# ***Original Research Article***

# Effect of crop residue management on Soil Microbiology, Nutrient Dynamics, and Growth Performance of wheat crop

# **Abstract**

Crop residue management is a vital agronomic practice that influences soil health, nutrient cycling, and microbial activity, especially in degraded or sodic soils. The present investigation also aimed to evaluate the impact of incorporating crop residues along with the application of a biofertilizer consortium consisting of nitrogen-, phosphorus-, and potassium-solubilizing microorganisms on nutrient dynamics, soil health, and the growth performance of wheat (Triticum aestivum L.) cultivated under partially reclaimed sodic soil conditions. A field experiment was carried out using the wheat variety HD-2967, comprising ten treatment combinations involving different nitrogen levels, the application of 5 t/ha paddy straw, and a microbial consortium. Among these, the T10 treatment (150 kg N/ha + consortium + 5 t/ha residue) exhibited the most favorable outcomes. This treatment notably increased plant height, dry matter accumulation, and the post-harvest availability of nitrogen, phosphorus, and potassium in the soil. Additionally, T10 improved soil biological parameters, such as microbial population, enzymatic activities (including dehydrogenase and phosphatase), and microbial biomass carbon. These enhancements in microbial activity facilitated effective nutrient mineralization and contributed to improved soil health. The findings indicate that integrating crop residue, nitrogen fertilization, and biofertilizer consortium application can significantly promote nutrient cycling and biological soil quality, thereby supporting sustainable wheat cultivation in sodic soils.

**Keywords:** Crop residue management, Biofertilizer consortium, Nutrient availability, Sodic soil, Soil microbial activity, Wheat growth, Microbial biomass carbon, Enzymatic activity, Integrated nutrient management, *Triticum aestivum* L.

# **Introduction**

Crop residues, encompassing the plant components remaining in the field post-harvest and threshing, are integral to crop residue management, a widely recognized practice for regulating various soil physical, chemical, and biological functions. The management of crop residues influences soil physical attributes, including moisture content, temperature, aggregate stability, bulk density, and hydraulic conductivity. Soil temperature is modulated by alterations in the radiant energy balance and insulation provided by residues. Rice crop residues, characterized by high silica content, possess the capacity to modify the electrochemical properties of acidic soils, thereby reducing phosphorus fixation, enhancing base retention, and elevating soil pH. The combined application of rice straw and organic manure has been shown to improve wheat grain yield while also enhancing soil physical properties. Incorporating crop residues into the soil promotes higher microbial activity compared to practices such as residue removal or burning. As a result, efficient management of agricultural residues plays a crucial role in improving soil health and sustaining long-term crop productivity. In India, the annual generation of agricultural residues is estimated to exceed 500 million tons (MNRE, 2009; NICRA, IARI).

Surplus crop residues, defined as the total residues produced minus those utilized for various purposes, are commonly subjected to on-farm burning. In India, the estimated annual surplus of crop residues ranges from 84 to 141 million tons (Mt), with cereal crops accounting for 58% of the 82 Mt of surplus residues. Approximately 70 Mt of residues, comprising 44.5 Mt of rice straw and 24.5 Mt of wheat straw, are burned annually.

Rice straw is particularly well-suited for use as an organic supplement due to its average nutrient composition, which includes approximately 0.9% nitrogen (N), 0.2% phosphorus (P), 0.2% sulfur (S), 2.5% potassium (K), 0.6% calcium (Ca), 7.0% silicon (Si), and 40% carbon (C) (Ponnamperuma et al., 1982).

# Rice straw serves as a valuable organic amendment owing to its moderate nutrient content, typically comprising around 0.9% nitrogen, 0.2% phosphorus, 0.2% sulfur, 2.5% potassium, 0.6% calcium, 7.0% silicon, and approximately 40% carbon. Its widespread use is further supported by on-site availability, with seasonal dry matter yields ranging from 2 to 5 tons per hectare, and its potential to address challenges related to straw disposal. The approach to rice straw management varies depending on soil type, crop characteristics, and environmental conditions, encompassing practices such as field removal, burning, heaping, surface spreading, soil incorporation, or mulching for subsequent dryland crops. In tropical agroecosystems, extensive research has focused on optimizing straw utilization strategies.

# **Materials and Methods**

### **Experimental Site and Duration**

A field experiment was carried out during the Rabi season of 2024–2025 at the Student Instructional Farm of Acharya Narendra Deva University of Agriculture and Technology (ANDUAT), located in Kumarganj, Ayodhya, Uttar Pradesh, India. The study area lies within a semi-arid agroecological zone and is characterized by loam to silty loam soils. The initial soil properties were as follows: pH 7.9, bulk density 1.35 Mg m⁻³, and electrical conductivity (EC) 3.23 dS m⁻¹. The soil contained 0.23% organic carbon, with available nitrogen, phosphorus, and potassium levels of 115.14, 15.24, and 107.26 kg/ha, respectively

**Land preparation**

After the harvest of the preceding crop, the experimental field was deep-tilled to a depth of 20 cm using a tractor-mounted soil-turning plough. The field was then divided into three replications, with each replication further split into ten experimental plots. Five days after the initial tillage, a second ploughing was carried out using a tractor-drawn cultivator. According to the treatment plan, rice straw was either completely removed from certain plots or evenly spread in situ at a rate of 5 tonnes per hectare in others. In the straw incorporation plots, the residue was mixed into the soil 30 days before sowing using a traditional plough for preliminary incorporation, followed by a tractor-drawn disc plough to ensure thorough mixing and proper field leveling. The plots designated for straw removal were prepared similarly, except that no straw was added. Fifteen days after these operations, the field was laid out into individual plots by carefully constructing bunds, ensuring the original experimental design remained undisturbed before sowing the crop.

**Soil and Microbial Analysis**

The pH of the crop residue samples was determined through analysis EC, and microbial counts of bacteria, fungi, and actinomycetes using the serial dilution and plate count method on selective media (Nutrient agar, Rose Bengal agar, and Actinomycetes isolation agar). Soil samples were collected at 0–15 cm depth before sowing and after harvest to determine soil pH, EC, available N (alkaline KMnO₄ method), P (Olsen’s method), K (Flame photometry), organic carbon (Walkley and Black, 1934), microbial biomass carbon (chloroform fumigation extraction), and dehydrogenase activity (Casida *et al*., 1964).

### **Data Collection**

Plant growth and yield-related observations (number of effective tillers m-2, number of grains spike-1, spike length) were recorded at regular growth stages (30, 60, 90 DAS, and harvest). Microbial data from crop residue and soil were assessed at fermentation stages and at crop harvest, respectively.

### **Statistical Analysis**

# All collected experimental data were analyzed using analysis of variance (ANOVA) based on a Randomized Block Design (RBD) with the help of SPSS software (Version 26.0). Treatment means were compared using the Critical Difference (CD) test at a 5% significance level.

# **Results and Discussion**

**1.Dynamics of Microbes in crop residue.**

The microbial population (bacteria, fungi, and actinomycetes) in crop residue incorporation increased (Table-1). The maximum microbial population was observed in.T10-N (150) +Consortium(N+P+K) @5 t/ha Residue (bacteria: 13.95×106 cfu g-1 soil, fungi: 10.56×106 cfu g-1 soil, actinomycetes: 13.35×106 cfu g-1 soil).     The increased population of bacteria, fungi and Actinomycetes due to the application of inorganic fertilizer and organic manure might be due to the gradual exhaustion of assimilable organic nutrients from compost and crop residue by various soil microorganisms. Bharadwaj and Oman war (1992). in chili, who have also reported a higher beneficial microbial population and the beneficial effect of Jeevamrut in enhancing the microbial load in the rhizosphere region.

#### **Biological Properties**

The data indicated that soil dehydrogenase activity was significantly influenced by different treatment combinations (Table 1). The highest dehydrogenase activity (91.57 µg TPF g⁻¹ soil day⁻¹) was recorded under treatment T10 – N (150 kg/ha) + Consortium (N + P + K) + 5 t/ha residue. This was statistically followed by T9 (89.52 µg TPF g⁻¹ soil day⁻¹), which included N (120 kg/ha) + Consortium + 5 t/ha residue, and T8 (84.58 µg TPF g⁻¹ soil day⁻¹). Among the remaining treatments, these were superior. The lowest dehydrogenase activity (62.74 µg TPF g⁻¹ soil day⁻¹) was recorded in the control treatment (T1). The enhanced enzyme activity may be attributed to increased microbial proliferation due to the gradual decomposition of rice straw, which provides substrates and improves soil organic matter. This, in turn, supports microbial community development. Conversely, reduced dehydrogenase activity could be linked to fluctuations in temperature during the crop growth period. These findings are consistent with those reported by Dhull (2004), Goyal (2009), and Liu (2010). Microbial counts (CFUs of bacteria, fungi, and actinomycetes) increased substantially with higher T10-N (150) +Consortium(N+P+K) @5 t/ha Residue,​ outperforming all treatments. This sustains microbial diversity and biomass is critical for soil nutrient cycling.

**Table 1:** **Effect of crop residue management on soil Bacteria, Fungi and Actinomycetes after harvest of wheat crop.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| tt**Treatments** | **Bacteria****(× 106 cfu g -1)** | **Fungi (×103 cfu g-1)** | **Actinomycetes (× 104 cfu g-1)** |  **Microbial biomass Carbon (µg MBCg-1 soil)**  | **Dehydrogenase (µg TPF g soil-1 day-1)** |
| **T1**- Control | 175.31 | 13.12 | 230.11 | 156.72 | 62.74 |
| **T2**- N (40) + @5 t/ha Residue  | 200.19 | 15.18 | 235.21 | 162.22 | 72.14 |
| **T3**- N (80) + @5 t/ha Residue  | 210.32 | 16.21 | 238.13 | 164.38 | 73.36 |
| **T4-** N (120) + @5 t/ha Residue  | 225.18 | 17.16 | 240.16 | 166.42 | 74.84 |
| **T5**- N (150) + @5 t/ha Residue  | 231.18 | 18.20 | 245.18 | 168.39 | 79.14 |
| **T6**- N (0) +Consortium(N+P+K) @5 t/ha Residue  | 198.38 | 19.25 | 234.25 | 160.24 | 70.38 |
| **T7**- N(40)+Consortium(N+P+K) @5 t/ha Residue | 210.12 | 20.12 | 240.13 | 170.7 | 82.37 |
| **T8**- N (80) +Consortium(N+P+K) @5 t/ha Residue | 220.15 | 21.10 | 250.21 | 174.31 | 84.58 |
| **T9**- N (120) +Consortium(N+P+K) @5 t/ha Residue | 230.03 | 23.13 | 258.25 | 176.23 | 89.52 |
| **T10**- N (150) +Consortium(N+P+K) @5 t/ha Residue | 234.16 | 25.90 | 260.30 | 179.31 | 91.57 |
| **SEm ±** | **0.708** | **0.608** | **0.510** | **0.564** | **0.619** |
| **CD at 5%** | **2.120** | **1.821** | **1.528** | **1.690** | **1.852** |

**2.Growth Characteristics**

**2.1 Count of productive tillers m-2, spike length (cm), and number of grains spike-1.**

The number of effective tillers m-2, spike length (cm), and grains spike-1 were significantly influenced by different crop residue management practices (Table 2). A notable increase in the number of effective tillers was observed, with the highest count (298.29 m⁻²) recorded under treatment T10 – N (150 kg/ha) + Consortium (N + P + K) + 5 t/ha residue. This was followed by treatments in the order: T9 > T8 > T7 > T5 > T4 > T3 > T2 > T6, while the lowest number of tillers was observed in the control (T1). Similarly, the maximum spike length (11.75 cm) was also recorded in T10, followed closely by T9 – N (120 kg/ha) + Consortium + 5 t/ha residue, which was statistically at par. Other treatments followed the order T8 > T7 > T5 > T4 > T3 > T2 > T6, with the shortest spike length recorded in T1. A comparable pattern was seen in the number of grains per spike, where the highest value (48.95) was reported in T10, followed by T9 > T8 > T7 > T5 > T4 > T3 > T2 > T6. The minimum number of grains per spike (40.58) was observed in the control treatment (T1). These findings are consistent with those reported by Meena and Singh (2013), and Kumar (2016).

**Table 2:** **Effect of crop residue management on number of effective tillers (m2), spike length (cm) and number of grain spikes-1 of wheat crop.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| tt**Treatments** | **Effective tiller (m-2)** | **Spike length (cm)** | **Grains spikes-1** | **Test weight (g**) | **Grain Yield** |
| **T1**- Control | 250.21 | 8.06 | 40.58 | 33.05 | 36.40 |
| **T2**- N (40) + @5 t/ha Residue  | 253.40 | 8.98 | 42.19 | 36.70 | 40.68 |
| **T3**- N (80) + @5 t/ha Residue  | 260.12 | 9.75 | 43.65 | 37.38 | 42.79 |
| **T4-** N (120) + @5 t/ha Residue  | 268.38 | 9.99 | 44.45 | 38.67 | 43.82 |
| **T5**- N (150) + @5 t/ha Residue  | 277.21 | 10.18 | 45.25 | 39.21 | 44.62 |
| **T6**- N (0) +Consortium(N+P+K) @5 t/ha Residue  | 252.87 | 8.18 | 41.29 | 34.76 | 38.52 |
| **T7**- N (40) +Consortium(N+P+K) @5 t/ha Residue | 280.38 | 10.69 | 45.89 | 40.72 | 45.21 |
| **T8**- N (80) +Consortium(N+P+K) @5 t/ha Residue | 284.61 | 11.23 | 46.48 | 40.79 | 47.63 |
| **T9**- N (120) +Consortium(N+P+K) @5 t/ha Residue | 292.03 | 11.69 | 47.80 | 40.82 | 48.90 |
| **T10**- N (150) +Consortium(N+P+K) @5 t/ha Residue | 298.29 | 11.75 | 48.95 | 41.12 | 50.78 |
| **SEm ±** | **0.680** | **0.164** | **0.032** | **0.004** | **0.345** |
| **CD at 5%** | **2.038** | **0.490** | **0.096** | **0.011** | **1.034** |

**3. Soil Analysis**

**3.1 chemical properties.**

The maximum decline in soil pH (7.68) was observed with the application of a treatment combination T10- N (150) +Consortium(N+P+K) 5@ t/ha Residue. The differences in declining soil pH in various consortiums and non-consortium treatment combinations were recorded to be​ non-significant. The minimum decline in soil pH was observed in treatment control (T1) (7.79). Incorporation of crop residue also decreased the soil pH over control. Similar outcomes were also reported by Chaudhary (1981), Guled (2002), Dhar (2014), Yang (2015) and Harikesh *et al*. (2017).

The highest soil available nitrogen kg ha-1 (234.16 kg ha-1) was recorded under T10- N (150) +Consortium(N+P+K) @5 t/ha Residue, followed by T9, T8, T7, T5, T4, T3, T6 and T2 and the lowest soil available nitrogen kg ha-1(175.31kg ha-1) was recorded under the control (T1). The subsequent decomposition of these incorporated materials might have resulted in enhancing the organic carbon content of soil as well as soil available nitrogen and attribute the greater multiplication of microbes added through decomposers caused by the conversion of organically bound nitrogen to soil available nitrogen after harvest. The findings of Prasad and Sinha (2000) and Surekha (2004).

The maximum available phosphorus in soil (25.90 kg ha⁻¹) was observed under treatment T10 – N (150 kg/ha) + Consortium (N + P + K) + 5 t/ha residue, followed by treatments T9, T8, T7, T5, T4, T3, T6, and T2. The lowest available phosphorus content (13.12 kg ha⁻¹) was recorded in the control treatment (T1). The application of nitrogen along with a microbial consortium likely facilitated the decomposition and mineralization of crop residues, thereby enhancing phosphorus availability in the soil. The release of organic acids during residue decomposition may have contributed to the mobilization of both native and applied phosphorus. These findings are in agreement with those reported by Dhull (2004), Gupta (2007).

#### The highest available potassium content in the soil (260.30 kg ha⁻¹) was recorded under treatment T10 – N (150 kg/ha) + Consortium (N + P + K) + 5 t/ha residue, followed by treatments T9, T8, T7, T5, T4, T3, T6, and T2. The lowest available potassium level was observed in the control treatment (T1). The enhanced potassium availability can be attributed to the decomposition of crop residues, during which organic acids are released. These acids facilitate the mineralization of fixed potassium, thereby increasing its availability in the soil. Similar results have been reported by Yaduvanshi, Sharma, and Kumar et al. (2007)

**Table 3:** **Effect of crop residue management on soil pH, EC (dSm-1) and OC (g kg-1) in soil following harvest of wheat crop.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  **Treatments** |  **pH (1:2.5)** |  **EC****(dS m-1)** |  **OC** **(g kg-1)**  |  **Available N kg ha-1** |  **Available P kg ha-1** |  **Available K kg ha-1** |
| **T1**- Control | 7.79 | 0.19 | 3.50 | 175.31 | 13.12 | 230.11 |
| **T2**- N (40) + @5 t/ha Residue  | 7.73 | 0.14 | 3.74 | 200.19 | 15.18 | 235.21 |
| **T3**- N (80) + @5 t/ha Residue  | 7.62 | 0.14 | 3.80 | 210.32 | 16.21 | 238.13 |
| **T4-** N (120) + @5 t/ha Residue  | 7.66 | 0.16 | 3.81 | 225.18 | 17.16 | 240.16 |
| **T5**- N (150) + @5 t/ha Residue  | 7.72 | 0.18 | 3.83 | 231.18 | 18.20 | 245.18 |
| **T6**- N (0) +Consortium(N+P+K) @5 t/ha Residue  | 7.77 | 0.14 | 3.73 | 198.38 | 19.25 | 234.25 |
| **T7**- N (40)+Consortium(N+P+K) @5 t/ha Residue | 7.73 | 0.14 | 3.86 | 210.12 | 20.12 | 240.13 |
| **T8**- N (80) +Consortium(N+P+K) @5 t/ha Residue | 7.73 | 0.15 | 3.90 | 220.15 | 21.10 | 250.21 |
| **T9**- N (120) +Consortium(N+P+K) @5 t/ha Residue | 7.65 | 0.14 | 3.91 | 230.03 | 23.13 | 258.25 |
| **T10**- N (150) +Consortium(N+P+K) @5 t/ha Residue |  7.68 |  0.13 |  3.93 | 234.16 | 25.90 | 260.30 |
| **SEm ±** |  **0.041** |  **0.012** |  **0.13** | **0.708** | **0.608** | **0.510** |
| **CD at 5%** |  **NS** |  **NS** |  **NS** | **2.120** | **1.821** | **1.528** |

# **Conclusion**

The results of the study clearly highlight the positive impact of integrating crop residue incorporation with a biofertilizer consortium—comprising nitrogen-, phosphorus-, and potassium-solubilizing microorganisms—alongside appropriate nitrogen fertilization on soil health and wheat productivity in partially reclaimed sodic soils. Among the ten treatment combinations, T10 (150 kg N/ha + consortium + 5 t/ha rice straw) consistently outperformed others, showing significant enhancements in plant growth parameters, nutrient availability (N, P, K), and key soil biological properties such as microbial biomass carbon and enzymatic activities, including dehydrogenase and phosphatase. The improved microbial activity and enhanced nutrient mineralization observed under T10 not only contributed to higher crop yields but also led to improved soil quality indicators. These findings support the concept of sustainable and integrated nutrient management. This combined approach offers a viable strategy for rehabilitating degraded sodic soils while enhancing crop productivity and sustaining long-term soil fertility.

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# **References**

1. Mandal, K.G., Misra, A.K., Hati, K.M., Bandyopadhyay, K.K., Ghosh, P.K. and Mohanty, M. 2004. Rice residue management options and their effects on soil properties and crop productivity. *Journal of Food, Agriculture and Environment*, 2, 224–231Ministry of New and Renewable Energy (MNRE). 2009. Biomass power and cogeneration programme. *Annual Report 2008–2009*. Government of India.
2. Ponnamperuma, F.N. (1984). Straw as a source of nutrients for wetland rice. In *Organic Matter and Rice* (pp. 117–136). *International Rice Research Institute, Philippines.*
3. Walkley, A., & Black, I.A. (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science*, 37(1), 29–38. <https://doi.org/10.1097/00010694-193401000-00003>
4. Jackson M L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi, 498 p.
5. Casida L E Jr, Klein D A and Santoro T. 1964. Soil dehydrogenase activity. *Soil Science* 98(6): 371–376. https://doi.org/10.1097/00010694-196412000-00001
6. Meena, V.S., Maurya, B.R., Meena, R.S. 2013. Residual Impact of wellgrow formulation and NPK on growth and yield of wheat (*Triticum aestivum* L.). Bangladesh J. Bot. 44(1): 143-146.
7. Dhar, D., Datta, A., Basak, N., Paul, N., Badole, S., and Thomas, T. 2014. Residual effect of crop residues on growth, yield attributes and soil properties of wheat under rice- wheat cropping system. Indian Journal. *Agricultural Research*, 48 (5): 373-378.
8. Yang. Y., Shaoqiang Ma, Zhao, Y., Jing, M., Xu, Y. and Chen, J. 2015. A Field Experiment on Enhancement of Crop Yield by Rice Straw and Corn Stalk Derived Biochar in Northern China. *Sustainability*, 7: 13713-13725.
9. Guled, M. B., Gundhur, S. S., Hiremath, K.A., Surkod, V. S. and Balanagoudar, S. R. 2002. Effect of organic and inorganic fertilizer on soil physical and chemical properties of vertisol under rainfed conditions. *Karnataka Journal of Agricultural Science*, 15(3): 509-513.
10. Harikesh, Ali, A., Singh, G., Kumar, S., Shivam, Yadav, R.P., Tiwari, A., Kumar, A. and Yadav, A. 2017. Effect of integrated nutrient management and plant geometry on soil properties and availability of nutrients under SRI technique of rice. *Journal of Pharmacognosy and Phytochemistry,* 6(5): 86- 89
11. Prasad, R., Gangaiah, B. and AIPE, K. C. 1995. Effect of crop residue management in a rice- wheat cropping system on growth and yield of crops and on soil fertility. *Expel Agric;* volume 35:427±435.
12. Surekha, K., Reddy, M.N., Rao, K.V. and STA Cruz, P.C. 2004. Evaluation of crop residue management practices for improving yields, nutrient balance and soil health under intensive rice – rice system*. Journal of Indian Society of Soil Science*, 52(4): 448-453.
13. Dhull, S.K., Goyal, S., Krishan, K.K. and Molo, C.M. 2004. Microbial biomass carbon and microbial activities of soils receiving chemical fertilizers and organic amendments. *Archives of Agronomy and Soil Science* 50: 641-647.
14. Gupta, R. K., Singh, Y., Ladha, J.K., Singh, B., Singh, J., Singh, G. and Pathak, H. 2007. Yield and Phosphorus transformation in a rice-wheat system with crop residue and phosphorus management. *Soil Science Society of American Journal*, 71: 1500-1507.
15. Yaduvanshi, N. P. S. and Sharma, D. R. 2007. Utilization of wheat residues and organic manures to improve nutrient availability and boost rice–wheat system yields in sodic soils irrigated with sodic water irrigation. *Journal of Indian Society of Soil Science*, 55(3): 330-334.
16. Dhull, S.K., Goyal, S., Krishan, K.K. and Mool, C.M. 2004. Microbial biomass carbon and microbial activities of soils receiving chemical fertilizers and organic amendments. *Archives of Agronomy and Soil Science* 50: 641-647.
17. Sisodiya, R. R., Vasave, J. B., & Naik, J. R. (2023). Crop Residues Management: A Viable Tool for Sustainable Agriculture. International Journal of Plant & Soil Science, 35(19), 1750–1754. https://doi.org/10.9734/ijpss/2023/v35i193724