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EFFECTS OF CROP RESIDUE AND NUTRIENT SOURCES (ORGANIC AND INORGANIC) ON SOIL PHYSICO-CHEMICAL PROPERTIES UNDER RICE - WHEAT CROPPING SYSTEM IN *MOLLISOL* OF THE TARAI REGION OF UTTARAKHAND INDIA

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ABSTRACT

The experiment was carried out during *kharif* and *rabi* seasons of 2020-21 at Norman E. Borlaug Crop Research Centre of the Govind Ballabh Pant University of Agriculture and Technology, Pantnagar. The experiment was laid out in RBD and replicated three times with ten treatments. Findings indicated that the incorporation of wheat residue in rice crop and rice residue in wheat crop, combined use of inorganic fertilizer with organic sources (FYM, GM) significantly influences the soil Physico-chemical properties of rice at (0-15 cm soil) i.e. bulk density varied from 1.24 to 1.35 Mg m^{-3}, soil pH 7.22 to 7.45, EC ranged from 0.29 to 0.37 dSm^{-1}, and Organic carbon (0.79 to 0.94 %). Available N in the soil varied from 207.54 to 261.65 kg ha^{-1}, P_2O_5 10.89 to 19.32 kg ha^{-1} and K_20 162.89 to 207.89kg $ha^{-1,}$ significantly influenced as compared to the absolute control. After harvesting of the wheat crop bulk density varied from 1.24 to 1.35 Mg m^{-3}, soil pH 7.23 to 7.46, EC ranged from 0.29 to 0.37 dSm^{-1}, and Organic carbon (0.79 to 0.96 %). Available N in the soil varied from 207.89 to 254.55 kg ha^{-1}, P_2O_5 10.99 to 20.88.32 kg ha^{-1} and K_20 162.25 to 208.94 kg ha^{-1}. Similar findings were observed under the sub-surface soil (15-30 cm). It is concluded rice and wheat residue incorporation with a combination of inorganic and organic sources significantly improves the soil physical and chemical properties and nutrient status in general.
***Keywords*:** Crop Residue, Nutrient Sources, Soil Physico-Chemical Properties, Rice - Wheat Cropping System.

Introduction

One of the most widely adopted agricultural systems, like the rice-wheat cropping system, is globally crucial for food security. (Shah *et al*., 2025). According to the Ministry of Agriculture & Farmers Welfare, Government of India (2024-2025), the total area under rice cultivation is 47.832 million hectares, with a production of 136.444 million tonnes, resulting in an average productivity of 2838 kg per hectare. The total area under wheat cultivation in India during the 2024-2025 period was 32.606 million hectares, with a production of 115.430 million tonnes, resulting in an average productivity of 3541 kg per hectare.

About 85% of the rice-wheat cropping system is practiced in Indo-Gangetic plain in south Asia (Banjara *et al.*, 2021). For the past 55-60 years, rice - wheat has been the main farming pattern in India's indo-gangetic plains with guaranteed irrigation. Uttar Pradesh, Punjab, and Haryana are the three most important RWCS-growing states in India, accounting for over 10 million hectares mha of the total indo-gangetic plains region (Kaur *et al.*, 2021). Rice in Uttarakhand cultivated in an area of about 2,43,666 hectare with total production of 5,74,963 metric tons and productivity of 23.60 q ha^{-1}, where wheat is grown in area of about 3,07,452 hectare with the production of 9,27,657 metric tons, having productivity 30.17 q ha^{-1}.

Generally, it has been estimated that rice-wheat system yielding 7 t ha^{-1} rice and 4t ha^{-1} wheat respectively, extract more than 300 kg N, 30 kg P, and

300 kg K ha^{-1} from the soil (Singh and Singh, 2001). Gupta *et al.* (2002) had estimated about 730 kg NPK removed from the soil by the crop yielding 10 t ha^{-1} never returned back to soil. This practice in a long run might be a reason of net negative balance and multi-nutrient deficiencies in crops. To minimize negative balance of nutrients the recycling of nutrients through incorporation of crop residue could be the better option.

The crop residues are plant pieces left after harvest. Earlier, these materials were considered as waste that needed to be disposed of, but it is now widely acknowledged that they are valuable natural resources of plant nutrients rather than waste (Mandal *et al*., 2004). Crop residues are crucial components for the sustainability of agricultural ecosystem as they are good source of plant nutrients and must be recycled properly. Crop residues retain about 25% of nitrogen (N) and phosphorus (P) intake, 50% of sulphur (S), and 75% of potassium (K) uptake by cereal crops, making them excellent nutritional sources, if recycled. Rice and wheat are both voracious eaters, and the double cropping technique depletes the soil's nutritional level significantly (Singh and Singh, 2001).

Rice residue is valuable natural resources, and their recycling in soil improves the physical, chemical, and biological properties of the soil. Burning, incorporation, surface retention, mulching, as well as baling and removal of the straw are all alternatives for management of crop residue. Burning resulted in significant losses of nitrogen (up to 80%), phosphorus (25%), potassium (21%), and sulphur (40-60%), as well as air pollution (@ CO_2 13 t/ha) and depletion of organic matter in soils (SOM). One of the major concerns or sustainability is the loss of soil organic matter. Soil organic matter, soil N, P, and K levels increase as a result of incorporation of crop residue. The immobilization of N is a key disadvantage of incorporation of residue, compared to burning, N at 15-20 kg/ha as a starting dose with straw incorporation boosts wheat and rice yield (Chauhan *et al.,* 2012).

Residue management is a new challenge for Indian agriculture's long-term growth and environmental protection. Out of the 620 mt of crop residues produced in the country each year, 234 mt is surplus, with rice and wheat accounting for 30% of the total. Rice and wheat contribute 62 percent of total crop residue burnt, accounting for approximately 16 percent of total crop residue burnt. We currently lack a viable and systematic approach to deal with crop residues. As a result, the vast majority of farmers follow burning of rice residue in the field, which resulted in massive nutrient loss as well as deterioration of the environment and human health. The primary forces driving residue burning are harvesting through mechanized way like combiner, and slow decomposition rate of residue due to higher silica content, lack of sensitization to farmers for its proper use, no resting period between two crops i.e. intensive cropping system, and very less alternative use of rice straw.

Loose straw can cause problem in timely sowing and seed germination, so farmers are compelled to burn straw because it takes little time to handle in order to assure smooth sowing of the following crop in standing stubble. Field burning of crop residues was not given much attention by policymakers in the last two decades because it was done on a small scale, but now it is recognized as a major source of environmental pollution and global warming that has a direct impact on human health. Punjab, Haryana, Western Uttar Pradesh, and Delhi suffer from severe pollution after harvesting and burning paddy residue and thus decreasing soil fertility (Singh *et al.,* 2019).

The Indian Agriculture Research Institute recently developed a microbial cocktail called "Pusa Decomposer" which can decompose residues into compost such as through accelerated decomposition. It entails creating a liquid formulation with decomposer capsules, fermenting it, and then spraying stubbles on the field to ensure faster decomposition. Microbial agents in the capsule or solution help lighten the straw, break down its molecular components, and release nutrients in to field. (Ranjan and Sow, 2021).

Rice crop residues are abundant in silica, and they have the potential to change the electrochemical characteristics of acidic soils, reducing P fixation while boosting base retention and raising pH. Incorporating rice straw with organic manure boosts crop yield and improves soil physical condition. Microbial activity is higher when residues are incorporated rather than removed or burned. Due to greater resource use efficiency and soil health, continual rice residue inclusion increased wheat output by 34.89 percent over residue burning throughout the course of the 13-year experiment (Mandal *et al*., 2004). Prudent crop residue management is particularly important for maintaining soil fertility and recycling soil nutrients. A crop residue management not only improves soil productivity and nutritional status, but it also improves the health of farm animals (Kumar *et al*., 2021). Crop residue incorporation along with green manuring has been reported to have greater influence over crop yield and enrichment of soil physico-chemical and biological properties by several researchers at different locations in India and abroad, Mandal *et al.* (2004), Samra *et al.* (2003). The potential of recycling crop residues as an important source of plant nutrients for crop production and means for improving soil properties for sustained crop production is enormous. This can only be achieved with better management of soil and crop residues, which affect the decomposition of residues and nutrient release process (Kumar and Goh, 2000).

In the short-term, incorporation of plant residues provides the energy and nutrients for microbial growth and activity, acts as a driving force for the mineralization-immobilization processes in the soil and is a source of nitrogen (N) for plants (Jansson and Persson, 1982). Thus, residue management in rice and wheat cropping system is very important not only for good productivity but also for other issues related to air pollution and maintenance of soil fertility and farmer wellbeing.

Materials and Methods

The present study was carried out at Norman E. Borlaug Crop Research Centre Pantnagar. It has a latitude of 29^o N, a longitude of 79^o 29' E, and an elevation of 243.84 m, above mean sea level. Climate of Pantnagar is sub-humid and sub-tropical, with hot and dry summers and cold winters. It is in the Tarai region, and the dry season lasts from early October to mid-June, and the wet season lasts from mid-June to early October. The maximum temperature ranges between 40 and 45^o C in May and June, and minimum 2 to 5^o C in December and January. The average relative humidity is highest in July and lowest in April and May. The average annual rainfall is 1400 mm, with the majority coming from the south-west monsoon, with 85-90 percent falling between June and September. The soil at the experimental location is alluvial in origin and characterized as Mollisol (Deshpande *et al*., 1971). The soils are well-drained to poorly-drained, dark in colour, and formed beneath calcareous alluvium out wash of the Shivalik range of mountains. The experimental soils come under mollisol order and silty clay soil texture, soil having pH 7.3, Electrical conductivity 0.28 dS m^{-1} soil organic carbon (SOC) 0.75 %, soil, alkaline potassium permanganate ($KMnO_4$) – hydrolyzable nitrogen (N) 196 kg ha^{-1}, 0.5 M sodium bicarbonate ($NaHCO_3$) (pH 8.5) - extractable phosphorus (P) 10.21 kg ha^{-1}, and 1 N ammonium acetate (pH 7.0) – extractable potassium (K) 160.35 kg ha^{-1}.

For rice and wheat crop the different treatments combination were, T_1: 100 % RDF (NPK), T_2: 50 % residue + 50 % RDF, T_3: 50 % residue + 50 % RDF + Pusa decomposer, T4: 50 % residue + 50 % GM/GLM (Rice) / 50 % residue (Wheat), T5: 50 % residue + 50 % GM/GLM + Pusa decomposer (Rice) / 50 % residue + Pusa decomposer (Wheat), T_6: Residue @2.5 tones per acre + Pusa Decomposer, T_7: Residue @2.5 tones per acre + No Pusa Decomposer, T_8: Absolute Control, T_9: 150 % RDF (NPK) and T_{10}: 100 % RDF +FYM@ 5t/h +Zn+B, these treatments are same for both crop rice and wheat except T_4 and T_5 in these treatments green manuring was not used in case of wheat crop.

Soil bulk density, pH, EC, organic carbon, available nitrogen, phosphorus and potassium were all determined using soil samples.

Sources of Nutrients and Their Composition and Rate of Application.

Inorganic sources of nutrients

S. No.	Nutrient	Nutrient Source
1.	Zinc	$ZnSO_4$ @ 25 kg ha^{-1}
2.	Boron	Borax @ 5 kg ha^{-1}
3.	Nitrogen	Urea
4.	Phosphorous	SSP
5.	Potassium	MOP

Application of Organic Manures and Fertilizers

Before incorporation, the N, P, and K content of organic matter, such as residue, FYM, and Sesbania, was analysed. Sesbania was sown in April each year without fertiliser. Nitrogen, phosphorus, and potassium were provided by urea, single super phosphate, and muriate of potash as per the treatments, respectively. As a basal dose, one-third of the nitrogen and the complete amount of phosphorus and potassium were used. The remaining two-thirds of the nitrogen was applied in two equal portions. Fertilisers were appropriately incorporated into the soil in each plot as per the treatment and layout plan. No GLM was applied in T4 and T5 treatments in wheat.

Preparation of Pusa decomposer formulation

The Indian Agriculture Research Institute recently launched the "Pusa Decomposer" microbial mixture, which has the ability to increase the decomposition of residues into compost. For processing the solution 25 liters of water is boiled with 150 grams of jaggery, which helps in fungal multiplication. After this mixture is cooled, 50 grams of besan (or gram flour) is added to it along with Pusa 'decomposer' capsules. Then the solution is covered with a thin piece of cloth and left in a dark room for four days. On the fourth day, a thick growth of fungi will be seen on the top of the solution. This is mixed well and the solution is ready for use. Maheshwari *et al.* (2020):(Ranjan and Sow., 2021)

Collection and Processing of Soil Samples

Soil samples were collected using an auger at 0-15 cm and 15-30 cm. depths. The samples were air dried in the shade and crushed with a hardwood roller, sieved with a 2 mm sieve and stored in a labeled polythene bag for further analysis work.

Soil Analysis

The processed soil samples were subjected to chemical analysis, The following standard methods used to make analyze the soil samples. Soil physical properties, Soil texture was determined using the Bouyoucos hydrometer method (Bouyoucos,1936), Bulk density was determined using the dried mass and volume of the soil sample (Blake and Hartage, 1986), Soil reaction (pH) was determined in a 1:2 soil and water suspension using a glass electrode on a microprocessor-based pH meter, as described by Jackson (1967), Soil electrical conductivity (EC) was determined with the help of conductivity meter in 1:2 Soil: water suspension (Bover and Wilcox, 1965), Soil organic carbon was determined by modified Walkley and Black method (1934) as described by Jackson (1967), Available nitrogen was determined by alkaline $KMnO_4$ method(Subbiah and Asija, 1956) as described by Jackson (1973), Available phosphorus was determined by Olsen's method (Olsen *et al.*,1954) as described by Jackson (1973), Available potassium was determined by neutral normal ammonium acetate (NH4OAc) method as described by Jackson (1973). The data sets were analyzed using analysis of variance in compliance with the randomised block design, using the least significant difference as described by Gomez and Gomez (1984).

Result and Discussion

Physical Properties

Bulk density

Bulk density (Table 1) showed non-significant differences among treatments at both surface (0–15 cm) and sub-surface (15–30 cm) soil layers. Bulk density ranged from 1.24 Mg m^{-3} (T5/T3) to 1.35 Mg m^{-3} (T8-control). Lower bulk density under residue and green manure treatments may be attributed to increased organic matter, improved soil aggregation, and higher porosity, whereas higher bulk density in control plots was due to absence of organic inputs. Bulk density increased with soil depth due to comparatively lower organic matter and greater compaction in sub-surface soil. Similar findings were reported by Sarkar *et al*. (1997).

Chemical Properties

Soil pH

Soil pH differed significantly among treatments at both depths. After rice harvest, pH varied from 7.22 (T5) to 7.45 (T8), while after wheat harvest it ranged from 7.23 (T3) to 7.46 (T8). Lower pH under organic treatments may be due to release of organic acids during decomposition of crop residues and green manure. Continuous addition of organic inputs reduced soil pH compared to control and inorganic fertilizer treatments. Similar findings were reported by Kharub *et al.* (2003) and Bahadur *et al*. (2013).

Soil Electrical Conductivity (EC)

Soil EC varied significantly among treatments. After rice harvest, EC ranged from 0.29 dS m^{-1} (T8) to 0.37 dS m^{-1} (T5), while after wheat harvest it ranged from 0.29 dS m^{-1} (T8) to 0.37 dS m^{-1} (T3). Higher EC values under integrated nutrient treatments may be due to addition of soluble salts from fertilizers and decomposition of organic residues, which increased availability of soluble ions such as Ca, Mg, K, and Na. Similar trends were reported by Gangola *et al.* (2012) and Gogoi *et al*. (2015).

Soil Organic Carbon (SOC)

SOC showed significant improvement under crop residue incorporation with organic and inorganic nutrient sources. After rice harvest, SOC ranged from 0.79% (T8) to 0.94% (T5), while after wheat harvest it ranged from 0.79% (T8) to 0.96% (T3). Higher SOC in T5 and T3 may be attributed to addition of green manure (dhaincha) having a narrow C : N ratio, which increased the availability of nutrients in comparison to other residue treatment and application of Pusa decomposer, which enhanced residue decomposition and microbial activity, leading to greater carbon accumulation. Control plots showed lowest SOC due to absence of organic inputs. Higher SOC in surface soil compared to sub-surface soil may be due to greater root biomass, crop residues, and microbial activity near the soil surface. Raju and Reddy (2000) revealed that organic carbon status decreased in the control plots, and more organic carbon was found in the straw-incorporated plots than in the normally fertilized plots. This might be due to the growth of micro-flora that feed on the residue/GM, resulting in mineralization of the added residue in the availability of N-fertilizers and C sequestration. Sharma and Sharma (2005) reported that incorporation of rice, wheat, or both crop residues increased soil organic C in the top 15 cm soil layer after 2 years (four crops) in comparison with both the initial soil organic carbon. The SOC content of surface soil was higher than that of subsurface soil due to the greater addition of root biomass, root exudates, and plant biomass, and it decreased with depth, possibly due to organic amendments that provide root biomass, exudates, and plant residues.

Table 1 : Effect of crop residue incorporation along with organic and inorganic nutrient sources on soil physicochemical properties.

Treatments	After harvesting of rice Bulk density (Mg m^{-3})		After harvesting of wheat Bulk density (Mg m^{-3})		After harvesting of rice Soil pH		After harvesting of wheat Soil pH		After harvesting of rice Soil EC (dS m^{-1})		After harvesting of wheat Soil EC (dS m^{-1})		After harvesting of rice Soil OC (%)		After harvesting of wheat Soil OC (%)	
	0-15 cm	**15-30 cm**	**0-15 cm**	**15-30 cm**	**0-15 cm**	**15-30 cm**	**0-15 cm**	**15-30 cm**	**0-15 cm**	**15-30 cm**	**0-15 cm**	**15-30 cm**	**0-15 cm**	**15-30 cm**	**0-15 cm**	**15-30 cm**
	1.31	1.34	1.32	1.35	7.32	7.38	7.32	7.36	0.33	0.35	0.33	0.36	0.83	0.77	0.82	0.76
T_1	1.27	1.3	1.25	1.29	7.25	7.31	7.23	7.3	0.34	0.36	0.36	0.38	0.88	0.82	0.95	0.86
T_2	1.26	1.3	1.24	1.28	7.24	7.3	7.23	7.29	0.35	0.37	0.37	0.39	0.9	0.84	0.96	0.9
T_3	1.25	1.29	1.27	1.31	7.23s	7.31	7.29	7.35	0.36	0.38	0.36	0.37	0.92	0.86	0.91	0.85
T_4	1.24	1.28	1.26	1.3	7.22	7.28	7.27	7.34	0.37	0.39	0.35	0.36	0.94	0.88	0.92	0.86
T_5	1.29	1.34	1.26	1.3	7.26	7.32	7.31	7.39	0.33	0.35	0.34	0.36	0.84	0.78	0.87	0.81
T_6	1.3	1.33	1.27	1.31	7.27	7.34	7.33	7.41	0.32	0.34	0.33	0.35	0.82	0.76	0.86	0.8
T_7	1.35	1.36	1.35	1.37	7.45	7.52	7.46	7.53	0.29	0.3	0.29	0.31	0.79	0.73	0.79	0.74
T_8	1.33	1.35	1.33	1.36	7.3	7.38	7.31	7.37	0.33	0.35	0.34	0.36	0.82	0.76	0.81	0.73
T_9	1.27	1.31	1.26	1.3	7.24	7.3	7.23	7.57	0.32	0.34	0.33	0.35	0.87	0.81	0.9	0.84
T_{10}	**0.02**	**0.02**	**0.02**	**0.02**	**0.03**	**0.04**	**0.02**	**0.04**	**0.01**	**0.01**	**0**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
SEm ±	**NS**	**NS**	**NS**	**NS**	**0.09**	**0.11**	**0.07**	**0.13**	**0.02**	**0.02**	**0.01**	**0.02**	**0.04**	**0.04**	**0.02**	**0.04**
C.D.at 5%	**1.37**	**1.39**	**1.37**	**1.39**	**7.51**	**7.66**	**7.51**	**7.66**	**0.28**	**0.3**	**0.28**	**0.3**	**0.75**	**0.71**	**0.75**	**0.71**

Notes:- T_1: 100 % RDF (NPK), T_2: 50 % residue + 50 % RDF, T_3: 50 % residue + 50 % RDF + Pusa decomposer, T4: 50 % residue + 50 % GM/GLM (Rice) / 50 % residue (Wheat)T5: 50 % residue + 50 % GM/GLM + Pusa decomposer (Rice) / 50 % residue + Pusa decomposer (Wheat), T_6: Residue @2.5 tones per acre + Pusa Decomposer, T_7: Residue @2.5 tones per acre + No Pusa Decomposer, T_8: Absolute Control, T_9: 150 % RDF (NPK) and T_{10}: 100 % RDF +FYM@ 5t/h +Zn^+

Available nitrogen

The data presented in table 2. reveled that significant difference among all the treatments at surface as well as sub surface layer of soil in case of available nitrogen. After harvesting of rice in surface soil (0-15 cm) observed that soil available nitrogen varied from 207.54 kg ha^{-1} (T_8) to 261.65 kg ha^{-1} (T_9). Highest 261.65 kg ha^{-1} soil available nitrogen reported under the treatment T_9, it could be due to the use of higher doses of fertilizer that offer more inorganic forms of nitrogen. While lowest 207.54 kg ha^{-1} available nitrogen shown under the treatment control (T_8). In sub surface (15-30 cm) soil, available nitrogen varied from 199.38 kg ha^{-1} (T_8) to 252.35 kg ha^{-1} (T_9). In same way after harvesting of wheat in surface soil (0-15 cm) observed that soil available nitrogen varied from 207.89 kg ha^{-1} (T_8) to 263.54 kg ha^{-1} (T_9).

Among all the treatments where Pusa decomposer was applied the maximum available nitrogen was observed in T_3, due to application of 50 % RDF and increased rate of decomposition of crop residue by Pusa decomposer. The availability of nitrogen in soil was increased due to organic materials application to attribute the greater multiplication of microbes caused by conversion of organically bound nitrogen to inorganic form. Similar results were reported by Prasad and Sinha (2000). It was found that the amount of nitrogen that is widely available in soil increased after the application of graded doses of NPK fertilizers, such as 100% NPK (T_1) and 150 % NPK (T_9). Similar trend of results was found in subsurface soil, where 100% NPK (T_1) and 150 % NPK (T_9) increased the amount of nitrogen that is readily available in soil over the initial value. Application of organic materials enhanced soil nitrogen availability, which is thought to be the source of the larger bacterial growth followed by the transformation of organically bound nitrogen to inorganic form. Similar results were reported by Surekha *et al.* (2003).

Available phosphorus

The data presented in table 2. revealed that significant difference among the treatments at surface as well as sub surface layer of soil in case of available phosphorus in soil. After harvesting of rice in surface soil (0-15 cm) the available phosphorus varied from 10.89 kg ha^{-1} (T_8) to 20.98 kg ha^{-1} (T_9). Highest 20.98 kg ha^{-1} soil available phosphorus reported under the treatment T_9, it might be due to increased solubility and inorganic fertilizer application which is a readily available source of nutrient as shown by the maximum availability of soil phosphorous. While lowest 10.89 kg ha^{-1} available phosphorus shown under the treatment control (T_8). In sub surface (15-30 cm) available phosphorus varied from 9.87 kg ha^{-1} (T_8) to 19.91 kg ha^{-1}. In same way after harvesting of wheat in surface soil (0-15 cm) the available phosphorus varied from 10.99 kg ha^{-1} (T_8) to 21.26 kg ha^{-1} (T_9). Among all the treatments where Pusa decomposer was applied the maximum available nitrogen was observed in T_3. It might be due to application of nitrogen 50 % RDF could help in increasing the mineralization of the crop residue and thus causing higher available phosphorus in the soil. The solubility action of organic acids produced during degradation of organic matter (crop residue) result in the more release of native and applied phosphorus. Iqbal (2009) evaluated the association between net phosphorous mineralization and phosphorous content, finding that net immobilization increases when phosphorous content is less than 0.07 % and that net phosphorous mineralization increases when phosphorous content is more than 0.24 % during microbial decomposition. Rajneesh *et al.* (2017) concluded that there was more readily available phosphorus in the surface layer than in the subsurface layers. It might be because P compounds in the soil are immobile, and another possible reason is that the surface soil has more organic matter than the subsurface soil.

Available potassium

Significant difference among the treatments at surface as well as sub surface layer of soil in case of available potassium in soil. After harvesting of rice in surface soil (0-15 cm) the available potassium varied from 162.89 kg ha^{-1} (T_8) to 215.26 kg ha^{-1} (T_9). Highest 215.26 kg ha^{-1} soil available potassium reported under the treatment T_9, while lowest 162.89 kg ha^{-1} available potassium shown under the treatment control (T_8). In sub surface (15-30 cm) available potassium varied from 143.56 kg ha^{-1} (T_8) to 193.25 kg ha^{-1} (T_9). In same way after harvesting of wheat in surface soil (0-15 cm) the available potassium varied from 163.25 kg ha^{-1} (T_8) to 217.23 kg ha^{-1}(T_8). Among all the treatments where Pusa decomposer was applied the maximum available nitrogen was observed in T_3. This might be due to the reason that application of crop residue secreted organic acid during process of decomposition which led to mineralization of the fixed potassium and increased the availability of potassium. Similar results were recorded by Yaduvanshi and Sharma (2007).

Plots treated with T_9 and T_1 application showed much potassium that was readily available in comparison to other organically treated plots because potassium from organic sources was released slowly. The lowest value of available K in the control plot may be a result of potassium removal without the addition of any organic or inorganic sources and potassium depletion in the soil. The use of both organic and inorganic potassium sources together helps enhance potassium supply in the early and late stages in plots treated with chemical fertilizers and organic matter, respectively.

Naidu *et al.* (2009) reported that the addition of organic manure directly to the soil and the solubilization of K during the process of the organic matter decomposition increased the amount of potassium that was easily available in the soil after the application of inorganic fertilizers with FYM. Kumar *et al.* (2008) obtained similar results, reported that the application of organic manure released organic acid during the decomposition process, resulting in mineralization of the fixed potassium and increased potassium availability.

Conclusion

During the course of this experiment, the incorporation of rice-wheat residue influenced the soil's bulk density, pH, EC, and available nitrogen, phosphorous, and potassium levels at the surface (0-15) and sub-surface (15-30) soil. In addition to crop residue incorporation, soil organic carbon differs significantly.

Although treatment T_9 having 150 percent RDF was found to be superior to the other treatments, it was comprise of only inorganic nutrient sources, which may not be profitable in the long term. As a result, treatment T_{10} having 100 percent RDF + FYM @ 5t ha^{-1} + Zn @ 25 kg ha^{-1} + B @5 kg ha^{-1} and T_3 having 50% residue + 50 percent RDF + Pusa decomposer might be the best option for maintaining soil health and crop yield. Besides, the inorganic fertilizer sources used in this treatment ensure immediate and easy nutrient availability, but the organic sources ensure long-term nutrient availability and improve soil quality.

Table 2 : Effect of crop residue incorporation along with organic and inorganic nutrient sources on available nitrogen, available phosphorus and available potassium in soil after crop harvesting.

Treatments	After harvesting of rice N (kg ha^{-1})		After harvesting of wheat N (kg ha^{-1})		After harvesting of rice P (kg ha^{-1})		After harvesting of wheat P (kg ha^{-1})		After harvesting of rice K (kg ha^{-1})		After harvesting of wheat K (kg ha^{-1})	
	0-15 cm	**15-30 cm**	**0-15 cm**	**15-30 cm**	**0-15 cm**	**15-30 cm**	**0-15 cm**	**15-30 cm**	**0-15 cm**	**15-30 cm**	**0-15 cm**	**15-30 cm**
T_1	248.54	235.24	250.25	238.98	19.25	18.54	19.89	18.79	200.45	182.54	202.78	189.54
T_2	243.54	232.25	244.2	235.89	17.25	16.87	18.24	17.98	180.25	160.87	177.56	159.65
T_3	245.98	234.58	247.98	237.98	18.12	17.89	19.25	18.21	182.59	163.54	189.65	160.89
T_4	234.56	223.54	236.24	225.45	15.16	14.87	17.23	16.02	174.59	156.35	182.25	163.87
T_5	237.54	227.89	239.78	229.84	16.87	15.89	18.23	16.21	176.32	158.45	185.98	165.89
T_6	231.25	222.98	233.45	224.45	14.21	13.25	15.23	14.01	172.98	153.25	173.21	154.89
T_7	228.54	218.78	229.45	219.54	13.24	12.54	14.23	13.21	170.56	150.54	172.45	153.89
T_8	207.54	199.38	207.89	200.24	10.89	9.87	10.99	9.89	162.89	143.56	163.25	145.89
T_9	261.65	252.35	263.54	254.89	20.98	19.91	21.26	20.12	215.26	193.25	217.23	195.54
T_{10}	252.96	243.54	254.54	245.54	19.32	18.87	20.88	19.32	207.89	190.54	208.94	193.54
SEm ±	**3.49**	**3.56**	**2.96**	**2.91**	**0.23**	**0.26**	**0.25**	**0.28**	**2.83**	**2.25**	**3.36**	**2.41**
C.D.at 5%	**10.36**	**10.56**	**8.81**	**8.64**	**0.7**	**0.79**	**0.74**	**0.82**	**8.42**	**6.68**	**9.98**	**7.16**
Initial value	**196.25**	**188.35**	**196.25**	**188.35**	**10.21**	**9.58**	**10.21**	**9.58**	**160.35**	**142.54**	**160.35**	**142.54**

Notes:- T_1: 100 % RDF (NPK), T_2: 50 % residue + 50 % RDF, T_3: 50 % residue + 50 % RDF + Pusa decomposer, T4: 50 % residue + 50 % GM/GLM (Rice) / 50 % residue (Wheat)T5: 50 % residue + 50 % GM/GLM + Pusa decomposer (Rice) / 50 % residue + Pusa decomposer (Wheat), T_6: Residue @2.5 tones per acre + Pusa Decomposer, T_7: Residue @2.5 tones per acre + No Pusa Decomposer, T_8: Absolute Control, T_9: 150 % RDF (NPK) and T_{10}: 100 % RDF +FYM@ 5t/h +Zn+

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