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Crop Residues Management with Different Crop Establishment Methods in Rice (*Oryza sativa* L.)–Wheat (*Triticum aestivum* L.) Cropping System

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted during *Kharif* and *rabi* seasons of 2015 and 2016 at farmer's field of Banka District as an On Farm Trial to study the crop residues management with different crop establishment methods in rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L.) cropping system. Treatment comprised two levels of crop residue management *ie.* residue removal and residue retention (33%) and three levels of crop establishment methods *ie.* (a) conventional puddled transplanted rice *fb* conventional-till wheat (PTR-CTW), two times ploughing with cultivator followed by two times puddling and one planking was done before the manual transplanting of 21 days old seedling at 20 cm spacing from row to row. After rice harvesting, wheat was sown by broadcasting in conventional tillage plots with two times harrowing with cultivator followed by one planking; (b) unpuddled transplanted rice *fb* zero-till wheat (UPTR-ZTW): two times ploughing with cultivator followed by planking, after that water is submerged for transplanting and wet tillage was avoided. 21 days old rice seedlings were transplanted at a spacing of 20 x 15 cm. Wheat crop was sown under ZT using zero tillage machines; (c) zero-till direct-seeded rice *fb* zero-till wheat (ZTDSR-ZTW): direct-seeding of rice was done using zero-till seed-cum-fertilizer drill in ZT-flat plots at 20 cm row spacing. Wheat crop was sown in zero tillage using zero till machine. Rice variety (*Rajendra Sweta*) was sown directly by zero till in ZTDSR-ZT plots in the first fortnight of June. On the same date, rice

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seedlings for transplanting were raised in nursery by ‘Wet bed method’. Experiment was conducted in a split plot design which is replicated by thrice. Grain/panicle or spike, panicle or ear length and effective tillers/m^2 recorded more in residue retention treatment and it was registered significantly superior with residue removal treatment under crop residue management in rice and wheat crop during both the years of experiment. Amongst crop establishment method, ZTDSR-ZTW was recorded more Grain/panicle or spike, panicle or ear length and effective tillers/m^2 and it was significantly superior with UPTR-ZTW and PTR-CTW treatments under crop establishment methods in rice and wheat crop during both the years of experiment. Residues retention (33%) significantly improved the grain yield of both the component crops. For rice crop, 8.2–10.0% higher grain yield was realized with retention of crop residues. Grain and straw yield of rice were registered more in ZTDSR-ZTW (3.86-3.99 t/ha) & (5.56-5.75 t/ha) closely followed by UPTR-ZTW (4.38-4.45 t/ha). Concerning the data of residue management on economics revealed that the residue retention was recorded more gross return, net return as well as B: C ratio followed by residue removal treatment in both years of experimentation for rice and wheat crop and ZTDSR-ZTW was recorded more gross return, net return as well as B: C ratio followed by UPTR-ZTW and PTR-CTW treatments under crop establishment methods in rice and wheat crop during both the years of experiment.

Keywords: Direct-seeded rice; Economics; productivity; residue retention; unpuddled transplanting; tillage; zero tillage transplanting.

1. INTRODUCTION

Crop residues are good sources of plant nutrients, are the primary source of organic matter (as C constitutes about 40% of the total dry biomass) added to the soil, and are important components for the stability of agricultural ecosystems. About 40% of the N, 30-35% of the P, 80-85% of the K, and 40-50% of the S absorbed by rice from vegetative growth to maturity [1]. Similarly, about 25-30% of N and P, 35-40% of S, and 70-75% of K uptake are retained in wheat residue. Typical amounts of nutrients present in rice straw at harvest are 5-8 kg N, 0.7-1.2 kg P, 12-17 kg K, 0.5-1 kg S, 3-4 kg Ca, 1-3 kg Mg, and 40-70 kg Si per ton of straw on a dry weight basis [2]. Rice-wheat cropping system (RWCS) has been developed through the introduction of rice in the traditional wheat-growing areas and vice versa in India [3]. Recycling of rice residue poses more problems to succeeding wheat than wheat straw to the following rice crop because of the shorter window between rice residue incorporation and wheat sowing, and the slow rate of decomposition of rice straw due to high silica content and low temperature. Presently, the RWCS covers an area of 10.5 million ha in India [4]. The productivity and sustainability of the RWCS is very crucial for the country’s food security and livelihood of farmer’s community in the Indo-Gangetic plain zone [5]. However, several major challenges are now progressively being evident in RWCS like degradation of soil native fertility and multi-nutrient deficiency, the decline in watertable and increased pest pressure including weeds [6,7,8,9]. In the post-green revolution era, resource conservation issues have assumed greater importance in view of the widespread land and water degradation problems due to mechanized intensive tillage in RWCS [10]. Several alternative rice-establishment practices and conservation tillage practices are now being advocated for RWCS [11,12] in place of puddle transplanted rice- conventional till wheat (PTR-CTW). Under this critical situation, it becomes obligatory to focus on aim oriented research to lift the rice and wheat yields to fulfil large gaps between biologically and climatically achievable potential yield. In this context several resource-conserving technologies (RCTs) such as zero tillage (ZT), reduced tillage (RT) and unpuddled transplanting have been found to be beneficial in terms of improving soil health, water use, crop productivity and farmer’s income [13,4]. The unpuddled transplanting of rice, direct-seeding of rice, ZT technology with direct-seeding of rice and successive wheat-crop establishment under ZT often recommended for conserving the natural resources and improving the sustainability of RWCS [14]. Potential productivity and assured high returns could be realized from these alternative tillage practices in RWCS, which also improves the livelihood of the farmers of the region. ZT and surface maintained crop residues result in resource improvement gradually and benefits come about only with time [15]. Therefore, as major components of crop residue management in RWCS suitable tillage-cum-crop-establishment techniques has to be identified based on system productivity, resource-conservation efficiency and profitability.

The present investigation is an attempt to evaluate the crop residues management with different crop establishment methods in rice-wheat cropping system.

2. MATERIALS AND METHODS

A field experiment was conducted during *Kharif* and *rabi* seasons of 2015 and 2016 at farmer's field of Banka District as an On Farm Trial to study the crop residue management with different crop establishment methods in rice–wheat cropping system. The geographical location of the farm lies at 24°30' N latitude and 86°30' E latitude at an altitude of 79 m from the mean sea level. The soil of experimental site was sandy-clay-loam in texture with neutral pH value (7.36). It was low in organic C (0.44%) and available N (183.4 kg/ha), medium in available P (14.2 kg/ha) and K (207.1 kg/ha). Treatment comprised two levels of crop residue management *ie.* residue removal and residue retention (33%) and three levels of crop establishment methods *ie.* (a) conventional puddled transplanted rice *fb* conventional-till wheat (PTR-CTW): two times ploughing with cultivator followed by two times puddling and one planking was done before the manual transplanting of 21 days old seedling at 20 cm spacing from row to row. After rice harvesting, wheat was sown by broadcasting in conventional tillage plots with two times harrowing with cultivator followed by one planking; (b) unpuddled transplanted rice *fb* zero-till wheat (UPTR-ZTW): two times ploughing with cultivator followed by planking, after that water is submerged for transplanting and wet tillage was avoided. Rice seedlings of 21 days old were transplanted at 20 x 15 cm spacing. Wheat crop was sown under ZT using zero tillage machines; (*c*) zero-till direct-seeded rice *fb* zero-till wheat (ZTDSR-ZTW): direct-seeding of rice was done using zero-till seed-cum-fertilizer drill in ZT-flat plots at 20 cm row spacing. Wheat crop was sown in zero tillage using zero till happy-seeder machine. Rice variety (*Rajendra Sweta*) was sown directly by zero till in ZTDSR-ZT plots in the first fortnight of June. On the same date, rice seedlings for transplanting were raised in nursery by 'Wet bed method'. Twenty-one days old seedling was transplanted in the plots with different tillage practices (PTR-CTW and UPTR-ZTW) was conducted in a split plot design replicated thrice. An uniform fertilizer dose of 120, 60, 60 kg N, P_2O_5 and K_2O/ha and 120, 60, 40 kg N, P_2O_5 and K_2O/ha in the form of urea, di-ammonium phosphate and muriate of potash was applied to each experimental unit of paddy and wheat, respectively. Full dose of phosphorus, potassium and half dose of nitrogen were applied at the time of sowing and remaining half dose of nitrogen was top dressed in two split doses two split doses after 30 and 60 days after sowing/ transplanting. The wheat crop (variety 'HD 2967') was sown in the second fortnight of November with the help of row spacing of 22.5 cm and manually broadcasted in conventional plot (PTR-CTW). Data on yield attributes, grain yield and straw yield were recorded from the net plot, whereas tillers density was measured by using quadrat of 0.5 m × 0.5 m by selecting 2 spots randomly and density was expressed in number of tillers/m^2 at the time of harvest. The economics of treatments was computed on the basis of prevailing market prices of inputs and outputs under each treatment. For calculating economics of the systems, the input costs of all the items like tillage operation, costs of seed, herbicide application, chemical fertilizers and the hiring charges of human labour and machines for land preparation, irrigation, fertilization, harvesting, and threshing were used in cost of cultivation. While, gross output was calculated based on the grain and straw price produced from the field. The benefit: cost ratios were calculated for each treatments applied in the system as the ratios of net returns to cost of cultivation. The data collected for all parameters at different crop stages were compiled and subjected to statistical analysis using the analysis of variance technique [16] and the critical difference (at 5% level of probability) was computed for comparing treatment.

3. RESULTS AND DISCUSSION

3.1 Yield Attributes

Grain/panicle or spike, panicle or ear length and effective tillers/m^2 recorded more in residue retention (33%) treatment and it was significantly superior with residue removal treatment under crop residue management in rice and wheat crop during both the years of experiment. Yield attributes were recorded more, might be due to presence of crop residue around seeds can impede adequate seed-to-soil contact needed for good crop emergence, crop growth, maintains soil temperature as well as soil moisture and increasing the macro porosity which is known to decrease the degree of contact.

Amongst crop establishment method, ZTDSR-ZTW was recorded more grain/panicle or spike,

Table 1. Effect of crop residues management with different crop establishment methods in rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L.) cropping system on yield attributes

Treatment	Yield attributes															
	Grain/panicle and spike				1000-grain weight (g)				Panicle and ear length (cm)				Effective tiller/m^2			
	2015-16		2016-17		2015-16		2016-17		2015-16		2016-17		2015-16		2016-17	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
Residue management																
Residue removal	208.67	38.83	211.56	37.71	16.34	37.89	15.34	38.01	19.23	7.22	19.23	7.18	246.43	128.56	251.22	131.86
Residue retention	222.23	42.99	226.66	43.19	15.82	38.11	16.39	36.99	22.39	7.99	22.39	8.06	292.55	176.33	299.66	168.35
SEm±	5.42	2.00	6.21	2.00	-	-	-	-	1.01	0.24	1.01	0.25	9.54	10.22	10.55	11.11
CD (P=0.05)	16.24	6.01	18.96	6.01	NS	NS	NS	NS	3.12	0.70	3.12	0.77	28.65	30.56	33.12	33.76
Crop establishment methods																
PTR-CTW	202.11	39.76	205.78	39.99	15.09	38.93	16.38	37.28	18.67	6.92	18.99	6.98	254.33	131.09	260.11	133.65
UPTR-ZTW	218.91	42.13	221.41	43.13	17.01	37.56	15.37	36.69	20.85	7.19	21.16	7.13	270.56	153.21	273.41	154.61
ZTDSR-ZTW	233.82	45.38	239.52	46.12	16.48	37.28	17.33	38.28	23.91	8.81	24.20	9.14	289.32	182.23	292.01	186.71
SEm±	4.65	1.61	4.78	1.61	-	-	-	-	0.95	0.51	0.91	0.49	5.40	8.04	5.55	8.52
CD (P=0.05)	14.1	4.78	15.19	4.88	NS	NS	NS	NS	2.88	1.55	2.70	1.52	15.92	24.09	16.37	25.71

PTR-CTW- Puddled transplanted rice fb conventional-till wheat; UPTR-ZTW- Unpuddled transplanted rice fb zero-till wheat; and ZTDSR-ZTW- Zero-tillage direct-seeded rice fb zero-till wheat

Table 2. Effect of crop residues management with different crop establishment methods in rice-wheat cropping system on grain yield, straw yield, system productivity and economics (Mean data of 2 years)

Treatment	Grain yield (t/ha)				Straw yield (t/ha)				System productivity (t/ha)		Economics (Rice and wheat)		
	2015-16		2016-17		2015-16		2016-17		2015-16	2016-17	GR ($\times 10^3$/ha)	NR ($\times 10^3$ /ha)	B:C Ratio
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat			
Residue management													
Residue removal	3.44	2.96	3.42	2.94	4.95	4.26	4.92	4.23	6.40	6.36	115.73	79.66	2.03
Residue retention	3.75	3.13	3.80	3.22	5.40	4.51	5.47	4.64	6.88	7.02	119.11	88.65	2.31
SEm±	0.03	0.02	0.04	0.03	0.05	0.04	0.06	0.05	0.08	0.09	-	-	-
CD (P=0.05)	0.09	0.07	0.10	0.08	0.16	0.11	0.19	0.14	0.25	0.26	-	-	-
Crop establishment methods													
PTR-CTW	3.09	2.66	3.12	2.61	4.45	3.83	4.38	3.76	5.75	5.65	99.42	69.23	1.75
UPTR-ZTW	3.38	3.06	3.47	3.10	4.92	4.41	5.00	4.46	6.34	6.57	116.91	84.78	2.15
ZTDSR-ZTW	3.86	3.33	3.99	3.40	5.56	4.80	5.75	4.90	7.19	7.39	122.97	91.23	2.44
SEm±	0.07	0.08	0.10	0.08	0.10	0.11	0.11	0.10	0.13	0.14	-	-	-
CD (P=0.05)	0.22	0.25	0.30	0.24	0.31	0.34	0.32	0.32	0.40	0.43	-	-	-

REY-Rice-equivalent yield (t/ha); PTR-CTW- Puddled transplanted rice fb conventional-till wheat; UPTR-ZTW- Unpuddled transplanted rice fb zero-till wheat; ZTDSR-ZTW- Zero-tillage direct-seeded rice fb zero-till wheat, GR- Gross return, NR- Net return and B:C ratio-Benefit: Cost ratio panicle or ear length and effective tillers/m^2 and it was significantly superior with UPTR-ZTW and PTR-CTW treatments under crop establishment methods in rice and wheat crop during both the years of experiment. However, the differences in 1,000-grain weight were also non-significant due to crop residue management and crop establishment methods.

3.2 Grain, Straw Yield and System Productivity

In the present study, residues retention (33%) significantly improved the grain and straw yield of both the component crops. For rice crop, 8.2–10.0% higher grain yield was realized with retention of crop residues. Likewise, residues retention increased the wheat grain yield by 8.69-9.90% (Table 1). In consistent with our results, [17,18] also reported the improved crop productivity with residues retention in rice-wheat cropping system. The crop residue retention practice had improved the grain yield of both rice and wheat crop over conventional puddled transplanted rice. The grain yield in ZT was significantly higher owing to greater number of ear-bearing tillers/m^2. This might have resulted from greater sink and good growth in the reproductive phase also there may be a positive impact of ZT and residues on soil water balance, because of reduction in soil evaporation and better soil water retention that ultimately increased wheat yields [6,19,12]. Similarly, higher system productivity is due to fact that ZT and residues retention increased the crop yield component by improving soil condition, with higher soil water content and other soil physical, chemical and biological properties.

Amongst crop establishment methods, grain and straw yield of rice were registered more in ZTDSR-ZTW (3.86-3.99 t/ha) & (5.56-5.75 t/ha) closely followed by UPTR-ZTW (3.38–3.47 t/ha) & (4.92-5.00 t/ha) and recorded the least in PTR-CTW (3.09–3.12 t/ha) & (4.38-4.45 t/ha). Like rice crop, wheat grain and straw yield was also higher in ZT-based crop establishment and higher yield was realized in ZTDSR-ZTW (3.33–3.40 t/ha) indicating that the tillage practices adopted in preceding rice crop may impact largely to the successive wheat crop (Table 2). Indeed, wheat crop was particularly suffered after puddling for rice which can be attributed to poor rooting due to soil compaction and poor aggregation, as reported by other researchers in the region [20,11,21]. The increased grain and straw yield of rice and wheat was mainly associated with the increased tiller formation under zero tillage crop-establishment practices.

3.3 Economics

Concerning the data of residue management on economics revealed that the residue retention was recorded more gross return, net return and B: C ratio followed by residue removal treatment in both years of experimentation for rice and wheat crop. The positive effects of zero tillage and residue management on yield were well reflected into more favorable economics both for rice and wheat production and thus for the system as well. Higher net returns in zero tillage direct seeded rice systems can be attributed mainly to reduced cost of production. Zero tillage resulted in lower cost of cultivation because of less use of machinery, labour and less fuel cost.

4. CONCLUSION

It can be concluded that crop residue retention (33%) and zero-tillage crop establishment of rice and wheat crop could improve the crop production, yields and economics of farm income in rice-wheat cropping system.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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