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Tillage and residue management on nutrient uptake by wheat under rice-wheat cropping system

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ABSTRACT

A 2-year field experiment was carried out to investigate the effects of tillage and residue management practices on yield and NPK uptake by wheat under rice wheat cropping system at Birsa Agricultural University, Ranchi, Jharkhand. There were four tillage practices and four residue management practices arranged in split plot design with three replications. Higher NPK uptake by wheat, protein productivity, grain and straw yield as well as yield attributes *viz*., number of spikes m^{-2}, number of grains spike^{-1} and 1000-seed weight (g) recorded under conventional tillage wheat sown after conventional tillage rice (CT-CT) and residue retained in both crops (R-R) whereas lower recorded under zero tillage wheat sown after zero tillage rice (ZT-ZT) and without residue retained in both crops (NR-NR) during both the year of experimentations.

Key words: *NPK uptake, Protein content, Rice residue, Tillage and Yield*

Introduction

Wheat (*Triticum aestivum* L.) is the most significant and strategic cereal crop for the majority of the world's populations. Approximately 16 per cent of the total arable land in the world is cultivated with wheat. Whereas paddy is mainly cultivated in Asia, wheat is grown in all the continents of the world. It supplies about 20 per cent of the food calories for the world's growing population. Global wheat production touched 760.9 million tonnes in 2020 while India is the second largest producer of wheat after China. India produces 107.6 million tonnes of grain wheat (FAO, 2020). Carbohydrate and protein are two main constituents of wheat.

Tillage is the basic and most important requirement of crop production. The efficiency of input use, such as water, fertilizers, herbicides and others depend on tillage and crop establishment practices (Behera and Sharma, 2009). So it is essential that the soil environment be manipulated suitably for ensuring a good crop stand and improve resource-use efficiency. Continuous tillage in both the season, i.e *kharif* and *rabi* is found to have detrimental effect on soil health and structure. Continuous tillage also make energy requirement quite high. At the same time applying double zero tillage in both *kharif* and *rabi* season is found to be difficult about weed management. Under such situation skipping tillage for rice in *kharif* season or for wheat in *rabi* season seem to be more beneficial in case of input use efficiency and energy saving (Karunakaran and Behera, 2013).

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Crop residue modifies the hydrothermal regime of the soil surface by reducing soil temperature during summer and acting as barrier against the loss of water. Crop residues also increase the soil water storage and maintain soil temperature. Residue keeps the soil surface cool, wetter and mellows for long period of time, which may enhance crop's root and shoot growth. In addition, decomposing residues on soil surface possibly release allele-chemicals which further have the inhibitory effects on weed seed germination and early growth. It is always beneficial to use crop residues as mulch wherever it is available. Conservation tillage, which is based on zero or reduced tillage practices, and maintaining crop residues on soil surface, play a critical role in improving soil fertilization (Rezvani Moghaddam *et al*., 2013; Shah *et al*., 2016) by increasing soil organic matter and nutrients availability, especially nitrogen and potassium (Liu *et al*., 2010). Furthermore, considering the positive effects of crop residue in stimulating microbial activity, improving soil structure and permeability and reducing water erosion (Bastian *et al*., 2009), it seems that application of crop residue would improve nutrient uptake efficiency and nutrient use efficiency through increasing nitrogen availability and reducing nitrogen leaching. In this context, it has been reported that application of preceding crop residue as a mulch on soil surface could increase growth characteristics, yield and nutrient uptake by wheat (Seyyedi and Rezvani Moghaddam, 2011).

Materials and Methods

Site and soil

A field experiment was carried out in 2019-20 and 2020-21 at agronomical research farm of Birsa Agricultural University, Ranchi (23.442°N, 85.320°E, elevation 611 m). The climate of the area is sub-tropical, with an average annual rainfall of 1430 mm (75–80% of which is received during June-September), minimum temperature ranges from 3-5 ^{o}C in January, and maximum temperature ranges from 35-38 ^{o}C in May. Mean monthly temperature, sunshine duration, wind velocity and monthly rainfall during given seasons of rice are given in Table-1. The soil at the study site had a sandy loam texture, slightly acidic (pH 5.7), low in available nitrogen (219.5 kg ha^{-1}) and potassium (128.9 kg ha^{-1}) whereas, medium in available phosphorus (14.9 kg ha^{-1}) and organic carbon (5.11 g kg^{-1}).

Treatments detail

The experiment was initiated in second fortnight of November 2019 with wheat crop after the harvest of rice. The experimental design was a split plot which consister of four tillage sequences *viz.*, conventional tillage (CT) in rice and wheat (CT-CT), zero tillage (ZT) in rice and wheat (ZT-ZT), and two rotational tillage sequences that alternated between CT and ZT (CT-ZT and ZT-CT) and four residue management practices *viz.*, no residue (No Res.) in rice and wheat (NR-NR), residue applied in rice and wheat (R-R), residue applied in rice (R-NR) only and residue applied in wheat (NR-R) only with three replications. Residue of the preceding crop was used @ 5 tonne per ha. Each sub-plot measured 8.5 m × 5 m. Crops were either seeding without tillage (ZT) or conventionally tillage (CT) after the soil was tilled to a depth of 15 cm (CT). CT consisted of tillage twice with a field cultivator and with rotavator to prepare a fine seedbed before seeding the crops. CT and ZT wheat was sown using tractor mounted seed-cum-fertilizer drill. In both CT and ZT, seeds were placed at 2-3 cm depth in dry soil.

Crop management

Wheat cultivar 'HD 2967' (double dwarf with 135 days duration) was done in the third week of November with 100 kg ha^{-1} seed. All the plots received 150 kg N as urea and di-ammonium phosphate (DAP), 60 kg P_2O_5 as DAP, and 40 kg K_2O as muriate of potash per hectare. Full dose of phosphorus and potash and 1/3rd of nitrogen were placed 2-3 cm below the seed as basal dose using ferti-seed drill (conventional/zero) at the seeding. Remaining 2/3rd nitrogen were applied in two equal splits at CRI stage (25 DAS) and maximum tillering stage (55 DAS). Four irrigations were given during reproductive stage due to lack of precipitation. Wheat was harvested manually with sickle at a height of 10–12 cm from ground level in the first week of April and threshed by thresher.

Observations

Chemical analysis of plant samples

At harvest of the crops, the samples of grain and straw from wheat was taken. These samples were first dried under the sun and then oven dried at 65 ^{0}C till a constant weight was reached. The grain samples were finely ground in a small grinding mill while the straw samples were finely ground in a Wiley Mill. These straw and grain samples were used for the estimat on the nitrogen, phosphorus and potassium content.

Nitrogen content and uptake

The samples obtained as mentioned above were tested for determining the nitrogen content through modified Micro-Kjeldhal's method (Subbiah and Asija, 1956). Oven dried 0.5 g sample was subjected to wet digestion using 10 ml concentrated sulphuric acid plus pinch of digestion mixture. Digested material was taken in a 50 ml volumetric flask and the volume was made to 50 ml by adding distilled water. In the distillation flask of Micro-Kjeldhal's assembly, 5 ml of distilled sample was taken and 10 ml of sodium hydroxide was poured into tube. Flask containing 10 ml boric acid 4 % was kept under consideration until the appearance of green colour. Then distilled sample was titrated against N/50 sulphuric acid until appearance of purple colour. Volume of N/50 H_2SO_4 used was recorded for N content calculation. The nitrogen uptake was calculated by multiplying the percent N content of sample grain and straw with its respective grain yield and straw yield. It was expressed as kg ha^{-1}.

N uptake (kg ha^{-1}) by grain/straw = [% N content in grain/straw × grain/straw yield (kg ha^{-1})]

Total uptake of N (kg ha^{-1}) = N uptake by grain (kg ha^{-1}) + N uptake by straw (kg ha^{-1})

Phosphorus content and uptake

The 0.5 g oven dried grounded sample was digested in triple acid mixture, *i.e.* nitric acid (HNO_3), perchloric acid ($HClO_4$) and sulphuric acid (H_2SO_4) in the ratio of 9:3:1, respectively. The intensity of colour developed was measured by using Spectronic-20 Colorimeter at wavelength of 470 nm using blue filter. Percent content of phosphorus in different samples was multiplied by respective grain and straw yields to calculate the phosphorus uptake. It was expressed as kg ha^{-1}.

P uptake (kg ha^{-1}) by grain/straw = [% P content in grain/straw × grain/straw yield (kg ha^{-1})]

Total uptake of P (kg ha^{-1}) = P uptake by grain (kg ha^{-1}) + P uptake by straw (kg ha^{-1})

Potassium content and uptake

The aliquot (digested material of different samples) used for phosphorus determination, was used for the determination of potassium content in different samples using Lange's Flame Photometer (Jackson, 1973). The reading from photometer was compared with standard curve to calculate the potassium content in samples. The potassium uptake by different samples (kg ha^{-1}) was calculated by multiplying per cent content of potassium with their respective grain and straw yields.

K uptake (kg ha^{-1}) in grain/straw = [% K in grain/straw × grain/straw yield (kg ha^{-1})]

Total uptake of K (kg ha^{-1}) = K uptake in grain + K uptake in straw

Protein content and productivity

Crude protein content in grains was calculated by multiplying the percent nitrogen content in grain with a factor 6.25. While protein production calculated by multiplying the percent protein content in grain with their respective grain yield.

Yield and yield attributes

One meter row length was selected from two different randomly selected spots in the wheat plots. The total numbers of spike were counted and the average count of these was expressed as number of spikes per square meter area. The ten spikes selected for grains count were threshed. Their average was taken as the number of grains per spike from that plot. From the grain stock of each net plot, 1000

Table 1. Weather data during wheat crop.

Month	Max Temp. (°C)		Min. Temp. (°C)		Sunshine Duration (hrs.)		Rainfall (mm)	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
Nov.	26.9	28.5	12.7	15.0	117.9	92.1	0.0	10.0
Dec.	23.4	23.6	7.2	5.6	190.8	215.3	22.8	0.0
Jan.	21.2	25.0	4.7	7.7	189.9	244.6	17.9	0.0
Feb.	24.3	25.8	9.3	7.9	192.5	229.9	1.0	4.0
Mar	29.5	34.4	16.2	15.4	223.8	300.8	91.0	18.4
Apr	36.8	36.7	22.6	17.7	124.1	123.2	2.0	0.0

grains were taken to form a representative sample. After drying and cleaning, the weight of these 1000 grains was recorded and expressed in grams. Grain yield obtained from net plot area which was harvested separately. It was tied into bundles and weighed for recording total biological yield. Then these samples (bundles) were threshed in a thresher. The grains thus obtained were cleaned and weighed, and expressed in kg ha^{-1} and total biological yield of each net plots, the weight of grain was subtracted to obtain the weight of straw, which was expressed as straw yield in kg ha^{-1}.

Results and Discussion

NPK uptake by wheat

Different tillage combinations and residue management practices significantly influenced mean (2019-20 and 2020-21) nitrogen, phosphorus and potassium uptake by wheat grain and straw as well as by total biomass (Table 1). However maximum nitrogen (93.81 kg ha^{-1}), phosphorus (27.10 kg ha^{-1}) and potassium (64.85 kg ha^{-1}) uptake by wheat recorded under conventionally tilled wheat sown after conventionally tilled rice (CT-CT) and it was statistically at par with conventionally tilled wheat sown after zero tilled rice (ZT-CT), whereas lower mean nitrogen (82.46 kg ha^{-1}), phosphorus (22.92 kg ha^{-1}) and potassium (56.68 kg ha^{-1}) uptake by wheat recorded under zero tilled wheat sown after zero tilled rice (ZT-ZT). Conventionally tilled wheat resulted higher nutrient uptake than zero tillage during both the years which could be due to higher nutrient concentration and dry matter production. Gupta and Seth *et al*. (2007) also reported the similar result.

While in case of residue management practices, maximum mean nitrogen (98.78 kg ha^{-1}), phosphorus (28.52 kg ha^{-1}) and potassium (68.37 kg ha^{-1}) uptake by wheat observed under residue applied in wheat and rice both crops (R-R) and it was closely followed by residue applied in wheat crop only (NR-R), whereas minimum mean nitrogen (77.11 kg ha^{-1}), phosphorus (21.46 kg ha^{-1}) and potassium (52.68 kg ha^{-1}) uptake by wheat observed under without residue mulch in both crops (NR-NR). This may be because of the fact that split top dressing of nitrogenous fertilizer along with residue reduced the C: N ratio of rice straw, which favours faster mineralization and helps in release of organically bound N, P_2O_5 and K_2O, thus, increased the availability of nutrients to crop plants. Sharma *et al.* (2005); Surya *et al.* (2006) also supported this findings.

Protein content and productivity

Different tillage practices significantly did not influenced protein content but residue management practices significantly influenced protein content in wheat grain and protein productivity per hectare (Table 2).

Table 1. Effect of tillage and residue management on NPK uptake by wheat in rice-wheat cropping system.

Treatments		Total N uptake (kg ha^{-1})			Total P uptake (kg ha^{-1})			Total K uptake (kg ha^{-1})		
Tillage		2019-20	2020-21	Mean	2019-20	2020-21	Mean	2019-20	2020-21	Mean
Rice	Wheat									
CT	CT	92.58	95.05	93.81	26.44	27.76	27.10	63.87	65.83	64.85
CT	ZT	85.51	88.18	86.85	24.08	25.26	24.67	58.87	60.73	59.80
ZT	CT	89.93	92.24	91.08	25.32	26.46	25.89	61.78	63.38	62.58
ZT	ZT	80.90	84.03	82.46	22.28	23.57	22.92	55.56	57.81	56.68
SEm±	1.59	1.05	1.00	0.52	0.40	0.40	1.37	0.82	0.91	
CD (P=0.05)	5.50	3.63	3.46	1.81	1.38	1.37	4.74	2.85	3.13	
Residue Management										
No Res	No Res	76.69	77.54	77.11	21.27	21.65	21.46	52.42	52.93	52.68
Res	No Res	86.88	88.80	87.84	24.31	25.30	24.80	59.84	61.18	60.51
No Res	Res	88.95	92.00	90.48	25.11	26.49	25.80	61.24	63.47	62.36
Res	Res	96.40	101.15	98.78	27.42	29.61	28.52	66.57	70.17	68.37
SEm±	2.85	3.29	3.00	0.87	1.24	1.09	1.90	2.39	2.18	
CD (P=0.05)	8.32	9.60	8.76	2.53	3.61	3.19	5.54	6.97	6.36	
Interaction										
SEm±	3.65	3.84	3.26	1.05	1.10	0.95	3.11	2.72	2.30	
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	

However maximum mean protein content in wheat grain (9.75 %), and protein production by wheat (424.7 kg ha^{-1}) were observed in CT-CT and was closely followed by ZT-CT where protein content in grain (9.63 %) and protein production (412.5 kg ha^{-1}) were observed but lower protein content and productivity obtained 9.39 % and 372.2 kg ha^{-1} with continuous zero tillage practices respectively. Under different residue management practices, application of residue mulch in both crops (R-R) had higher protein content in grain (9.93 %) and protein production (446.7 kg ha^{-1}) were recorded during the experimentation whereas lower protein content (9.21 %) and protein production (349.2 kg ha^{-1}) were observed with no residue in both crops. It might be due to conventional tillage and residue mulch produce comparatively higher grain yield and higher nitrogen content in grain, nitrogen is a constituent of protein. Conventional tillage and residue mulch provide favorable environment for crop growth at grain formation stage which increase nitrogen content in grain resulting higher protein content and productivity. This result was conformity with Gupta and Seth *et al*. (2007)**.**

Yield attributes and yield

Grain and straw yield and yield attributes *viz*., number of spikes per square meter and number of grains per spike significantly influenced by tillage as well as residue management practices except 1000-seed weight (Table 3).

Higher two year mean number of spikes m^{-2} (298), number of grains $spike^{-1}$ (44), 1000-seed weight (44.88 g), grain (4343 kg ha^{-1}) and straw yield (4726 kg ha^{-1}) were recorded under conventionally tilled wheat sown after conventionally tilled rice (CT-CT) and it was significantly at par with conventionally tilled wheat sown after zero tilled rice (ZT-CT) where number of spikes m^{-2} (286), number of grains $spike^{-1}$ (42), 1000-seed weight (44.73 g), grain (4276 kg ha^{-1}) and straw yield (4666 kg ha^{-1}) were recorded. Whereas lower mean number of spikes m^{-2} (265), number of grains $spike^{-1}$ (39), 1000-seed weight (44.44 g), grain (3958 kg ha^{-1}) and straw yield (4410 kg ha^{-1}) were recorded under zero tilled wheat sown after zero tilled rice (ZT-ZT). Higher yield attributes and yield were recorded under conventional tillage might be due to in conventional tillage soil become soft during field preparation. Under soft soil the roots of crop grow better as compared to zero tillage. Better root growth helps the plant to extract more nutrients from the soil and more nutrient uptake was there by the crop. In zero tillage higher immobilization and C: N ratio may be the reason of lower yield. Similar result was also reported by Singh *et al*. (2006).

Among residue management practices, residue applied in wheat and rice both crop (R-R) had

Table 2. Effect of tillage and residue management on protein content in wheat grain and protein production of wheat in rice-wheat cropping system.

Treatments		Protein content in grain (%)			Protein production by wheat (kg ha^{-1})		
Tillage		2019-20	2020-21	Mean	2019-20	2020-21	Mean
Rice	Wheat						
CT	CT	9.71	9.80	9.75	419.5	429.9	424.7
CT	ZT	9.47	9.54	9.51	387.6	399.1	393.4
ZT	CT	9.60	9.66	9.63	407.4	417.6	412.5
ZT	ZT	9.37	9.42	9.39	365.7	378.7	372.2
SEm±	0.11	0.13	0.13	7.38	8.17	6.95	
CD (P=0.05)	NS	NS	NS	25.5	28.3	24.0	
Residue Management							
No Res	No Res	9.19	9.23	9.21	347.4	350.9	349.2
Res	No Res	9.50	9.57	9.53	393.7	401.2	397.4
No Res	Res	9.58	9.65	9.61	403.0	415.9	409.5
Res	Res	9.88	9.98	9.93	436.2	457.2	446.7
SEm±	0.12	0.15	0.14	12.13	16.50	14.78	
CD (P=0.05)	0.35	0.44	0.37	35.4	48.2	43.1	
Interaction							
SEm±	0.13	0.12	0.10	16.0	19.3	15.9	
CD (P=0.05)	NS	NS	NS	NS	NS	NS	

Table 3. Effect of tillage and residue management on yield and yield attributes of wheat in rice-wheat cropping system.

Treatments		No of spikes m^{-2}			No of grains spike^{-1}			1000-seed weight (g)			Grain Yield (kg ha^{-1})			Straw Yield (kg ha^{-1})		
Tillage																
Rice	Wheat	2019-20	2020-21	Mean	2019-20	2020-21	Mean	2019-20	2020-21	Mean	2019-20	2020-21	Mean	2019-20	2020-21	Mean
CT	CT	294	303	298	43	45	44	44.77	44.99	44.88	4311	4376	4343	4710	4741	4726
CT	ZT	270	283	276	40	42	41	44.47	44.70	44.58	4088	4178	4133	4502	4567	4535
ZT	CT	281	291	286	42	43	42	44.61	44.84	44.73	4238	4314	4276	4647	4684	4666
ZT	ZT	257	273	265	39	40	39	44.33	44.54	44.44	3901	4015	3958	4346	4474	4410
SEm±	6	5	5	0.8	0.7	0.7	0.54	0.62	0.55	61	53	55	53	48	48	
CD (P=0.05)	20	17	19	2.6	2.3	2.4	NS	NS	NS	211	184	190	185	167	165	
Residue Management																
No Res	No Res	250	251	251	38	38	38	43.40	43.61	43.50	3778	3802	3790	4202	4213	4207
Res	No Res	267	278	272	40	42	41	44.20	44.39	44.29	4145	4193	4169	4570	4598	4584
No Res	Res	285	297	291	41	44	43	44.92	45.16	45.04	4206	4310	4258	4626	4715	4670
Res	Res	301	323	312	44	46	45	45.67	45.91	45.79	4409	4577	4493	4807	4942	4874
SEm±	8	9	9	1.2	1.0	0.9	0.45	0.43	0.33	73	94	84	74	108	81	
CD (P=0.05)	22	28	26	3.4	2.9	2.7	NS	NS	NS	214	273	246	216	314	235	
Interaction																
SEm±	15	15	11	2.5	2.0	1.8	0.90	0.86	0.67	147	187	148	251	215	161	
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	

higher mean number of spikes m^{-2} (312), number of grains spike^{-1} (45), 1000-seed weight (45.79 g), grain (4493 kg ha^{-1}) and straw yield (4874 kg ha^{-1}), and it was closely nearby residue applied in wheat crop

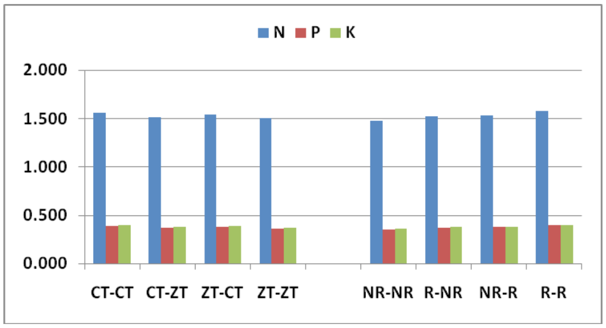

Fig. 1(a). NPK content in grain during 2019-20

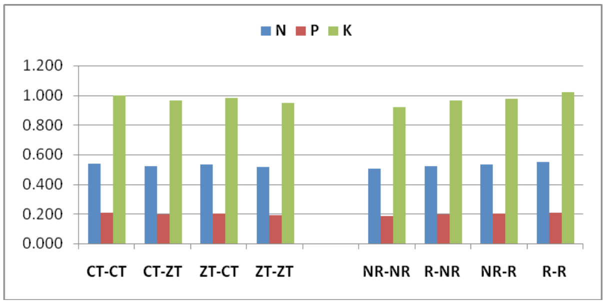

Fig. 1(b). NPK content in straw during 2019-20

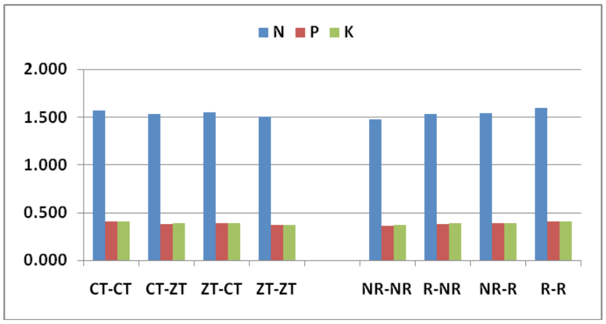

Fig. 2(a). NPK content in grain during 2020-21

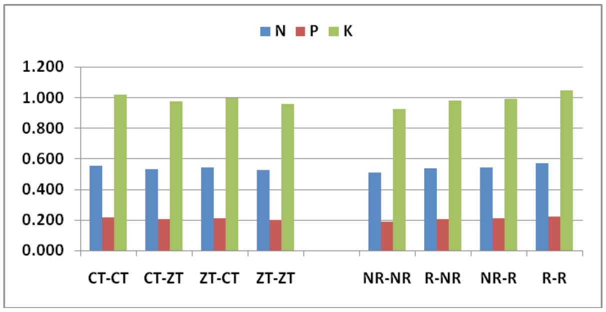

Fig. 2(b). NPK content in straw during 2020-21 only (NR-R) whereas lower mean number of spikes m^{-2} (251), number of grains spike^{-1} (38), 1000-seed weight (43.50 g), grain (3790 kg ha^{-1}) and straw yield (4207 kg ha^{-1}) were recorded under without residue in both crops. It might be due to favourable soil moisture, moderated soil temperature, and improved soil fertility due to constant supply of nutrients through mineralization of crop residues. Similarly, Ram *et al.* (2010) reported similar results under residue retained treatment.

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