure not only improves nitrogen availability but also enhances soil fertility and microbial activity, leading to better crop performance. For example, the incorporation of *Sesbania* green manure has been shown to increase nitrogen uptake and productivity in rice-wheat cropping systems.

Total uptake of phosphorus by wheat: In the first year of the study, wheat phosphorus uptake ranged from 14.05 to 38.87 kg ha⁻¹, with the highest uptake observed in treatment T9 (38.87 kg ha⁻¹) and the lowest in the control treatment T8 (14.05 kg ha⁻¹). Treatments involving crop residue (T2, T3, T4, T5, T6, and T7) exhibited lower phosphorus uptake compared to treatments T1 and T9. In the second trial, phosphorus uptake ranged from 12.82 to 39.68 kg ha⁻¹, following a similar trend (Table 4). These findings align with previous research indicating that the incorporation of crop residues can influence phosphorus dynamics in soil. For instance, studies have shown that residue management practices, such as incorporation,

Table 1. Effect of crop residue management on rice grain and straw yield of rice crop in 2020-21 and 2021-22

Treatment	Rice 2020-21		Rice 2021-22	
	Grain yield (q/ha)	Straw yield (q/ha)	Grain yield (q/ha)	Straw yield (q/ha)
T1: 100 % RDF (NPK)	49.54	68.54	54.99	69.62
T2: 50 % N from residue + 50 % RDF	44.25	63.01	45.61	64.13
T3: 50 % N from residue + 50 % RDF + Pusa Decomposer	46.56	64.25	49.78	68.17
T4: 50 % N from residue + 50 % GM	41.25	59.32	45.16	62.13
T5 :50 % N from residue + 50 % GM + Pusa Decomposer	43.24	62.25	45.34	62.89
T6: Residue @ 2.5 t ha-1 + Pusa Decomposer	34.15	60.25	39.19	61.68
T7: Residue @ 2.5 t ha-1 + No Pusa Decomposer	33.21	58.35	35.97	60.47
T8: Absolute control	30.25	44.12	28.54	46.58
T9: 150 % RDF (NPK)	55.24	70.87	59.00	71.40
T10: 100 % RDF +FYM @ 5 t ha-1 + Zn + B	54.56	69.55	56.11	71.16
SEm +	0.61	1.12	0.67	1.00
CD at 5%	1.80	3.32	1.99	2.97

Table 2. Effect of crop residue management on wheat grain and straw yield of wheat crop in 2020-21 and 2021-22

Treatment	Wheat 2020-21		Wheat 2021-22	
	Grain yield (q/ha)	Straw yield (q/ha)	Grain yield (q/ha)	Straw yield (q/ha)
T1: 100 % RDF (NPK)	50.00	72.65	51.21	73.80
T2: 50 % N from residue + 50 % RDF	48.90	69.80	49.89	70.06
T3: 50 % N from residue + 50 % RDF + Pusa Decomposer	49.21	71.35	50.98	72.62
T4: 50 % N from residue	41.89	62.78	43.54	64.63
T5 :50 % N from residue + Pusa Decomposer	42.25	63.78	43.65	64.91
T6: Residue @ 2.5 t ha-1 + Pusa Decomposer	39.45	60.48	41.32	62.52
T7: Residue @ 2.5 t ha-1 + No Pusa Decomposer	38.12	59.84	40.89	60.04
T8: Absolute control	32.45	41.25	23.64	43.15
T9: 150 % RDF (NPK)	52.21	75.05	54.61	77.10
T10: 100 % RDF +FYM @ 5 t ha-1 + Zn + B	51.19	73.09	53.81	74.19
SEm +	0.55	1.16	0.70	0.87
CD at 5%	1.63	3.46	2.07	2.57

Table 3. Effect of crop residue management on Total N uptake in rice-wheat crop in 2020- 21 and 2021-22

Treatment	Total N uptake (kg ha ⁻¹)			
	Rice		Wheat	
	2020-21	2021-22	2020-21	2021-22
T1: 100 % RDF (NPK)	76.71	86.42	86.17	84.03
T2: 50 % N from residue + 50 % RDF	63.93	71.84	73.69	72.3
T3: 50 % N from residue + 50 % RDF + Pusa Decomposer	67.42	80.33	77.12	78.86
T4: 50 % N from residue + 50 % GM	52.79	62.64	63.78	61.39
T5: 50 % N from residue + 50 % GM+ Pusa Decomposer	58.12	63.97	66.00	64.87
T6: Residue @ 2.5 t ha ⁻¹ + Pusa Decomposer	48.36	59.12	60.15	56.24
T7: Residue @ 2.5 t ha ⁻¹ + No Pusa Decomposer	45.8	51.21	53.93	49.83
T8: Absolute control	22.67	30.91	24.23	23.72
T9: 150 % RDF (NPK)	93.7	102.03	97.76	102.34
T10: 100 % RDF + FYM @ 5t ha ⁻¹ + Zn + B	90.13	96.93	88.20	91.99
SEm ±	3.66	3.02	4.78	3.47
C.D.at 5%	10.87	8.97	14.20	10.32

Table 4. Effect of crop residue management on Total P uptake in rice-wheat crop in 2020- 21 and 2021-22

Treatment	Total P uptake (kg ha ⁻¹)			
	Rice		Wheat	
	2020-21	2021-22	2020-21	2021-22
T1: 100 % RDF (NPK)	28.19	29.07	34.87	34.88
T2: 50 % N from residue + 50 % RDF	23.79	21.36	32.45	32.04
T3: 50 % N from residue + 50 % RDF + Pusa Decomposer	26.08	25.27	33.38	33.77
T4: 50 % N from residue + 50 % GM	19.07	20.30	27.83	27.46
T5: 50 % N from residue + 50 % GM+ Pusa Decomposer	20.97	20.82	28.69	27.86
T6: Residue @ 2.5 t ha ⁻¹ + Pusa Decomposer	15.49	16.59	25.52	26.00
T7: Residue @ 2.5 t ha ⁻¹ + No Pusa Decomposer	14.26	15.26	23.57	24.22
T8: Absolute control	6.49	7.48	14.05	12.82
T9: 150 % RDF (NPK)	37.07	35.47	38.87	39.68
T10: 100 % RDF + FYM @ 5t ha ⁻¹ + Zn + B	32.09	31.90	36.97	36.88
SEm ±	2.58	2.08	2.80	3.34
C.D.at 5%	7.65	6.18	8.32	9.91

Table 5. Effect of crop residue management on Total K uptake in rice-wheat crop in 2020- 21 and 2021-22

Treatment	Total K uptake (kg ha ⁻¹)			
	Rice		Wheat	
	2020-21	2021-22	2020-21	2021-22
T1: 100 % RDF (NPK)	119.32	115.56	68.27	64.77
T2: 50 % N from residue + 50 % RDF	103.10	96.50	56.33	52.64
T3: 50 % N from residue + 50 % RDF + Pusa Decomposer	103.82	102.27	80.33	57.31
T4: 50 % N from residue + 50 % GM	90.21	88.73	45.58	44.53
T5: 50 % N from residue + 50 % GM+ Pusa Decomposer	94.12	87.70	49.79	46.20
T6: Residue @ 2.5 t ha ⁻¹ + Pusa Decomposer	80.52	79.05	41.12	41.34
T7: Residue @ 2.5 t ha ⁻¹ + No Pusa Decomposer	74.54	73.34	37.22	35.69
T8: Absolute control	48.80	45.61	20.66	13.73
T9: 150 % RDF (NPK)	139.15	137.56	81.25	74.70
T10: 100 % RDF + FYM @ 5t ha ⁻¹ + Zn + B	127.72	127.61	75.89	68.65
SEm ±	1.25	1.32	4.50	4.97
C.D.at 5%	3.73	3.93	13.37	14.77

can affect phosphorus availability and uptake in wheat cropping systems. Additionally, the application of green manures, such as *Sesbania aculeata*, in combination with recommended fertilizer doses has been reported to enhance phosphorus uptake in rice and wheat crops. This improvement is attributed to increased soil nutrient availability and microbial activity. In summary, the study highlights the significant role of phosphorus management practices in wheat cropping systems. Incorporating crop residues and utilizing green manures can enhance phosphorus availability and uptake, contributing to improved crop productivity.

K total uptake by wheat: After two years of experimentation, the total potassium uptake by wheat in the first year ranged from 20.66 to 81.25 kg ha⁻¹. The highest uptake was observed in treatment T9 (81.25 kg ha⁻¹), while the lowest was in T8 (20.66 kg ha⁻¹). All treatments involving crop residue (T2–T7) exhibited lower potassium uptake compared to T1 (Table 5). In comparison to T8, all treatments demonstrated superior performance. A similar trend was observed in the second trial, with uptake ranging from 13.73 to 74.7 kg ha⁻¹. The higher potassium uptake in treatments with crop residue can be attributed to the gradual release of potassium during decomposition, which enhances soil potassium availability. Incorporation of crop residues has been shown to increase potassium uptake in wheat by improving soil potassium content and availability. These findings underscore the importance of integrated nutrient management practices, combining crop residue retention with appropriate potassium fertilization, to enhance nutrient uptake and improve wheat productivity.

4. CONCLUSION

Incorporating rice and wheat crop residues into soil significantly enhances both its physical and chemical properties, fostering improved soil health and sustained crop productivity. This practice not only enriches soil organic carbon content but also promotes nutrient cycling and microbial activity, which are crucial for maintaining soil fertility. While inorganic fertilizers like 150% RDF (Recommended Dose of Fertilizer) can boost immediate crop yields, they may not be sustainable in the long term due to potential negative impacts on soil health. Conversely, treatments combining organic inputs such as 100% RDF + FYM (Farmyard Manure) @ 5 t ha⁻¹ + Zn @ 25 kg ha⁻¹ + B @ 5 kg ha⁻¹,

and 50% residue + 50% RDF + Pusa Decomposer, offer a balanced approach. These combinations provide both immediate nutrient availability and long-term soil enrichment, promoting sustainable agricultural practices. Among these, the treatment combining 50% crop residue with green manuring and Pusa Decomposer (T5) stands out. This integrated approach not only enhances nutrient availability but also improves soil structure, water retention, and microbial activity, leading to increased crop yields and better soil health. Therefore, adopting such integrated nutrient management practices is recommended for sustainable and productive rice-wheat cropping systems.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

- Banjara, T. R., Bohra, J. S., Kumar, S., Ram, A., & Pal, V. (2021). Diversification of rice–wheat cropping system improves growth, productivity and energetics of rice in the Indo-Gangetic Plains of India. *Agricultural Research*, 1–10.
- Canton, H. (2021). Food and agriculture organization of the United Nations—FAO. In *The Europa directory of international organizations 2021* (pp. 297–305). Routledge.
- Chesti, M. H., Kohli, A., Mujtaba, A., Sofi, J. A., Qadri, T. N., Peer, Q. J. A., Dar, M. A., & Bisati, I. A. (2015). Effect of integrated application of inorganic and organic sources on soil properties, yield and nutrient uptake by rice (*Oryza sativa* L.) in intermediate zone of Jammu and Kashmir. *Journal of the Indian Society of Soil Science*, 63(1), 88–92.
- Dhaliwal, S. S., & Walia, S. S. (2008). Integrated nutrient management for sustaining maximum productivity of rice-wheat system under Punjab conditions. *J. Res. Punjab Agric. Univ*, 45, 12–16.

- Dhar, D., Datta, A., Basak, N., Paul, N., Badole, S., & Thomas, T. (2014). Residual effect of crop residues on growth, yield attributes and soil properties of wheat under rice-wheat cropping system. *Indian Journal of Agricultural Research*, 48(5), 373–378.
- Dileep Kachroo, D. K., Dixit, A. K., & Bali, A. S. (2006). Influence of crop residue, flyash and varying starter dosages on growth, yield and soil characteristics in rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system under irrigated conditions of Jammu region.
- Government of Pakistan. (2011). *Agricultural Statistics of Pakistan 2010-11*, Statistics Division, Pakistan Bureau of Statistics Islamabad, Pakistan.
- Kumar, A., Kushwaha, K. K., Singh, S., Shivay, Y. S., Meena, M. C., & Nain, L. (2019). Effect of paddy straw burning on soil microbial dynamics in sandy loam soil of Indo-Gangetic plains. *Environmental Technology & Innovation*, 16, 100469.
- Ladha, J. K., Pathak, H., Tirol-Padre, A., Dawe, D., & Gupta, R. K. (2003). Productivity trends in intensive rice-wheat cropping systems in Asia. *Improving the productivity and sustainability of rice-wheat systems: Issues and impacts*, 65, 45–76.
- Mandal, K. G., Misra, A. K., Hati, K. M., Bandyopadhyay, K. K., Ghosh, P. K., & Mohanty, M. (2004). Rice residue-management options and effects on soil properties and crop productivity. *Journal of Food Agriculture and Environment*, 2, 224–231.
- NPMCR.(2019). http://agricoop.nic.in/sites/default/files/NPMCR_1.pdf (accessed on 6 March).
- Pasha, M. L., & Reddy, P. R. R. (2018). Response of rice to different nitrogen and phosphorous levels under irrigated conditions. *Journal of Pharmacognosy and Phytochemistry*, 7(3), 675–678.
- Pathak, H., Ladha, J. K., Aggarwal, P. K., Peng, S., Das, S., Singh, Y., Singh, B., Kamra, S. K., Mishra, B., Sastri, A. S. R. A. S., & Aggarwal, H. P. (2003). Trends of climatic potential and on-farm yields of rice and wheat in the Indo-Gangetic Plains. *Field Crops Research*, 80(3), 223–234.
- Paul, J., Choudhary, A. K., Suri, V. K., Sharma, A. K., Kumar, V., & Shobhna. (2014). Bioresource nutrient recycling and its relationship with biofertility indicators of soil health and nutrient dynamics in rice-wheat cropping system. *Communications in Soil Science and Plant Analysis*, 45(7), 912–924.
- Prasad, R. K., Kumar, V., Prasad, B., & Singh, A. P. (2010). Long-term effect of crop residues and zinc fertilizer on crop yield, nutrient uptake and fertility build-up under rice-wheat cropping system in calciorthents. *Journal of the Indian Society of Soil Science*, 58(2), 205–211.
- Rajkhowa, D. J., & Borah, D. (2008). Effect of rice (*Oryza sativa*) straw management on growth and yield of wheat (*Triticum aestivum*). *Indian Journal of Agronomy*, 53(2), 112–115.
- Ryan, J., Estefan, G., & Rashid, A. (2001). *Soil and plant analysis laboratory manual*. ICARDA.
- Sing, R. B., & Paroda, R. S. (1994). Sustainability and productivity of rice-wheat systems in the Asia-Pacific region: Research and technology development needs. *RAPA Publication (FAO)*, (1994/11).
- Singh, P. P., Pawar, R., & Meena, R. (2017). Response of integrated nutrient management on yield and chemical properties of soil under rice-wheat cropping system. *International Journal of Chemical Studies*, 5(2), 366–369.
- Singh, R. K., Sharma, G. K., Kumar, P., Singh, S. K., & Singh, R. (2019). Effect of crop residues management on soil properties and crop productivity of rice-wheat system in Inceptisols of Seemanchal region of Bihar. *Current Journal of Applied Science and Technology*, 37(6), 1–6.
- Singh, R., & Yadav, D. S. (2006). Effect of rice (*Oryza sativa*) residue and nitrogen on performance of wheat (*Triticum aestivum*) under rice-wheat cropping system. *Indian Journal of Agronomy*, 51(4), 247–250.
- Singh, R., Yadav, D. B., Ravisankar, N., Yadav, A., & Singh, H. (2020). Crop residue management in rice-wheat cropping system for resource conservation and environmental protection in north-western India. *Environment, Development and Sustainability*, 22(5), 3871–3896.
- Snedecor, G. W., & Cochran, W. G. (1967). *Statistical methods* 6th edition. *The Iowa State University*.
- Soltanpour, P. N., & Workman, S. (1979). Modification of the NH₄ HCO₃-DTPA soil test to omit carbon black. *Communications in Soil Science and Plant Analysis*, 10(11), 1411–1420.

- Thuy, N. H., Shan, Y., Wang, K., Cai, Z., & Buresh, R. J. (2008). Nitrogen supply in rice-based cropping systems as affected by crop residue management. *Soil Science Society of America Journal*, 72(2), 514–523.
- Upadhaya, B., Kishor, K., Kumar, V., Kumar, N., Kumar, S., Yadav, V. K., ... & Hossain, A. (2022). Diversification of rice-based cropping system for improving system productivity and soil health in eastern Gangetic plains of India. *Agronomy*, 12(10), 2393.
- Usda.gov. (2025). Wheat. <https://www.ers.usda.gov/topics/crops/wheat>
- Verma, S. K., Singh, S. B., Rajpoot, S. K., Bhushan, C., Vaheed, M., Shrivastava, S., Yadav, D. K., Pratap, V., & Jaysawal, P. K. (2025). A review on drawbacks of rice-wheat cropping system: Opportunities and challenges in north-western Indo-Gangetic Plains. *Journal of Advances in Biology & Biotechnology*, 28(6), 170–183.
- <https://doi.org/10.9734/jabb/2025/v28i62383>
- Viridia, H. M., & Mehta, H. D. (2009). Integrated nutrient management in transplanted rice (*Oryza sativa* L.). *Journal of Rice Research*, 2(2), 99–104.
- Whitbread, A., Blair, G., Konboon, Y., Lefroy, R., & Naklang, K. (2003). Managing crop residues, fertilizers, and leaf litters to improve soil C, nutrient balances, and the grain yield of rice and wheat cropping systems in Thailand and Australia. *Agriculture, Ecosystems & Environment*, 100(2-3), 251–263.
- Wright, R. J., & Stuczynski, T. (1996). Atomic absorption and flame emission spectrometry. In *Methods of Soil Analysis: Part 3 Chemical Methods* (5th ed., pp. 65–90).
- Yadav, R. L., Gangwar, K. S., & Prasad, K. (1998). Analysis of eco-regional production constraints in rice-wheat cropping system. *Project Directorate for Cropping Systems Research*, (ICAR).

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