Indian Journal of Agricultural Sciences **93** (2): 151–156, February 2023/Article
https://doi.org/10.56093/ijas.v93i2.129506

Nitrogen budgeting under the influence of *in situ* rice residue management options in rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system

MANU S M[1]*, Y V SINGH[1], Y S SHIVAY[1], LIVLEEN SHUKLA[1], V K SHARMA[1] NAMITA DAS SAHA[2], KAPILA SHEKHAWAT[1], K K BANDOPADHYAY[1] and HIMANSU SEKHAR GOUDA[3]

ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India

Received: 4 November 2022; Accepted: 29 December 2022

ABSTRACT

A field experiment was conducted during rainy (*kharif)* and winter (*rabi)* seasons 2019–20 and 2020–21 at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi to study the effect of rice establishment techniques (RETs) and microbial consortia mediated *in situ* rice residue management options on nitrogen (N) budgeting in a rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping system (RWCS). The experiment was laid out in split plot design with 3 replications having 2 main plot treatments, viz. aerobic rice (AR) and conventional transplanted rice (CTR) in *kharif* and 7 sub plot treatments, viz. clean cultivation (removal of paddy straw), paddy straw incorporation, paddy straw mulching, paddy straw incorporation + *Pusa* decomposer, paddy straw mulching + *Pusa* decomposer, paddy straw incorporation + urea @20 kg/ha, paddy straw incorporation + *Pusa* decomposer + urea @10 kg/ha. The residual effects of these treatments were observed in seed drill and zero till sown wheat in *rabi* seasons. Results showed that N uptake (95.1 kg/ha and 100.4 kg/ha in CTR and 79.4 kg/ha and 83.8 kg/ha in AR) was significantly superior in CTR than AR in *kharif* seasons. The residual effects of *in situ* rice residue management options in wheat, paddy straw incorporation + *Pusa* decomposer + urea @10 kg/ha resulted in significantly higher N uptake (136.4 and 141.5 kg/ha) than other treatments, and it was followed by paddy straw incorporation + *Pusa* decomposer in both the years. The nutrient uptake by the RWCS was an important indicator of soil fertility and plant nutrient status. This investigation concluded that there is need for use of microbial consortia mediated *in situ* rice residue management in RWCS for positive N balance in spite of enhanced nutrient uptake.

Keywords: Nitrogen budgeting, Paddy straw, Pusa decomposer, Rice, Uptake, Wheat

Rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L.) cropping system (RWCS) is a nutrient exhaustive cropping system. Crop residue is a good organic source of plant nutrients available for most rice cultivating farmers and an important component in maintaining the stability of agricultural ecosystems (Dotaniya 2013). Crop residue burning is one of the cause of environmental pollution and responsible for loss of essential plant precious nutrients in soil, viz. complete nitrogen, about $1/4^{th}$ of phosphorus and potassium and about $3/4^{th}$ of sulphur (Chaudhary *et al.* 2019). The rice straw contains 0.57% N, 0.07% P_2O_5, 1.5% K_2O, 0.1% S and 5% silicon (Si) at harvest (Ponnamperuma 1984). About 25% of N and P, 50% S and 75% of K uptake by cereal crops are retained in crop residue, making them viable nutrient sources. There is an urgent need to identify more productive, environmentally sound and socially acceptable residue management system. In India, about 10 million ha area under rice cultivation is planted with wheat after rice harvest. The soil condition and residual effects of the previous season's rice crop affect the performance of succeeding wheat. The short turn-around period (duration between harvesting of rice and sowing of wheat) and disposal of rice residue is challenging and crucial in the RWCS areas (Shahane *et al.* 2020). The removals of paddy straw and its incorporation or retention are considered as the alternatives to rice residue burning (Chaudhary *et al.* 2019). Most agricultural professionals believe that crop residues have greater value when retained on the land than when removed (Lupwayi *et al.* 2022). The straw incorporation practice helps to alleviate soil degradation, improves soil fertility and enhance crop yield and productivity in intensive agricultural systems. However, straw returning into soil in a short period of time increases nitrogen immobilization and mineralization, which causes N deficiency and low yield. Therefore, simultaneous N application with straw widely suggested (Guo *et al.* 2018). In India, presently the status of soil-nutrient balance is

[1]ICAR-Indian Agricultural Research Institute, New Delhi; [2]ICAR-Central Tobacco Research Institute, Regional Station, Dinhata, Cooch Behar, West Bengal; [3]CV Raman Global University, Bhubaneswar, Odisha. *Corresponding author email: msmanusm12@gmail.com

negative (10 million tonnes), which is due to the result of the increasing in nutrient uptake of year round cropping to meet the demands of an increasing population of both human and cattle; low addition of nutrient as compared to removal from soil and imbalanced and indiscriminate use of nutrient/fertilizer application. In this scenario, a comparative field experiment of rice establishment techniques (RETs) and rice residue management for their plant nutrient uptake is very importance for sustainability of cropping systems (Shahane *et al.* 2020). The contribution of the microbial inoculation in increasing the N uptake in rice-wheat cropping system as well as its to growth and yielding ability of rice and wheat was significance as reported by Davari *et al.* (2012). With this background, a field experiment was conducted to get insight into significance of RETs and microbial consortia mediated *in situ* rice residue management options on nitrogen budgeting and soil nutrient status in rice-wheat cropping system.

MATERIALS AND METHODS

A field experiment was conducted at the research farm of ICAR–Indian Agricultural Research Institute, New Delhi, India (28° 38′ N, 77° 10′ E and 228.6 m amsl (Arabian sea) during 2019–20 and 2020–21. The total amounts of rainfall (RF) received during the first (2019–2020) and second (2020–2021) cropping cycle of RWCS were 907.2 mm and 757 mm respectively. In the first and second rice cropping seasons, 603.3 mm and 685.9 mm RF was received whereas during wheat crop growing seasons 303.9 mm and 71.1 mm RF received. The soil of experimental field (15 cm soil depth) was sandy clay-loam in texture with the *p*H 7.97 and organic carbon of 0.42%. The amount of alkaline $KMnO_4$-extractable N, $NaHCO_3$-extractable P, 1 N ammonium acetate-extractable K was 183 kg/ha, 16.6 kg/ha and 262 kg/ha, respectively. Recommended dose of fertilizer was 120:60:60 kg $N:P_2O_5:K_2O$ in rice and 120:60:60 kg $N:P_2O_5:K_2O$ in wheat. The rice variety Pusa Basmati 1509 and wheat variety HD 296' were taken in the experiment which was conducted in split-plot design with three replications. The treatments comprised 2 main plot treatments, viz. aerobic rice (AR) [M_1] and conventional transplanted rice (CTR) [M_2] and 7 sub-plot treatments, viz. clean cultivation (removal of paddy straw) [S_1], paddy straw incorporation (S_2), paddy straw mulching (S_3), paddy straw incorporation + *Pusa* decomposer (S_4), paddy straw mulching + *Pusa* decomposer (S_5), paddy straw incorporation + urea @20 kg/ha (S_6), paddy straw incorporation + *Pusa* decomposer + urea @10 kg/ha (S_7). The residual effects of these treatments were observed in seed drill and zero till sown wheat in *rabi* seasons. The ICAR-Indian Agricultural Research Institute, New Delhi has developed low cost microbial inoculants named *Pusa* decomposer (both in liquid and capsule forms) for rapid decomposition of paddy straw and other crop residues. It contains 7 different types of beneficial microorganisms, which enhance the enzymatic activities in soil and straw for fast decomposition of biomass. It was sprayed on rice straw @25 litres liquid formulation/ha in the experiment as per the treatments to draw a scientific and agronomically authenticated inference to combat the crop residue burning menace in the northern western part of India (IARI 2021, Sruthy and Livleen 2021). The standard analytical methods were followed for estimation of nutrients from soil and plants (Subbiah and Asija 1956). The N concentration both in grains as well as straw was estimated by using modified Kjeldahl method. N content in plants was expressed in per cent age while N uptake (kg/ha) and partial factor productivity (PFP) was calculated using the following equations (Dotaniya 2013, Guo *et al.* 2018).

$$\text{Nitrogen uptake in grain (kg/ha)} = \text{N content in grain (\%)} \times \text{grain yield (kg/ha)} \times 10^{-2}$$

$$\text{Nitrogen uptake in straw (kg/ha)} = \text{N content in straw (\%)} \times \text{yield (kg/ha)} \times 10^{-2}$$

$$\text{Total nitrogen uptake (kg/ha)} = \text{Uptake in grain (kg/ha)} + \text{uptake in straw (kg/ha)}$$

$$\text{Partial Factor Productivity (PFP)} = \text{Grain yield (kg/ha)} / \text{total nitrogen applied (kg/ha)}$$

RESULTS AND DISCUSSION

Grain and straw yield of rice and wheat: The grain (4.23 and 4.42 t/ha) and straw yields (7.61 and 7.67 t/ha) in transplanted rice were significantly higher than aerobic rice (3.48 and 3.67 t/ha of grain yield; 6.73 t/ha and 6.79 t/ha of straw yield) in both the years of rice cultivation (Fig 1). It might be due to the adequate availability of water and nutrients and weed free conditions that favoured good crop growth and ultimately led to higher yield in conventional transplanted rice (Gouda *et al.* 2021).

The grain and straw yield of wheat were also significantly higher in paddy straw incorporation + *Pusa* decomposer + urea @10 kg/ha – wheat treatment compared to other treatments (Fig 1). It might be due to improved fertility with incorporation of rice residue and better decomposition of straw with *Pusa* decomposer, which led to improved physical, chemical and biological conditions available to the succeeding crop, viz. higher organic carbon, available NPK, nutrient uptake, microbial activity and better soil structure in the respective plots leading to lesser crop stress.

N concentration and uptake in grain and straw of rice: Rice establishment techniques significantly affected N concentration in grain and straw in both the years. The N concentration in grain (1.27 and 1.30%) and straw (0.54 and 0.55%) of conventional transplanted rice was higher than aerobic rice in both the years. The N uptake in grain and straw of CTR (54.09 and 57.84 kg/ha in grain, 41.02 and 42.56 kg/ha in straw) were significantly higher than AR (43.78 and 47.29 kg/ha in grain, 35.65 and 36.60 kg/ha in straw) in both the years (Table 1, Fig 2).

The partial factor productivity (PFP) for N (35.28 and 36.87 kg grain/kg N applied) was superior in CTR than AR (29.01 and 30.61 kg grain/kg N applied PFP) in both the years of cultivation (Fig 2). The N uptake was significantly

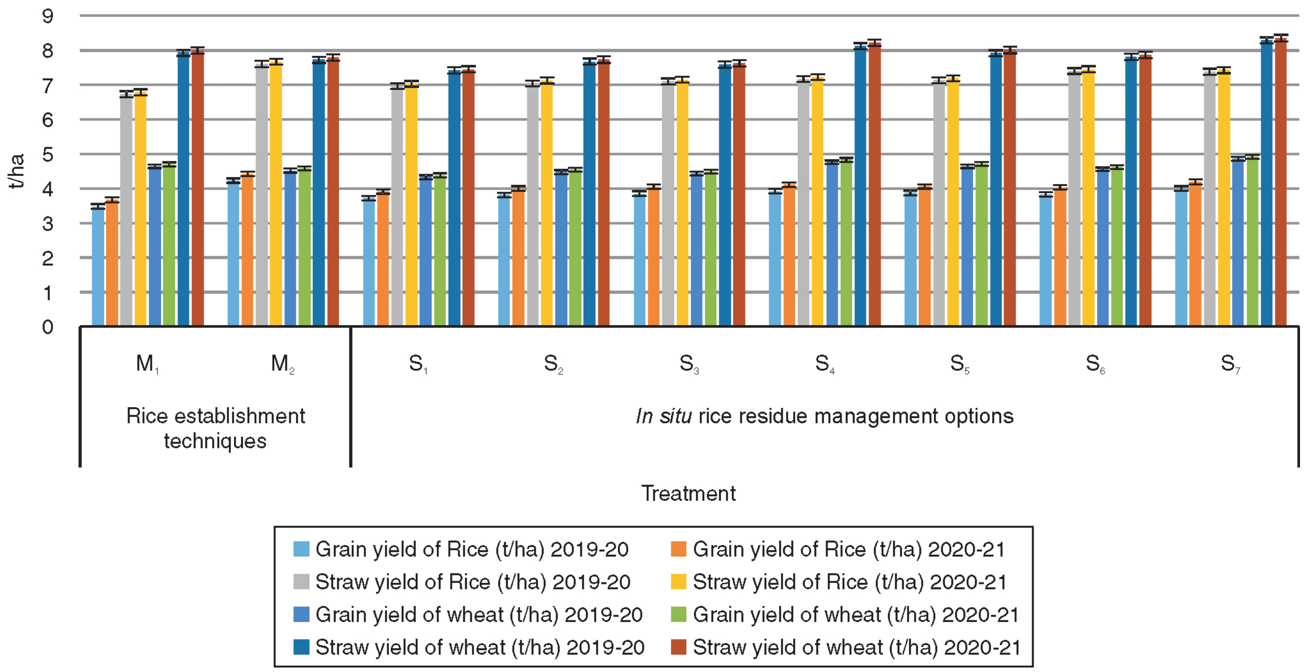

Fig 1 Effect of rice establishment techniques and *in situ* rice residue management options on grain and straw yield of rice and wheat. Treatment details are given under Materials and Methods.

higher in CTR than AR. Higher concentration of N in CTR might be due to higher availability of nutrient near the crop root zone which happens due to lesser intra and inter-plant competition in CTR as compared to AR. Due to presence of standing water, more prevalence of ammonium form of N as compared to nitrate form of N in the anaerobic condition resulting in lesser loss in the form of leaching or denitrification losses resulted in more availability and thereby its higher uptake in CTR as compared to AR. Due to the ponding of water in the CTR plots, neutrality in soil reaction is achieved which may be a good reason for more availability of phosphorus, zinc and thereby their higher uptake. Similar results were reported by Davari and Sharma (2010).

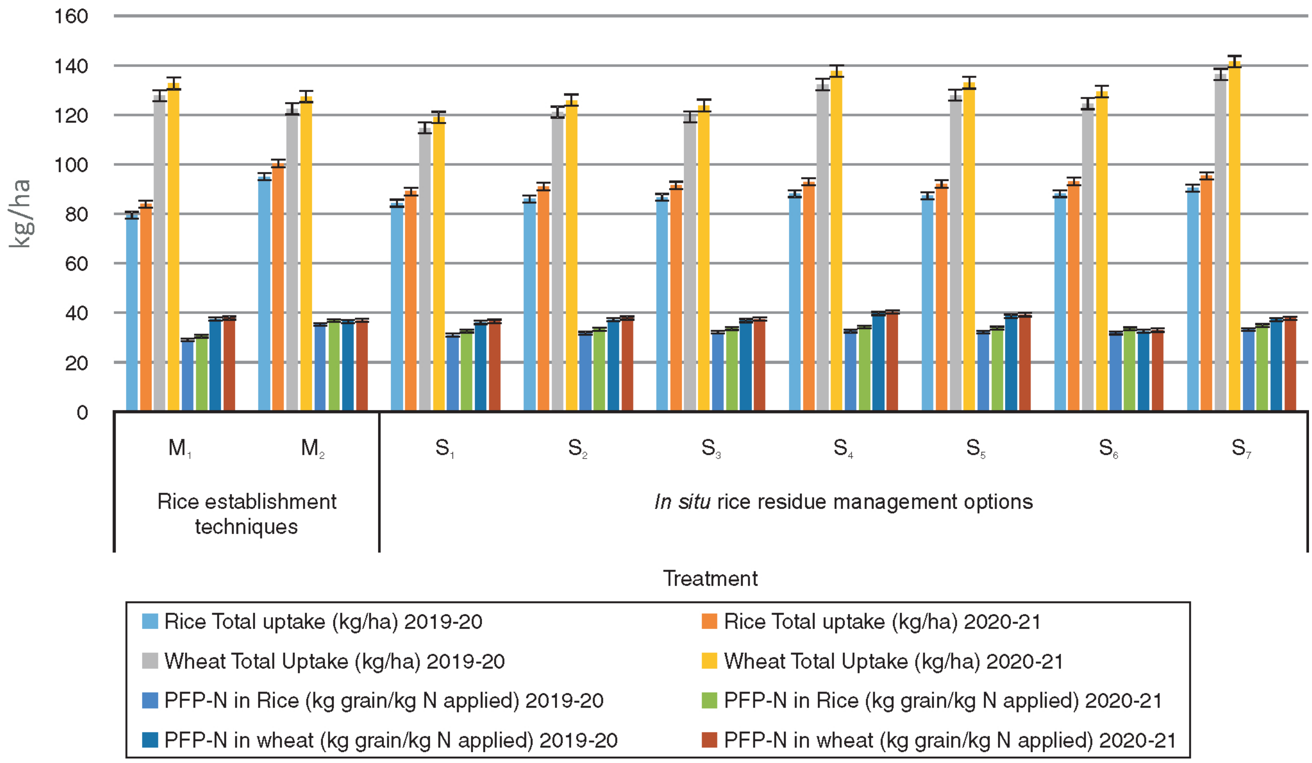

Fig 2 Effect of rice establishment techniques and *in situ* rice residue management options on total nitrogen uptake and partial factor productivity of rice and wheat.
Treatment details are given under Materials and Methods.

N concentration and uptake in grain and straw of wheat: Rice establishment techniques did not show much significant residual influence on concentrations of N and their uptake by grain and straw of wheat. However, *in situ* rice residue management options in conjunction with *Pusa* decomposer-microbial consortia showed significantly higher N concentration and uptake by grain and straw of wheat. The N concentration in grain (1.85 and 1.87%) and straw (0.56 and 0.55%) of paddy straw incorporation + *Pusa* decomposer + urea @10 kg/ha – wheat treatment were higher than other treatments and it was followed by paddy straw incorporation + *Pusa* decomposer in both the years. N uptake in paddy straw incorporation + *Pusa* decomposer + urea @10 kg/ha – wheat treatment (89.77 and 91.95 kg/ha in grain, 46.61 and 49.51 kg/ha in straw) was found to be significantly higher than others treatments and control and the next best treatment was paddy straw incorporation + *Pusa* decomposer – wheat in both the years (Table 1, Fig 2). The partial factor productivity for N (39.63 and 40.21 kg grain/kg N applied) was superior in paddy straw incorporation + *Pusa* decomposer treatment in both the years of wheat cultivation (Fig 2). The incorporating of crop residues will change the soil microbial community population and processes, which affect the nutrient availability and crop productivity. Therefore, evaluation of the straw decomposition pattern and the associated microbial communities involved in the decomposition under the different rates of N fertilizer application, gives an insights into the scientific management of crop residues apart from enhancing the nutrient uptake (Guo *et al.* 2018). Due to microbial decomposition crop residue converted into different easily mineralizable form of the soil organic matter (Brady and Weil 2005). Plants directly and indirectly take up the mineralized form of plant nutrients from the soil solution. The incorporation of crop residues can recycle nutrients and improve soil organic matter content (Kone *et al.* 2010). The combination of crop residue as compost with chemical fertilizer further enhanced the biomass and grain yield of both crops, which in turn was responsible for the higher uptake N compared to non-addition of residue and microbial inoculants (Sarwar *et al.* 2008, Dotaniya 2013).

Nitrogen budgeting: Analyses of the N balance in soil showed that the treatment, paddy straw incorporation + *Pusa* decomposer + urea @10 kg/ha having positive effect on available N soil status in RWCS followed by paddy straw incorporation + *Pusa* decomposer. The order of significance of allocated treatments in increasing the soil N after completion of two cropping cycle of RWCS compared to initial available soil N was: application of paddy straw incorporation + *Pusa* decomposer + urea @10 kg/ha treatment>paddy straw incorporation + *Pusa* decomposer with respective contribution of 30.47 and 26.49, N kg/ha, respectively (Table 2).

The order of significance indicated the important contributions of microbial consortia functioning and their application for efficient N nutrition of RWCS. The N balance status was mainly by plant nutrient uptake. This experiment

Table 1 Effect of rice establishment techniques and microbial consortia mediated *in situ* rice residue management options on concentrations of nitrogen and its uptake by rice and wheat

Treatment	N concentration in grain (%) of rice		N concentration in straw (%) of rice		N uptake by grain (kg/ha) of rice		N uptake by straw (kg/ha) of rice		N concentration in grain (%) of wheat		N concentration in straw (%) of wheat		N uptake by grain (kg/ha) of wheat		N uptake by straw (kg/ha) of wheat	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Rice establishment techniques (RET)																
M_1	1.258	1.288	0.530	0.539	43.78	47.29	35.65	36.60	1.83	1.85	0.54	0.57	85.03	87.18	42.73	45.50
M_2	1.278	1.307	0.539	0.555	54.09	57.84	41.02	42.56	1.81	1.83	0.53	0.56	81.64	83.83	40.90	43.54
SEm±	0.0002	0.0002	0.0003	0.001	0.196	0.148	0.401	0.383	0.0003	0.0003	0.0001	0.0001	0.078	0.077	0.042	0.045
LSD (P= 0.05)	0.0014	0.0014	0.002	0.003	1.193	0.899	2.439	2.329	0.0018	0.0018	0.0007	0.0007	0.472	0.467	0.256	0.274
In situ rice residue management options (IRM)																
S_1	1.265	1.284	0.533	0.539	47.13	50.69	37.14	38.35	1.79	1.81	0.50	0.52	77.44	79.38	37.30	39.67
S_2	1.267	1.296	0.534	0.547	48.34	51.95	37.63	39.03	1.81	1.83	0.52	0.55	81.00	83.16	40.10	42.69
S_3	1.266	1.295	0.533	0.546	48.80	52.44	37.88	39.09	1.80	1.82	0.52	0.55	79.88	82.03	39.28	41.76
S_4	1.270	1.299	0.535	0.548	49.75	53.40	38.35	39.57	1.84	1.86	0.55	0.58	87.46	89.80	44.86	47.87
S_5	1.269	1.298	0.535	0.547	49.09	52.71	38.18	39.39	1.83	1.85	0.54	0.57	84.89	87.11	42.99	45.86
S_6	1.268	1.297	0.534	0.547	48.64	52.25	39.57	40.81	1.82	1.84	0.53	0.56	82.90	85.08	41.58	44.28
S_7	1.271	1.300	0.536	0.549	50.80	54.52	39.58	40.82	1.85	1.87	0.56	0.59	89.77	91.95	46.61	49.51
SEm±	0.00002	0.00002	0.0004	0.0007	0.692	0.723	0.118	0.127	0.0002	0.0002	0.0002	0.0002	0.100	0.102	0.075	0.080
LSD (P=0.05)	0.00007	0.00007	0.0012	0.0020	2.020	2.111	0.345	0.370	0.0007	0.0007	0.0007	0.0007	0.291	0.297	0.218	0.233
I (RET×IRM)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.115	0.117	NS	0.092

Straw incorporated/mulched @6 t/ha; Recommended dose of Pusa compost inoculant/decomposer @25 litres/ha (liquid formulation); I, Interaction.
Treatment details are given under Materials and Methods.

Table 2 Effect of rice establishment techniques and *in situ* rice residue management options on nitrogen budgeting at the end of two years rice-wheat cropping system

Treatment	Initial available N (kg/ha)	N added to soil from different sources (kg/ha)				Nitrogen removed (total uptake) (kg/ha)	Available N present in the soil at the end of two seasons (kg/ha)	Actual N addition to soil after the end of two seasons (kg/ha)
		Fertilizer	Straw	Other source	Total			
Rice establishment techniques (CET)								
M_1	183	240	32.38	42.9	315.7	207.1	206.2	23.1
M_2	183	240	36.48	44.3	320.8	217.6	203.5	20.4
SEm±	–	–	–	–	–	0.52	0.03	0.03
LSD (P= 0.05)	–	–	–	–	–	3.14	0.19	0.19
In situ rice residue management options (IRM)								
S_1	183	240	0.00	35.6	275.6	199.0	182.6	-0.4
S_2	183	240	38.83	35.7	314.6	207.0	205.5	22.5
S_3	183	240	38.89	35.8	314.7	205.8	204.6	21.5
S_4	183	240	39.37	35.6	315.1	220.4	209.5	26.4
S_5	183	240	39.19	35.8	315.0	215.1	207.5	24.5
S_6	183	280	40.60	35.8	356.4	212.6	209.5	26.4
S_7	183	260	40.62	35.8	336.4	226.7	213.5	30.4
SEm±	–	–	–	–	–	0.76	0.06	0.05
LSD (P=0.05)	–	–	–	–	–	2.21	0.17	0.16
I (RET×IRM)	–	–	–	–	–	NS	NS	NS

Recommended dose of Pusa compost inoculant/decomposer @25 litres/ha (liquid formulation); I, Interaction; N added from other sources: (Rainfall N add assumed: 0.62 kg/ha; N added through irrigation assumed- ~35 kg/ha).

Treatment details are given under Materials and Methods.

resulted that the N uptake in terms of rice-wheat cropping system was significantly influenced by RETs, microbial inoculation, paddy straw incorporation, N fertilization in both the years of experiment. Among these factors, *Pusa* decomposer, paddy straw incorporation and N application brought about the maximum effect, while effect of RETs was minimal. In case of cropping system, the order of N uptake significance was: paddy straw incorporation+ *Pusa* decomposer + urea @10 kg/ha>paddy straw incorporation + *Pusa* decomposer>paddy straw mulching + *Pusa* decomposer. The positive effect of *Pusa* decomposer involved treatments on N uptake and increasing yield in RWCS was also a distinct in this experiment. The superior performance of the microbial consortia (*Pusa* decomposer) used in the study in terms of higher RWCS yield as well as N uptake highlights its promise in quick degradation of paddy straw and nutrient acquisition.

It was concluded that paddy straw incorporation + *Pusa* decomposer @25 litre/ha + urea @10 kg/ha (S_7) treatment significantly enhanced the nutrient uptake, crop productivity and soil nitrogen status in the rice–wheat cropping system (RWCS) under aerobic as well as transplanted rice and thus proved better *in situ* rice residue management option. The available N balance after completion of two cropping cycles of RWCS was found positive and higher with the same treatment.

ACKNOWLEDGEMENT

The first author duly acknowledge to ICAR-Indian Agricultural Research Institute, New Delhi for providing fellowship and facilities to carry out this research.

REFERENCES

Brady N C and Weil R R. 2005. *The Nature and Properties of Soil,* 13th edn, pp. 881. Macmillan Publishing Co., New York.

Chaudhary A, Singh R C, Yadav D B, Sindhu V K, Ram H, Sandeep R, Khedwal R S, Sharma R K and Gill S C. 2019. In situ paddy straw management practices for higher resource use efficiency and crop productivity in Indo-Gangetic Plains (IGP) of India. *Journal of Cereal Research* **11**(3): 172–98.

Davari M R and Sharma S N. 2010. Effect of different combinations of organic materials and biofertilizers on productivity, grain quality and economics in organic farming of basmati rice (*Oryza sativa*). *Indian Journal of Agronomy* **55**: 290–94.

Davari M, Sharma, S N and Mirzakhani M. 2012. Residual influence of organic materials, crop residues, and biofertilizers on viii performance of succeeding mung bean in an organic rice-based cropping system. *International Journal of Recycling of Organic Waste in Agriculture* **1**: 14.

Dotaniya M L. 2013. Impact of crop residue management practices on yield and nutrient uptake in rice-wheat system. *Current Advances in Agricultural Sciences* **5**(2): 269–71.

Gouda H S, Singh Y V, Shivay, Y S, Biswas D R, Poornima S and Manu S M. 2021. Effect of enriched compost and crop establishment methods on productivity and profitability of rice (*Oryza sativa*). *Indian Journal of Agricultural Sciences* **91**(6): 905–09.

Guo T, Qian Z, Chao A, Guoqing L, Ping H and Wei Z. 2018. Nitrogen enrichment regulates straw decomposition and its associated microbial community in a double-rice cropping system. *Scientific Reports* **8**: 1847 (1–12).

IARI. 2021. The Annual Report-2020, pp. 105. ICAR-Indian Agricultural Research Institute, New Delhi.

Kone F J, Kouadio Y, Yapo E S and Visser M. 2010. Effects of spontaneous plant residues and rice straw incorporated in soil on growth and yield parameters of a lowland rice cultivar (*Oryza sativa* L.) in sub humid Tropical area, Côte D'ivoire. *Journal of Applied Sciences Research* **6**: 1581–88.

Lupwayi N Z, Ellert B H, Bremer E, Smith E G, Petri R M, Neilson J A D and Janzen H H.2022. Ramifications of crop residue loading for soil microbial community composition, activity and nutrient supply. *Soil Use and Management* **00**: 1–13.

Ponnamperuma F. 1984. Straw as a source of nutrients for wetland rice. *Organic Matter Rice* **117**: 136.

Sarwar G, Hussain N, Schmeisky H, Muhammad S, Ibrahim M and Safdar E. 2008. Improvement of soil physical and chemical properties with compost application in rice-wheat cropping system. *Pakistan Journal of Botany* **40**: 275–82.

Shahane A A, Shivay Y S, Prasanna R and Dinesh K. 2020. Nutrient removal by rice–wheat cropping system as influenced by crop establishment techniques and fertilization options in conjunction with microbial inoculation. *Scientific Reports* **10**: 21944. https://doi.org/10.1038/s41598-020-78729-w

Sruthy K S and Livleen S. 2021. Development of a liquid formulation of lignolytic fungi for increased shelf life. *International Journal of Current Microbiology and Applied Science* **10**(01): 934–40.

Subbiah B V and Asija G L. 1956. A rapid procedure for the estimation of available nitrogen in soils. *Current Science* **25**(8): 259–60.