J. Soils and Crops 33 (2) 361-366, December 2023

ISSN 0971-2836 (Print)
ISSN 2582-2756 (Online)

INFLUENCE OF RICE RESIDUE MANAGEMENT PRACTICES AND VARYING LEVELS OF NITROGEN APPLICATION ON PHYSICO-CHEMICAL PROPERTIES OF SOIL IN WHEAT (*Triticum aestivum* L.)

Gurbir Singh[1], Manpreet Singh[2] and Parminder Kaur[3]

ABSTRACT

With the increase in production of wheat and rice crops, residue production also increased. Farmers started to burn the residues which severely impacted soil health. Therefore, this research was conducted to study the effect of different rice residue management practices and varying levels of nitrogen application on physico-chemical properties of soil at the Students's Research Farm, Department of Agriculture, Khalsa College, Amritsar, Punjab, India, during *rabi* 2021. The field experiment was laid out in a split-plot design, consisting main plot treatments of different rice residue management practices (burnt, removed, and incorporated with waste decomposer) and five subplot treatments of nitrogen levels in wheat (control, 50%, 75%, 100% and 125% Recommended dose of nitrogen fertilizer) and replicated three times. It was observed that the highest value of bulk density at two soil depths (0–15 cm and 15–30 cm) was recorded with rice residue removed *i.e.,* 1.39 and 1.47 g cm^{-3}, respectively. Different treatments had no significant effect on soil pH and EC. The highest value of organic carbon (0.49 and 0.42 %) was observed with rice residue incorporated with the decomposer. No significant increase in soil organic carbon was observed with the nitrogen levels. The available N, P and K was found to be highest in residue incorporated with decomposer and 125% recommended dose of nitrogen fertilizer at soil depths of 0-15 cm and 15-30 cm. The higher values of available zinc (1.35 and 1.09 mg kg^{-1}), soil available iron (19.52 and 8.13 mg kg^{-1}), available copper (0.98 and 0.63 mg kg^{-1}), and available manganese (12.19 and 9.33 mg kg^{-1}) were recorded under rice residue incorporated with a decomposer at both the soil depths of 0–15 cm and 15–30 cm. In treatments of different nitrogen levels, the highest values of all the cationic micronutrients (Zn, Cu, Fe, and Mn) were recorded with 125% recommended dose of nitrogen fertilizer at both soil depths. Rice residue incorporated with decomposer along with 125% RDNF improved soil physico-chemical parameters more than other residue management strategies.

(Key words: Decomposer, incorporation, rice residue management practices, macronutrients, micronutrients, nitrogen levels)

INTRODUCTION

To ensure agricultural output for future generations, continuous cropping systems must maintain and improve soil health. Because more nutrients are being removed from the soil than are being added through inorganic fertiliser, soil fertility is continuously declining. In north-western states of India especially Punjab, Haryana and Western Uttar Pradesh, 90-95% area of rice is followed by wheat crop (Ladha *et al*., 2000). An estimated 686 million tonnes of crop left overs are produced in India each year. Cereals are the crop type that generates the most agricultural leftovers (70%) whereas rice alone accounts for 34% and wheat for 22%. Surface retention, incorporation, mulching and removal of the rice straw are some viable management strategies for rice residue.

A tonne of paddy residue contains 6.1 kg Nitrogen, 0.8 kg phosphorus and 11.4 kg potassium. An entire loss of 79.38 kg ha^{-1} N, 183.71 kg ha^{-1} P and 108.86 kg ha^{-1} K were caused by burning (Lohan *et al*., 2018). Almost 19.7 million metric tons of paddy straw on average produced, of which almost 15.4 million metric tons are set on fire in open fields (Yadav, 2020). After burning the rice residue, the ash that remains on the soil's surface functions as an absorbent, if it is not mixed properly then it reduces the effectiveness of weedicides. Removing residue is a different approach to the residue management. It decreases the amount of organic matter. By eliminating nutrient-rich waste materials, it decreases soil's macronutrients and micronutrients. Removing residues also lowers the carbon content of microbial biomass (Blanco *et al.,* 2006). Soil organic carbon can be preserved by incorporating crop residue into the field (Spiegel *et al*., 2018). Due to the greater C:N ratio of rice straw, inclusion of rice straw in soil right before wheat sowing reduced grain production due to nitrogen immobilisation (Singh *et al*., 2008), but it can be successfully controlled if enough time is allowed between residue

---

1. P.G. Student, P.G. Dept. of Agriculture, Khalsa College, Amritsar-143001, Punjab, India
2. Asstt. Professor, P.G. Dept. of Agriculture, Khalsa College, Amritsar-143001, Punjab, India
3. Asstt. Professor, Dept. of Agriculture, Govind National College, Ludhiana-141203, Punjab, India

incorporation and wheat crop sowing.

The National Centre of Organic Farming (NCOF), in Ghaziabad, Uttar Pradesh created the waste decomposer product. Additionally, the Indian Council of Agricultural Research (ICAR) has approved it. As *in-situ* composting, 200 litres of waste decomposer solution could be used for one acre of crop residue (Kannan, 2020). The waste decomposer microorganism was a superior choice for lignocellulose degradation.

Nitrogen is one of the major nutrient which reduce the yield of wheat if not applied in proper amount as it is needed for fast growth of plants and to get high production hectare^{-1}. Nitrogen play important role in all the metabolic processes of plants. Crop productivity can be enhanced by nitrogen (N) fertilization and diverse/complex cropping systems, these practices may strongly interact and impact soil properties (Metwally and Hefney*,* 2018).

Wheat is an annual plant of gramineae family. Wheat is nutritionally important as it contains protein-28%, fat-3%, total carbohydrates-23%, Potassium-12%, cholesterol-nil. Globally wheat is the leading source of protein in human food because it contains higher protein than other major cereals (Deotale *et al.,* 2019) Keeping this in view the present investigation was initiated to evaluate the physico-chemical properties of soil as influenced by different rice residue management practices and varying levels of nitrogen application on wheat crop.

MATERIALS AND METHODS

The present study was conducted at Students's Research Farm, P.G. Department of Agriculture, Khalsa College, Amritsar, Punjab, India during *rabi* 2021. The geographical coordinates of the experimental site were 31^0 38'19" N and 74^{0}49'50" E and the height above the sea level was 230 m. The soil of experimental site was analysed for various physico-chemical properties before the start of the experiment. The field experiment was laid out in a split-plot design. keeping main plot treatments of different rice residue management practices (burnt, removed, and incorporated with waste decomposer) and five subplot treatments of nitrogen levels in wheat (control, 50%, 75%, 100% and 125%) recommended dose of nitrogen fertilizer and replicated three times. The analysis of the statistical data was done with the help of EDA software. The initial physico-chemical properties of the experimental soil at two depth 0-15 cm and 15-30 cm depicted that soil was sandy loam in texture with bulk density (1.36 g cm^{-3}), (1.46g cm^{-3}) determined by Core sampler method (Prihar and Hundal, 1971), pH (8.4), (8.6) determined by 1:2 soil:water suspension (Jackson, 1967), EC (0.26 dSm^{-1}), (0.24 dSm^{-1}) by 1:2 soil:water supernatant Solubridge conductivity meter (Jackson, 1967), medium organic carbon (0.42 % , 0.38%), which was determined by Walkley and Black's rapid titration method (Piper, 1966), low available N (194.79, 181.27 kg ha^{-1}) by modified alkaline potassium permaganate method (Subbiah and Asija, 1956), medium available P (20.17, 18.04 kg ha^{-1}) by 0.5 N sodium bicarbonate extractable P by Olsen's method (Olsen *et al.,* 1954), medium available K (249.71 kg ha^{-1}), (242.08 kg ha^{-1}) by ammonium acetate extractable K method (Merwin and Peech, 1950) and adequate levels of DTPA cationic micronutrients includes available Zn (1.22, 1.02 mg kg^{-1}), available Cu (0.88, 0.50 mg kg^{-1}), available Fe (16.27, 15.38 mg kg^{-1}), available Mn (10.49, 7.05 mg kg^{-1}) analysed by DTPA extractable method as described by Lindsay and Norwell (1978).

RESULTS AND DISCUSSION

Bulk density

The data presented in Table 1 at two soil depths 0-15 cm and 15-30 cm reveals that rice residue incorporation with decomposer (1.34 and 1.44 g cm^{-3}*)* and rice residue burnt (1.36 and 1.45 g cm^{-3}*)* recorded significantly reduced bulk density over rice residue removed during the experiment. The highest value of bulk density was recorded with rice residue removed *i.e.* (1.39 and 1.47 g cm^{-3}). The incorporation of crop residues decreased the bulk density which might be due to addition of organic matter and subsequent increase in porosity of soil and root growth.

Bulk density was not significantly affected by the nitrogen application but 125% RDNF at both the soil depths recorded highest bulk density (1.38 and 1.47 cm^{-3}), which was at par with 100% RDNF at both the soil depths (1.34 and 1.46 cm^{-3}). Singh (2005) also reported lower bulk density (1.33 g cm^{-3}) in rice residue incorporation as compared to residue removed (1.42 g cm^{-3}) and also recorded non-significant effect of nitrogen levels on bulk density.

Interaction effect of different rice residue management practices with varying levels of nitrogen with respect bulk density was found to be non-significant.

Soil pH

Among residue management techniques incorporation of the rice residues with decomposer records the least pH *viz.,* (8.34 and 8.59) at both the soil depths. Decrease in soil pH with the incorporation of crop residue with decomposer might be due to production of organic acids and release of CO_2 during the decomposition of organic matter. Mandal *et al.* (2004) observed that there was no significant difference recorded in pH among residue management methods.

The pH of soil under different nitrogen levels treatments ranged from 8.25 to 8.34 at soil depth of 0-15 cm and 8.59 to 8.64 in 15-30 cm. However, soil pH recorded after harvest of wheat was not affected significantly due to nitrogen levels during the experiment. Kaur (2020) also found that there was no significant effect of nitrogen levels on soil pH.

Interaction effect of different rice residue management practices with varying levels of nitrogen treatment with respect to soil pH was found to be non-significant.

Table 1. Bulk density, pH, EC and organic carbon of soil as influenced by different rice residue management practices and varying levels of nitrogen application in wheat

Treatments	Bulk density(g cm^{-3})		Soil pH		EC (dSm^{-1})		Organic carbon (%)	
	0-15 cm	**15-30 cm**	**0-15 cm**	**15-30 cm**	**0-15 cm**	**15-30 cm**	**0-15 Cm**	**15-30 cm**
Rice residue management practices								
Burnt	1.36	1.45	8.37	8.62	0.27	0.25	0.43	0.35
Removal	1.39	1.47	8.36	8.60	0.28	0.25	0.37	0.31
Incorporated with decomposer	1.34	1.44	8.34	8.59	0.28	0.28	0.49	0.42
SEm±	0.01	0.006	0.008	0.009	0.003	0.01	0.02	0.02
CD at 5%	0.03	0.02	-	-	-	-	0.06	0.06
Nitrogen levels								
Control	1.34	1.43	8.34	8.64	0.26	0.23	0.42	0.35
50% RDNF	1.36	1.45	8.43	8.62	0.26	0.24	0.43	0.36
75% RDNF	1.36	1.45	8.46	8.60	0.27	0.25	0.45	0.36
100% RDNF	1.37	1.46	8.35	8.59	0.28	0.26	0.46	0.37
125% RDNF	1.38	1.47	8.25	8.59	0.28	0.26	0.46	0.37
SEm±	0.007	0.006	0.03	0.009	0.004	0.005	0.008	0.004
CD at 5%	-	-	-	-	-	-	-	-
Interaction	-	-	-	-	-	-	-	-
SEm±	0.08	0.07	0.17	0.09	0.06	0.07	0.08	0.06
CD at 5%	-	-	-	-	-	-	-	-

RDNF- Recommended dose of nitrogen fertilizer

Soil EC

The data of EC presented in Table 1 indicated that the incorporation of rice residue with decomposer caused slight decrease in the electrical conductivity of soil irrespective of initial value of soil. In case of nitrogen levels electrical conductivity increases with the increase in nitrogen levels in both soil depths but the variation among themselves was non-significant. It might be due to release of organic acids during the organic matter decomposition which might have reacted with $CaCO_3$ to release CO_2. Dhar *et al.* (2014) also observed that rice residue incorporation, burnt and removed showed non-significant effect on EC.

Interaction effect of different rice residue management practices with varying levels of nitrogen treatment with respect to soil EC was found to be non-significant.

Soil organic carbon

Data regarding organic carbon status of soil was differed significantly with rice residue management practices are presented in Table 1. The highest value of organic carbon (0.49 and 0.42 %) at 0-15 cm and 15-30 cm soil depths was observed with rice residue incorporated with decomposer. The lowest value of soil organic carbon was observed in residue removed (0.37 and 0.31%). The soil organic carbon content in incorporation with decomposer plots was increased due to incorporation of organic materials. The subsequent decomposition of these incorporated materials might have enhanced organic carbon content of soil.

No significant increase in SOC was observed with the increase in RDNF levels from control to 125% RDNF. Kaur (2020) reported high Percentage of OC in residue incorporation (0.61%) followed by burning (0.46%) in residue management practices and non-significant effect of nitrogen levels on soil organic carbon.

Interaction effect of different rice residue management practices with varying levels of nitrogen treatment with respect to soil organic carbon was recorded to be non-significant.

Soil available nitrogen

The mean soil available nitrogen was found highest in residue incorporated with decomposer at both the soil depths 0-15 cm and 15-30 cm (212.00 and 198.20 kg ha^{-1}) followed by residue removal (205 and 190.73 kg ha^{-1}) and least in residue burnt (198.60 and 178.07 kg ha^{-1}). Higher N content in rice straw incorporation plots might be due to more biological activities stimulated by addition of microbes by waste decomposer, High 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. Thorat *et al.* (2015) observed significant higher value of available nitrogen in residue incorporation (83 kg ha^{-1}) and least value in residue burnt (21 kg ha^{-1}).

The available nitrogen concentration under 50%, 75%, 100% and 125% of RDNF found significantly higher over the control which was 4.38%, 6.18%, 7.31% and 9.21 % respectively at 0-15 cm soil depth and 5.16%, 8.02%, 12.69%

and 18.15% at 15-30 cm soil depth. Increase in available N content in soil with graded fertilizer level is attributed to higher addition of N in soil. Singh (2005) also reported higher value of available nitrogen in N_{100} (216.35 kg ha^{-1}) followed by N_{50} (211.47 kg ha^{-1}) and least in control (200.28 kg ha^{-1}).

Interaction effect of different rice residue management practices with varying levels of nitrogen treatment with respect to available nitrogen was found to be non-significant.

Soil available phosphorus

In case of residue management practices highest mean of soil available phosphorus at 0-15 cm and 15-30 cm was found in residue incorporated with decomposer (25.80 and 22.83 kg ha^{-1}) and lowest mean value of available phosphorus was found in residue burnt (20.89 and 16.91 kg ha^{-1}). This might be due to the organic acid releases microbes by decomposing plant residue which inactivates the Fe and Al and hydroxyl aluminium to prevent P fixation. Gupta *et al.* (2007) recorded that straw incorporation or residue burned release P by 21-32% higher than residue removed.

The available P concentration under 125% RDNF was found significantly higher *i.e.* 25.69 kg ha^{-1} at 0-15cm soil depth and 21.68 kg ha^{-1} at 15-30 cm soil depth. It is because of application of N enhanced P availability in soil through organic P mineralization because N is important basic for phosphatase enzymes that increase the mineralization rate of organic P. Kaur (2019) observed that there was an increase of P 3.73 and 5.05% under N_{120} and N_{150} respectively, which was found significantly higher over the control.

Interaction effect of different rice residue management practices with varying levels of nitrogen treatment with respect to available P was found to be non-significant.

Soil available potassium

The mean soil available potassium was found highest in residue incorporated with decomposer at both the soil depths of 0-15 cm and 15-30 cm (260.85 and 256.57 kg ha^{-1}) followed by residue burnt (253.18 and 251.77 kg ha^{-1}) and least in residue removal (249.41 and 245.80 kg ha^{-1}). Because rice straw contain 80 to 85% of the total K due to uptake by rice crop, therefore residue retention or incorporation practices significantly increased the soil K content as compared to removed. Sharma and Dhaliwal (2020) reported that available K increased with incorporation of straw (440-519 kg ha^{-1}) over control (377 kg ha^{-1}).

The available K concentration under 50%, 75%, 100% and 125% RDNF were found significantly higher over the control (248.78 kg ha^{-1}) which was (1.62%, 2.99%, 3.78% and 5.18%,) higher over the control at 0-15 cm soil depth and similar pattern was observed in 15-30 cm soil depth. Rukmanand (2019) also recorded that available K was increased with the increase in nitrogen level, the higher value of K recorded in N_{150} (119.2 kg ha^{-1}) and least in N_0 (111.5 kg ha^{-1}).

Interaction effect of different rice residue management practices with varying levels of nitrogen treatment with respect to available K was found to be non-significant.

DTPA extractable cationic micronutrients

The data presented in Table 2 showed that the available iron, copper and manganese status of soil was significantly affected due to rice residue management practices. The higher values of available zinc (1.35 and 1.09 mg kg^{-1}), values of soil available iron status (19.52 and 8.13 mg kg^{-1}), available copper status (0.98 and 0.63 mg kg^{-1}) and available manganese (12.19 and 9.33 mg kg^{-1}) were recorded under rice residue incorporated with decomposer as compared to residue burnt and removal at both the soil depths 0-15 cm and 15-30 cm, respectively. Increase in DTPA micronutrients in residue incorporated with decomposer plots might due to addition of organic materials which have enhanced the microbial activities in the soil and release of chelating agents which could prevent micronutrients from precipitation, oxidation and leaching and also addition of these micronutrients through rice residues after their decomposition which leads to an increase of micronutrient in the soil solution. Kumawat *et al.*(2023) reported that the availability of micronutrients, namely, Fe, Zn, Mn, and Cu, in the soil was found significantly (p d” 0.05) different under basmati rice-wheat based cropping systems. The maximum soil available Fe (32.7 mg kg$^{"1}$), Zn (2.8 mg kg$^{"1}$), Mn (13.5 mg kg$^{"1}$), and Cu (4.3 mg kg$^{"1}$) were observed under the rice-wheat system.

In treatments of different nitrogen levels result showed that the highest values of all the cationic micronutrients (Zn, Cu, Fe, Mn) were recorded in 125% RDNF at both the soil depth as compared to other levels of RDNF. The reason behind this was the additional N supplies energy to the microbes and substitute the nitrogen demand, caused by immobilization due to the formation of organic complex, which increased concentration of micronutrients in soil. Rukmanand (2019) observed that rice straw incorporation as well as nitrogen fertilization had significantly increased micronutrients. The higher value of Fe, Mn, Zn and Cu recorded in N_{150} (34.73 mg kg^{-1}, 8.47 mg kg^{-1}, 2.74 mg kg^{-1} and 1.15 mg kg^{-1}) respectively.

Interaction effect of different rice residue management practices with varying levels of nitrogen treatment with respect to micronutrients was found to be non-significant.

It is stated from the results that the incorporation of rice residue with decomposer (200 litres acre^{-1}) along with 125% RDNF improved the physico-chemical properties of soil but reduced the bulk density and increased the per cent of organic carbon of the soil. Whereas no significantly change in pH and electrical conductivity. The soil availability of Macro-nutrients (N, P and K) and Micro-nutrients (Fe, Zn, Cu, and Mn) was enhanced by incorporating rice residue with decomposer and 125% RDNF.

Table 2. Available N, P and K of soil as influenced by different rice residue management practices and varying levels of nitrogen application in wheat crop

Treatments	Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})		Available Zn (mg kg^{-1})		Available Fe (mg kg^{-1})		Available Cu (mg kg^{-1})		Available Mn (mg kg^{-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**	**0-15 Cm**	**15-30 cm**
Rice residue management practices														
Burnt	198.60	178.07	20.89	16.91	253.18	251.77	1.28	1.04	17.73	6.46	0.86	0.49	10.29	7.33
Removal	205.00	190.73	22.90	19.21	249.41	245.80	1.31	1.06	18.66	7.29	0.92	0.56	11.07	8.77
Incorporated with decomposer	212.00	198.20	25.80	22.83	260.85	256.57	1.35	1.09	19.52	8.13	0.98	0.63	12.19	9.33
SE(m)±	2.07	1.95	0.75	0.71	1.37	1.14	0.01	0.006	0.35	0.05	0.02	0.02	0.03	0.02
CD at 5%	6.21	5.87	2.19	2.14	4.12	3.32	0.04	0.02	1.04	0.16	0.05	0.06	0.08	0.06
Nitrogen levels														
Control	196.86	175.63	20.05	16.52	248.78	247.60	1.24	0.99	16.72	5.40	0.80	0.49	9.07	6.98
50% RDNF	205.49	184.70	21.80	17.94	252.83	250.74	1.29	1.04	17.83	6.49	0.83	0.51	10.17	7.20
75% RDNF	209.04	189.72	22.04	18.78	256.23	252.72	1.32	1.08	18.64	7.13	0.87	0.54	11.16	7.93
100% RDNF	211.27	197.93	23.21	20.10	258.20	255.03	1.35	1.16	19.42	8.06	0.91	0.58	12.35	8.54
125% RDNF	215.00	207.51	25.69	21.68	261.67	259.62	1.37	1.20	20.57	9.38	0.94	0.60	13.19	9.16
SE(m)±	1.41	1.10	0.49	0.52	0.82	0.79	0.01	0.02	0.4	0.17	0.02	0.01	0.02	0.02
CD at 5%	4.25	3.21	1.49	1.53	2.48	2.37	0.04	0.07	1.18	0.5	0.05	0.04	0.07	0.05
Interaction	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SE(m)±	1.18	1.04	0.70	0.72	0.90	0.88	0.1	0.14	0.63	0.41	0.14	0.1	0.14	0.14
CD at 5%	-	-	-	-	-	-	-	-	-	-	-	-	-	-

RDNF- Recommended dose of nitrogen fertilizer

REFERENCES

Blanco-Canqui, H., R. Lal, W.M. Post, R.C. Izaurralde and L. B. Owens, 2006. Rapid changes in soil carbon and structural properties due to stover removal from no till corn plots. Soil Sci. 171: 468–82.

Deotale, R.D., S.B. Korade, N.D. Guddhe, Jadhav and O.G. Thakare, 2019. Efficacy of Cow Urine and NAA on Chemical, Biological and Yield Contributing Parameters of Wheat. J. Soils and Crops.**29**(1): 176-82.

Dhar, D., A. Datta, N. Basak, N. Paul, S. Badole and T. Thomas, 2014. Residual effect of crop residues on growth, yield attributes and soil properties of wheat under rice-wheat cropping system. Ind. J. Agri. Res. **48**(5): 373-78.

Gupta R. K., Y. Singh, J. K. Ladha, B. Singh, J. Singh, G. Singh and H. Pathak, 2007. Yield and Phosphorus transformation in a rice-wheat system with crop residue and phosphorus management. Soil. Sci. Soc. Am. J. **71**: 1500-07.

Jackson, M.L. 1967. Soil chemical analysis. Prentice-Hall of India Pvt. Ltd., New Delhi, pp.498.

Kannan, 2020. Waste decomposer – a multifunctional microbial consortium. krishi science –eMagazine for Agricultural Sciences **1.**

Kaur, S. 2020. Long term effect of crop residue management on productivity and nitrogen requirement of wheat (*Triticum aestivum* L.) in rice-wheat cropping system under varied nitrogen levels.Unpublished M.Sc. Thesis, Punjab Agricultural University, Ludhiana-141004, Punjab, India.

Kumawat, A., D. Kumar, Y. S. Shivay, A. Bhatia, I. Rashmi, D. Yadav and A. Kumar, 2023. Long-term impact of biofertilization on soil health and nutritional quality of organic basmati rice in a typic ustchrept soil of India. Front. Environ. Sci. **11**:1031844.

Ladha, J.K., K.S. Fischer, M Hossan, P.R. Hobbs and B. Hardy, 2000. Improving the productivity and sustainability of rice–wheat systems of the Indo-Gangetic Plains:Anjali synthesis of NARS–IRRI partnership research. IRRI Discussion Paper Ser. 40, IRRI, Los Banos, Philippines, 2000.

Lindsay, W. L. and W. A. Norvell, 1978. Development of DTPA soil test for zinc, iron, manganese and Cu. Soil Sci. Soc. Am. J. **42**: 421-28.

Lohan, S. K., H. S. Jat, A. K. Yadav, H. S. Sidhu, M. L. Jat, M. Choudhary and P.C. Sharma, 2018. Burning issues of paddy residue management in north-west states of India. Renewable Sustain. Ener. Rev. **81**: 693-06.

Mandal, K.G., A. K. Misra, K. M. Hati, K. K. Bandyopadhyay, P. K. Ghosh and M. Mohanty, 2004. Rice residue management options and effects on soil properties and crop productivity. Food Agric. Environ. **2**: 224-31.

Merwin, H. D. and M. Peech, 1950. Exchangeability of soil potassium in the sand silt and clay fractions as influenced by the nature of the complementary exchangeable cations. Soil Sci. Soc. Am. Proc. **15**: 125-28.

Metwally, A.A. and Y.A.A Hefny, 2018 Influence of some cropping system and mineral nitrogen fertilizer levels on wheat productivity and its attributes under sandy soil condition. J. Soils and Crops. **28**(2): 259-64.

Olsen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean, 1954. Estimation of available phosphorus by extraction with sodium bicarbonate. United States Department of Agriculture Agency Circular Number, **939**: 1-19.

Piper, C. S. 1966. Soil and Plant Analysis, International Science Publisher, New York.

Prihar, S. S. and S. S. Hundal, 1971. Determination of bulk density of soil by core method. Geoder **5**: 283-86.

Rukmanand, R. P. 2019. Long term effect of rice straw incorporation on soil physical properties and crop productivity in rice-wheat system. Unpublished MSc. Thesis, Punjab Agricultural University, Ludhiana.

Sharma, S. and S.S. Dhaliwal, 2023. Rice residue incorporation and nitrogen application: effects on yield and micronutrient transformations under rice–wheat cropping system. J. Plant Nutri. **43**(18):1-15.

Singh, R. 2005. Effect of rice residue management and nitrogen levels on wheat (*Triticum aestivum* L.) under rice-wheat cropping system. Ph.D Thesis, Narendra Deva University of Agriculture and Technology, Narendra Nagar (Kumarganj), Faizabad- 24229 (U.P.), India.

Singh, R. P., H.S. Dhaliwal, H.S. Sidhu, M. Singh, Y. Singh and J. Blackwell, 2008. Economic assessment of the Happy Seeder for rice-wheat systems in Punjab, India. Conference Paper AARES 52nd Annual conference, Canberra. Australia: ACT.

Spiegel, H., T. Sandén, G. Dersch, A. Baumgarten, R. Grundling and U. Franko, 2018. Soil organic matter and nutrient dynamics following different management of crop residues at two sites in Austria. Book Chapter in "Soil Management and Climate Change: Effects on Organic Carbon, Nitrogen Dynamics and Greenhouse Gas Emissions", 253–265, Elsevier. ISBN: 978-0-12-812128-3.

Subbiah, B.V. and G.L. Asija, 1956. A rapid procedure for estimation of the available nitrogen in soil. Curr. Sci. **25**: 259-60.

Thorat, T.N., K. K. Agarwal, M. L. Kewat, G. Jha and S. Silawat, 2015. Crop residue management with conservation agriculture for sustaining natural resources. JNKVV Res J. **49**(2): 125-36.

Yadav, B.K. 2020. Effect of Crop Residue Burning on Micronutrients Availability in Arid Soils of Punjab, India. J. Soils and Crops. **30**(1): 69-73

Rec. on 15.05.2023 & Acc. on 29.05.2023