International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 14, No. 3, p. 221-236, 2019

INNSPUB

RESEARCH PAPER OPEN ACCESS

Crop residue management in rice-wheat system of Pakistan and its impact on yield and nutrient uptake

Ijaz Ali[1*], Ghulam Nabi[1], Shahid Maqsood Gill[1], Muhammad Mahmood-ul-Hassan[1], Imtiaz Hussain[2]

[1]*Land Resources Research Institute, National Agricultural Research Centre, Park Road, Islamabad-45500, Pakistan*

[2]*Crop Sciences Research Institute, National Agricultural Research Centre, Park Road, Islamabad-45500, Pakistan*

Key words: Crop residue management, Rice-wheat cropping system, Yield, Plant nutrient uptake, Soil nutrient status.

http://dx.doi.org/10.12692/ijb/14.3.221-236 Article published on March 27, 2019

Abstract

Heavy tillage in rice-wheat (RW) system has been resulting in deterioration of soil structure consequently reducing farm productivity. *In situ* burning of crop residue after combine harvesting further aggravates the problems. Hence, wise crop residue management practices (CRMPs) can be a better option for sustainable productivity in the RW system. Different CRMPs (residue removal (RR); residue burning (RB), residue incorporation (RI) and zero-tillage (ZT)) were investigated for four cropping seasons under field conditions in RW area at two farmers' fields. Rice paddy (12%) and straw (4%) yields and wheat grain (17%) and straw (3%) yields were generally higher at Ratta Ber Farm than Shahbaz Farm. Among various CRMPs, RI produced significantly higher paddy and straw yields of rice and grain and straw yields of wheat. Nitrogen (N), phosphorus (P) and potassium (K) uptake in rice as well as in wheat was significantly higher with RI as compared to other CRMPs. N, P and K uptake in wheat was 15, 11 and 11% higher, at Ratta Ber Farm as compared to Shahbaz Farm, respectively. Soil NO_3-N and P_2O_5 contents were significantly higher with RI followed by ZT as compared to RR and RB at both sites. Soil K_2O contents were significantly higher with RB, RI and ZT as compared to RR at both sites. The results revealed that there was improvement in soil nutrients by crop residue incorporation as well as zero-tillage at both sites, however crop productivity improved only by crop residue incorporation.

* **Corresponding Author:** Ijaz Ali ✉ ijaznarc@gmail.com

Introduction

Rice-wheat (RW) is the major cropping system in South Asia and practiced on about 13.5 million hectares in the Indo-Gangetic Plains (IGP) – Bangladesh, India, Nepal, and Pakistan (Ladha *et al.*, 2000; Dawe *et al.*, 2004). This system contributes 72, 85, 87, 100 and 71% of the cereal production in China, India, Pakistan, Bangladesh and Nepal respectively (Singh and Paroda, 1994; Yadav *et al.*, 1998; GoP, 2011). In Pakistan, this system is practiced over 2.2 million hectares (Mandal *et al.*, 2004) and nearly 75% of this area occurs in Punjab province of Pakistan (GoP, 2011). So far, this cropping system has successfully maintained food supply in accordance with population growth but many long-term studies (Ladha *et al.*, 2003, 2009; Pathak *et al.*, 2003; Tirol-Padre and Ladha, 2006) have shown stagnation or even decline in crop productivity. reported that the actual yields in the RW system of Pakistan are well below the potential (Byerlee *et al.*, 1984; Sheikh *et al.*, 2000). Main constraints are decreasing soil organic matter (Pathak *et al.*, 2003), nutrient deficiencies (Bhatt *et al.*, 2016; Khurana *et al.*, 2008) and deterioration of soil structure (Sharma *et al.*, 2005). The major reason of low soil organic carbon could be the use of mineral fertilizers alone (Pichot*et al.*, 1981), resulting in deterioration of soil structure (Jastrow *et al.*, 1996; Six *et al.* 1998) and thus higher yields due to mineral fertilizers does not remain sustainable in the long run (Bationo*et al.*, 2004). Further, seedbed preparation of anaerobic rice (puddling of wet soil for lowering permeability by creating plow-pan) also contributes to deteriorate soil structure (Aggarwal *et al.*, 1995; Kukal and Aggarwal, 2003a; Sharma and De Datta, 1986).The formation of plow-pan consequently restricts root growth and proliferation of following upland wheat crop in lowland RW cropping system (Hobbs and Gupta, 2002; Hobbs *et al.*, 2002; Kukal and Aggarwal, 2003b; Tripathi *et al.*, 2003; Sharma *et al.*, 2005).

About 10-14 Mg ha^{-1} crop residues are produced in RW cropping system of the IGP (Samra *et al.*, 2003). Before the advent of mechanized harvesting, whole residues were taken away for off-field use. With the introduction of combined harvester, large amounts of crop residues are left in the field, which obstruct conventional seedbed preparation for following wheat crop. Removal of these crop residues from field is very laborious, so farmers burn them in the field to get rid of them easily. In IGP, about 75% of crop residues are burned (Badrinath *et al.*, 2006) adversely affecting the environment and agro-ecosystem. Both, crop residue removal and burning are the basic causes of soil degradation in resource poor countries (FAO, 1990). Crop residue incorporation is a potential alternative and has significant beneficial impact on soil health – recycling of nutrients to the soil and increase soil organic carbon (Kone *et al.*, 2010; Krishna *et al.*, 2004; Kumar and Goh, 2000; Samra *et al.*, 2003).

Wet tillage (puddling) results in late sowing of the following wheat crop ultimately resulting in low yields (Gopal and Kumar, 2010; Hobbs and Gupta, 2003). Puddling also destroys soil structure, which adversely affects growth and yield of ensuing upland crops in the sequence (Gathala *et al.*, 2011; Sharma *et al.*, 2003). The late sowing of wheat can be dealt with zero tillage for wheat sowing, which can reduce cultivation costs and advances wheat sowing about 2-3 weeks (Sidhu *et al.*, 2007). In RW system, zero tillage for wheat has been adopted widely (Chhokar*et al.*, 2007; Erenstein, 2009; Jat*et al.*, 2009; Saharawat *et al.*, 2010) but rice is still transplanted in puddled soil. Since crop residue management practices are affected by climatic and soil conditions of an area and every crop residue management practice is not suitable under all conditions. Therefore, testing of different management practices is imperative before their adoption in the area (Kumar and Goh, 2000; Prasad and Power, 1991). This field study was conducted to evaluate the effect of different crop residue management practices on growth and nutrient uptake of rice and wheat.

Materials and methods

Field experiment was conducted in RW area of Punjab, Pakistan. Rice and wheat crops were grown in succession on two sites at farmers' fields. The experimental details have been given in preceding paragraphs.

Locations, climatic conditions and soils

The field experiment was started in summer 2012 at two sites in RW area of Punjab province of Pakistan. Two crops of each rice and wheat (Rice 2012, Wheat 2012-13, Rice 2013 and Wheat 2013-14) were grown in succession. Two sites, Ratta Ber Farm and Shahbaz Farms were 15 km apart located on Muredke-Sheikhupura Road. The area has bi-modal pattern of rainfall receiving ≈ 70% of the total annual rainfall during July-August in the form of torrential showers and the remaining during January-February in the form of gentle showers. Out of total 476 mm average rain fall, generally 262 mm is received in July-August. The mean maximum temperature during summer, ranges from 36°C to 42°C with extremes sometimes as high as 48°C.

From both the sites, composite soil samples were collected and analyzed for physical and chemical characteristics (Table 1). Soil of the Ratta Ber Farm was silty clay loam while that of the Shahbaz Farm was clay loam. Soils of both the sites had normal pH and low EC. Both the soils were calcareous in nature and deficient in soil organic carbon, mineral nitrogen and available phosphorus. Soil potassium was medium at Ratta Ber Farm while it was low at Shahbaz Farm.

Treatments and operations

At both sites, different crop residue management practices (CRMPs) were applied (Table 2) at start of the summer before rice sowing in 2012 (immediately after harvest of previous wheat crop). After harvesting of wheat (2012), same CRMPs were maintained by establishing 12 plots having 4 treatments randomized in 3 blocks with plot size of 10m × 23m each.

Previous wheat crop was harvested with combine harvester at both sites. After wheat harvesting, wheat residue in the RR plots was removed manually, while in RB plots the residue was partially burned, whereas in RI plots the residue was incorporated with a tractor drawn disc plough followed by ploughing with tine cultivator. Wheat residue in ZT plots was left as such until rice was direct seeded in June 2012. After rice harvesting in October 2012, same CRMPs were repeated before wheat sowing. Before rice planting, the field was flooded with water and puddled with a tractor drawn disc harrow under RR, RB and RI treatments. Rice variety Basmati-385 was transplanted in early July with 25 days old seedlings at the rate of 2 seedling per hill with row to row spacing of 20 cm and hill to hill distance of 10 cm. Under ZT treatment, paddy seed was drilled into plots with zero-till-drill in standing wheat residue 25 days earlier than nursery transplanting in RR, RB and RI treatments. Fertilizer nutrients at the rate of 60 kg ha^{-1} each of nitrogen (N), phosphorus (P) and potassium (K) were applied one day before transplanting and direct seeding of rice.

Another 60 kg of N ha^{-1} was applied 55 days after transplanting. Agronomic practices like weed control and irrigation management were performed as per crop requirements. At maturity, rice crop was harvested in late October and data on agronomic parameters was recorded. Just after harvesting of rice crop, CRMPs similar to those before rice transplanting were applied in each plot. Treatments were applied and wheat variety Faisalabad-2008 was sown in the mid of November with wheat-drill in plots under RR, RB and RI treatments. Whereas, in plots under ZT treatment, wheat was planted with zero-till-drill in standing rice residue. Fertilizer nutrients at the rate of 60, 90 and 60 kg ha^{-1} of N, P and K, respectively, were applied during seed bed preparation in plots under RR, RB and RI. Whereas, in ZT plots, these fertilizers were applied simultaneously with zero-drilling. Second dose of 60 kg N ha^{-1} was applied at booting stage of wheat. Urea, di-ammonium phosphate and sulphate of potash were used as N, P and K sources, respectively. Same practices were followed for the next rice and wheat crops.

Data collection

At maturity, both the crops were harvested from randomly selected area of 4 m^2 (2m × 2m) from each plot in triplicate. Grain and straw yields were recorded and composite samples were drawn for chemical analysis. Composite soil samples from each plot were also collected from 0-15 cm depth and stored for analysis.

Plant and soil analysis

P and K in rice paddy and straw as well as wheat grain and straw were determined by diacid (nitric acid and perchloric acid) digestion. P was measured calorimetrically (Ryan *et al.*, 2001) and K by flame-photometrically (Wright and Stuczynski, 1996). N was determined by Kjeldahl method (Helrich, 1995).

Nutrient uptake was calculated by multiplying straw and grain yields with their respective nutrient concentrations and adding subsequently.

Soil samples were air dried and plant debris and stones were removed manually.

They were ground and passed through 2mm stainless steel sieve and analyzed for AB-DTPA extractable NO_3-N, P_2O_5 and K_2O as described by Soltanpour and Workman (1979).

Statistical analysis

Soil and agronomic data were statistically analyzed using analysis of variance (ANOVA) combined over the years and locations for rice and wheat crops in Randomized Complete Block Design (Gomez and Gomez, 1984).

The treatment means of both soil and agronomic data were compared using Duncan's Multiple Range Test at 5% level of probability.

Results

Yield parameters of rice and wheat in RW cropping system

Data on paddy yield at two sites and years (Table 3) and under different CRMPs (Table 4) showed that paddy yield was significantly different (p=0.0008) between sites. Overall, paddy yield was 12% higher at Ratta Ber Farm as compared to Shahbaz Farm.

CRMPs significantly (p=0.0070) affected paddy yield wherein RI showed significantly higher (14 and 16%) paddy yield as compared to RR and ZT, respectively. Whereas, paddy yield with RB was statistically similar to RI as well as RR and ZT. However, paddy yield was not statistically different in both years.

Table 1. Soil properties of RattaBer and Shahbaz Farms.

Parameters	RattaBer Farm		Shahbaz Farm	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Clay (%)	28	36	25	29
Silt (%)	52	45	35	31
Sand (%)	20	19	40	41
Texture	Silty Clay Loam	Silty Clay Loam	Clay Loam	Clay Loam
$pH_{1:2.5}$	7.44	7.20	7.14	6.89
$EC_{1:2.5}$ (dS m^{-1})	1.35	1.71	1.18	1.30
Organic C (g kg^{-1})	5.9	1.9	3.5	1.4
$CaCO_3$ (%)	2.3	2.5	1.8	2.0
Mineral N (mg kg^{-1})	1.21	0.96	1.21	1.24
AB-DTPA Extractable				
P (mg kg^{-1})	3.44	5.27	0.74	0.74
K (mg kg^{-1})	156	158	80	82
Zn (mg kg^{-1})	1.212	0.742	0.602	0.356
Fe (mg kg^{-1})	14.8	9.1	18.8	12.4
Cu (mg kg^{-1})	1.374	1.116	0.984	0.740

Straw yield of rice at two sites and years (Table 3) under different CRMPs (Table 4) showed that straw yield was relatively higher in the second year, but the difference was not significant. No significant difference in straw yield was observed between the two sites, however, at Ratta Ber Farm straw yield was 4% higher than at Shahbaz Farm. CRMPs significantly (p=0.0023) affected straw yield wherein RI produced significantly higher (14, 10 and 16%) straw yield as compared to RR, RB and ZT, respectively. The differences in straw yield between RR, RB and ZT were not significant.

Table 2. Description of the experimental treatments.

CRMPs	Treatments details	
	Rice season	Wheat season
RR	– Wheat residue removing manually	– Rice residue removing manually
	– Rice transplanting in puddled field	– Wheat planting with drill
RB	– Wheat residue burning in field	– Rice residue burning in field
	– Rice transplanting in puddled field	– Wheat planting with drill
RI	– Wheat residue incorporation with disc plough	– Rice residue incorporation with disc plough
	– Rice transplanting in puddled field	– Wheat planting with drill
ZT	– Wheat residue retaining intact	– Rice residue retaining intact
	– Rice direct seeded with drill	– Wheat planting with zero-drill

Table 3. Paddy and straw yields of rice at two sites and years.

Years	RattaBer Farm	Shahbaz Farm	Mean
		Paddy Yield (kg ha⁻¹)	
Rice 2012	4236	3835	4036
Rice 2013	4477	3944	4210
Mean	4356 A	3890 B	
		Straw Yield (kg ha⁻¹)	
Rice 2012	5868	5596	5732
Rice 2013	6020	5863	5941
Mean	5944	5729	

Means of main or interactive effects for paddy or straw yield followed by different letters are significantly different at $p \leq 0.05$.

Data on grain yield of wheat at two sites and years (Table 5) and under different CRMPs (Table 6) revealed that grain yield was higher (7%) in the second year but the difference was not significant. Grain yield was also significantly (p=0.0189) different at both sites and was 17% higher at Ratta Ber Farm as compared to that at Shahbaz Farm. The interaction of sites and years was not significant. CRMPs significantly (p=0.0462) affected grain yield. RI significantly increased (27, 23 and 19%) grain yield as compared to RR, RB and ZT, respectively. While, RR, RB and ZT were statistically not different with each other.

Data on straw yield of wheat at two sites and years (Table 5) and under different CRMPs (Table 6) showed that straw yield between sites was not significantly different. However straw yield at Ratta Ber Farm was 3% higher than Shahbaz Farm while straw yield of wheat was significantly (p=0.0062) higher in the second year. Straw yield was 19% higher in the second year. CRMPs significantly (p=0.0044) affected straw yield. RI significantly increased straw yield (26, 24 and 21%) as compared to RR, RB and ZT, respectively. While RR, RB and ZT were statistically at par with each other.

N, P and K uptake by rice and wheat in RW cropping system

Data on N, P and K uptake by rice at two sites and years are given in Table 7. N (P=0.0025), P (P=0.0052) and K (P=0.0001) uptake in rice was significantly different over the years. N, P and K uptake was 12, 17 and 12% higher during the second year, respectively. N (P = 0.0025), P (P = 0.0022) and K (P = 0.0007) uptake was also varied significantly between the sites. At Ratta Ber Farm, N, P and K uptake was 16, 19 and 10% higher, respectively, as compared to Shahbaz Farm. However, the interaction between years and sites was not significant.

Table 4. Paddy and straw yields of rice as affected by different crop residue management practices in two years.

CRMPs	Rice 2012	Rice 2013	Mean
		Paddy Yield (kg ha^{-1})	
RR	3989	3935	3962 B
RB	4106	4165	4135 AB
RI	4189	4822	4506 A
ZT	3859	3920	3890 B
Mean	4036	4210	
		Straw Yield (kg ha^{-1})	
RR	5575	5668	5622 B
RB	5729	5867	5798 B
RI	6109	6696	6403 A
ZT	5515	5534	5524 B
Mean	5732	5941	

Means of main or interactive effects for paddy or straw yield followed by different letters are significantly different at $p \leq 0.05$.

Table 5. Grain and straw yields of wheat at two sites and years.

Years	RattaBer Farm	Shahbaz Farm	Mean
		Grain Yield (kg ha^{-1})	
Wheat 2012-13	4134	3513	3824
Wheat 2013-14	4427	3795	4111
Mean	4281 A	3654 B	
		Straw Yield (kg ha^{-1})	
Wheat 2012-13	4919	4771	4845 B
Wheat 2013-14	5889	5692	5791 A
Mean	5404	5232	

Means of main or interactive effects for paddy or straw yield followed by different letters are significantly different at $p \leq 0.05$.

Data regarding N, P and K uptake by rice under different CRMPs and years (Table 8) showed that CRMPs significantly affected N (P<0.0001), P (P<0.0001) and K (P<0.0001) uptake. Amongst the applied CRMPs, RI significantly increased N, P and K uptake as compared to others. The differences in N uptake among RR, RB and ZT were not significant. N uptake in RI was 33, 36 and 32% higher as compared to RR, RB and ZT, respectively. P uptake in RI was significantly higher than other CRMPs. It was 58, 28 and 32% higher than RR, RB and ZT, respectively. Whereas, its uptake in RB and ZT was statistically similar and it was significantly lowest in RR. Amongst different CRMPs, K uptake was significantly higher in RI. Its uptake in RI was 38, 11 and 29% higher than RR, RB and ZT, respectively. While, K uptake in RR and ZT was statistically similar, while it was significantly higher in RB as compared to RR and ZT. The interaction between CRMPs and years was also significant for N (P=0.0053), P (P=0.0521) and K (P=0.0011) uptake in rice. The interaction showed that RI significantly enhanced N, P and K uptake followed by RB over the other CRMPs only in Rice 2013.

Table 6. Grain and straw yields of wheat as affected by different crop residue management practices in two years.

CRMPs	Wheat 2012-13	Wheat 2013-14	Mean
		Grain Yield (kg ha^{-1})	
RR	3508	3635	3571 B
RB	3618	3865	3742 B
RI	4441	4722	4582 A
ZT	4028	4420	4224 B
Mean	3899	4161	
		Straw Yield (kg ha^{-1})	
RR	4555	5368	4961 B
RB	4647	5567	5107 B
RI	5440	6396	5918 A
ZT	4938	5834	5386 B
Mean	4895 B	5791 A	

Means of main or interactive effects for paddy or straw yield followed by different letters are significantly different at $p \leq 0.05$.

Table 7. N, P and K uptake by rice at two sites and years.

Years	RattaBer Farm	Shahbaz Farm	Mean
		Total N Uptake (kg ha^{-1})	
Rice 2012	84.87	73.64	79.26 B
Rice 2013	95.98	81.59	88.78 A
Mean	90.42 A	77.62 B	
		Total P Uptake (kg ha^{-1})	
Rice 2012	34.71	29.24	31.97 B
Rice 2013	40.47	34.11	37.29 A
Mean	37.59 A	31.67 B	
		Total K Uptake (kg ha^{-1})	
Rice 2012	103.10	92.63	97.86 B
Rice 2013	114.80	105.49	110.15 A
Mean	108.95 A	99.06 B	

Means of main or interactive effects for each nutrient followed by different letters are significantly different at $p \leq 0.05$.

Data regarding N, P and K uptake in wheat at two sites and years are given in Table 9. Variance analysis showed that K uptake was significantly (P=0.0447) higher at both sites, while N and P uptake were not changed significantly. Nutrient uptake was significantly higher at Ratta Ber Farm as compared to Shahbaz Farm. N, P and K uptake in wheat at Ratta Ber Farm was 15, 13 and 11% higher, respectively. Nutrient comparison between the years indicated that P (p=0.0089) and K (p=0.0021) uptake was significantly higher in the second year, while N uptake was not significantly different between the years. N, P and K uptake was 4, 13 and 17% higher during the second year, respectively.

Data regarding N, P and K uptake by rice under different CRMPs and years (Table 10) showed that CRMPs significantly affected N (P=0.0033), P (P=0.0056) and K (P=0.0001) uptake in wheat. RI significantly increased N (38, 38 and 19%), P (32, 17 and 21%) and K (48, 35 and 28%) uptake as compared to RR, RB and ZT, respectively. RR, RB and ZT were statistically at par regarding N, P and K uptake.

Table 8. N, P and K uptake by rice as affected by different crop residue management practices in two years.

CRMPs	Rice 2012	Rice 2013	Mean
		Total N Uptake (kg ha⁻¹)	
RR	78.05 bc	77.62 bc	77.83 B
RB	73.66 c	78.16 bc	75.91 B
RI	89.14 b	118.05 a	103.59 A
ZT	76.17 bc	81.32 bc	78.74 B
Mean	79.26 B	88.78 A	
		Total P Uptake (kg ha⁻¹)	
RR	27.20 d	28.12 cd	27.66 B
RB	32.83 bcd	35.48 bc	34.15 B
RI	36.66 b	50.74 a	43.70 A
ZT	31.21 bcd	34.83 bcd	33.02 B
Mean	31.97 B	37.29 A	
		Total K Uptake (kg ha⁻¹)	
RR	88.89 d	88.16 d	88.52 C
RB	104.33 c	115.86 b	110.09 B
RI	106.68 bc	138.33 a	122.51 A
ZT	91.55 d	98.23 cd	94.89 BC
Mean	97.86 B	110.15 A	

Means of main or interactive effects for each nutrient followed by different letters are significantly different at $p \leq 0.05$.

Table 9. N, P and K uptake by wheat at two sites and years.

Years	RattaBer Farm	Shahbaz Farm	Mean
		Total N Uptake (kg ha⁻¹)	
Wheat 2012-13	101.33	88.38	94.86
Wheat 2013-14	105.98	91.59	98.78
Mean	103.65 A	89.99 B	
		Total P Uptake (kg ha⁻¹)	
Wheat 2012-13	47.47	41.11	44.29 A
Wheat 2013-14	52.70	47.69	50.19 B
Mean	50.08 A	44.40 B	
		Total K Uptake (kg ha⁻¹)	
Wheat 2012-13	80.81	72.80	76.81 A
Wheat 2013-14	94.79	85.49	90.14 B
Mean	87.80 A	79.15 B	

Means of main or interactive effects for each nutrient followed by different letters are significantly different at $p \leq 0.05$.

AB-DTPA extractable soil NO_3-N, P_2O_5 and K_2O contents in RW cropping system

At termination of the experiment, after four crop seasons (rice-wheat-rice-wheat), nutrient status of the soil under different CRMPs was studied. CRMPs significantly affected AB-DTPA extractable soil NO_3-N, P_2O_5 and K_2O contents at both sites (Table 11). Soil NO_3-N contents were significantly higher in case of RI followed by ZT, RR and RB. NO_3-N contents were statistically similar in RI and ZT treatments at Ratta Ber Farm, while at Shahbaz Farm, RR and RB treatments were alike. RI had higher NO_3-N contents by 54, 20 and 2% at Ratta Ber Farm and 69, 51 and 20% at Shahbaz Farm as compared to RR, RB and ZT, respectively. RI significantly increased soil P_2O_5 contents as compared to other CRMPs at both sites. RI increased soil P_2O_5 contents by 41, 47 and 22% at Ratta Ber Farm and 40, 39 and 20% at Shahbaz Farm as compared to RR, RB and ZT, respectively. Soil K_2O contents were significantly lower in RR as compared to RB, RI and ZT at both sites. RB, RI and ZT increased soil K_2O contents by 17, 19 and 11% at Ratta Ber Farm and 20, 23 and 15% at Shahbaz Farm, respectively.

Table 10. N, P and K uptake by wheat as affected by different crop residue management practices in two years.

CRMPs	Wheat 2012-13	Wheat 2013-14	Mean
		Total N Uptake (kg ha^{-1})	
RR	83 c	88 c	85.52 B
RB	84 c	88 c	85.91 B
RI	115 ab	128 a	121.67 A
ZT	97 bc	107 b	102.00 B
Mean	94.75 B	102.75 A	
		Total P Uptake (kg ha^{-1})	
RR	35 c	44 bc	39.72 C
RB	42 bc	50 ab	46.14 B
RI	48 ab	58 a	58.08 A
ZT	42 bc	49 ab	45.02 B
Mean	44.25 B	50.00 A	
		Total K Uptake (kg ha^{-1})	
RR	65 d	68 d	66.52 C
RB	71 cd	96 bc	83.62 B
RI	96 bc	118 a	107.20 A
ZT	75 cd	78 c	76.56 C
Mean	76.75 B	90.00 A	

Means of main or interactive effects for each nutrient followed by different letters are significantly different at $p \leq 0.05$.

Discussion

Yield parameters of rice and wheat in RW cropping system

In this study, a slight increase in yield of rice and wheat was observed under residue burning treatments as compared to residue removal treatments. The earlier results obtained by Verma and Bhagat (1992) and JaiPaul *et al.* (2014) are also in line with our observations. They reported that there were no significant differences in grain yield of rice and wheat between crop residue removed and crop residue burned treatments. Contrarily, Dotaniya (2013) observed significant increase in rice (2%) and wheat (46%) yield under residue burning as compared to residue removal. The increase in yield with residue burning might be due to the instant availability of some plant nutrients from burned straw. A significant increase in yield of rice and wheat with residues incorporation in this study was also in line with the results of Dotaniya (2013), who observed significant increase in rice (4%) and wheat (49%) with residue incorporation as compared to residue removal. Increase in grain and straw yield of wheat and rice with incorporation of both wheat and rice crop residues was also observed by, Sarkar (1997), Prasad *et al.* (1999), Sarkar and Kar (2011) and Davari *et al.* (2012). Gupta *et al.* (2007) reported that straw incorporation tended to increase wheat yield, not significantly, after two years and reached the significant difference after four years, as compared to control. The possible reasons for the increase in straw and paddy yield with residue incorporation in this study might be the nutrient availability on decomposition of residue with time and improved soil organic carbon content (Singh *et al.*, 1995; Sarkar and Kar, 2011), soil physical conditions (Kirchhof *et al.*, 2000; Sarkar and Kar, 2011) and increased nutrient availability upon mineralization of incorporated crop residues with time.

Table 11. Soil AB-DTPA extractable NO_3-N, P_2O_5 and K_2O (mg kg^{-1}) as affected by different crop residue management practices at RattaBer and Shahbaz Farms at termination of the experiment.

CRMPs	NO_3-N	P_2O_5	K_2O
		RattaBer Farm	
RR	10.04 c	6.74 b	125 c
RB	12.93 b	6.47 b	146 a
RI	15.47 a	9.49 a	149 a
ZT	15.13 a	7.81 b	139 b
		Shahbaz Farm	
RR	9.53 c	6.34 c	123 b
RB	10.72 c	6.41 c	148 a
RI	16.15 a	8.89 a	151 a
ZT	13.44 b	7.41 b	141 a

Means within columns at each site followed by different letters are significantly different at $p \leq 0.05$.

Puddling and direct seeding in standing residue have their own significance. Puddling creates suitable edaphic conditions for rice growth and nutrient availability, while zero-tillage increases soil organic matter, nutrient contents and plant available water (Sudhir-Yadav *et al.*, 2011; Ali *et al.*, 2012).

Therefore, in our study, statistically similar results were observed in zero-till, residue burning and residue removal plots. Similarly, Ali *et al.* (2012) also reported that direct seeded rice is superior and economical than conventional transplanting of rice nursery in puddled field. However, Jat *et al.* (2009) observed adverse impact of direct seeding during the second year as rice yield was significantly lower than the puddling. In this study, the increase in yield of wheat and rice under ZT might be due to discontinuation of puddling practice in rice, consequently increased soil organic matter content, nutrient buildup, improved plant available water capacity and infiltration rate.

N, P and K uptake by rice and wheat in RW cropping system

Straw burning causes loss of about 80% N, 25% P and 21% K (Yadvinder-Singh *et al.*, 2005; Gangwar *et al.*, 2006) contributing a small amount of N and P to soil. Therefore, RB resulted in N and P uptake similar to RR. The low uptake of N in the RR and RB might be due to its exclusion from the system due to residue removal and substantial losses upon residue burning. Sharma and Mishra (2001) have reported 80-90% N losses upon residue burning. Verma and Bhagat (1992) and JaiPaul *et al.* (2014) also found that straw burning practice was at par with straw removal in nutrient uptake. The significant increase in K uptake by RB might be related to high K content of straw which on burning leaves behind about 80% K in the soil for crop uptake (Yadvinder-Singh *et al.*, 2005; Gangwar *et al.*, 2006). Lower N, P and K uptake in ZT may be attributed to low grain and straw yield in the respective plots.

Significant uptake of nutrients by rice and wheat was observed in this study which coincides with the results of Dotaniya (2013), who observed maximum N, P and K uptake by both rice and wheat in the residue incorporation treatments as compared to residue burning and removal. While Gupta *et al.* (2007) also reported a slight increase in P uptake by rice and wheat under crop residue incorporation in the initial 2 years which significantly increased after that as compared to residue removal. Tripathi *et al.* (2007) and JaiPaul *et al.* (2014) observed that residue incorporation significantly increased nutrient uptake which they attributed to high availability of soil N, P and K to the plants contributed from mineralization of crop residues. Utomo *et al.* (1990) and Stevenson and van Kessel (1996) also attributed high nutrient uptake with residue incorporation to nutrient supply from crop residue mineralization and improvement in physical and chemical conditions of soil. Adequate supply of nutrients in the root zone, under residue incorporation treatments, increased the movement of nutrients in soil solution and ultimately their greater absorption and utilization by the growing plants.

AB-DTPA extractable soil NO_3-N, P_2O_5 and K_2O contents in RW cropping system

Since rice and wheat crops remove about 35 to 40% of N, 10 to 15% of P and 80 to 90% of K in the straw (Sharma and Sharma, 2004), therefore, recycling of crop residues contributed considerable amounts of plant nutrients to the soil. Davari *et al.* (2012) and Sharma *et al.* (2010) also observed a significant increase in N, P and K contents of soil with incorporation of rice and wheat residues. Surekha *et al.* (2003) also recorded significantly higher values of N contents in straw incorporated treatments over burning and removal. Surekha *et al.* (2003) reported that available K increased significantly in straw burning plots followed by a significant increase in straw incorporated plots over residue removal plots. Straw contains high amount of K and its burning in rice-wheat cropping system causes 21% K losses (Gangwar*et al.*, 2006; Yadvinder-Singh *et al.*, 2005) and the remaining 79% contributes to the K content of the soil.

Conclusions

It can be concluded that the productivity of wheat and rice crops can be improved by residue incorporation under puddled and conventional tillage. However, crop productivity under zero-tillage was at par to that of residue burning and removal. Thus, improved technology of zero-till-drill may enhance crop productivity in rice-wheat system. Crop residue incorporation also did not affect yield in the first season under recommended mineral fertilizer dose. Further research is needed to evaluate long-term effects of these management practices on soil quality and crop productivity.

Acknowledgements

Financial support for this work was provided by the Project "Research for Agricultural Development Program", Pakistan Agricultural Research Council, Islamabad.

References

Aggarwal GC, Sidhu AS, Sekhon NK, Sandhu KS, Sur HS. 1995. Puddling and N management effects on crop response in a rice-wheat cropping system. Soil and Tillage Research **36**, 129-139.

Ali RI, Iqbal N, Saleem MU, Akhtar M. 2012. Effect of different planting methods on economic yield and grain quality of rice. International Journal of Agriculture and Applied Sciences **4(1),** 28-34.

Badrinath KVS, Chand TRK, Prasad VK. 2006. Agriculture crop residue burning in the Indo-Gangetic Plains – a study using IRSP6 WiFS satellite data. Current Science **91(8),** 1085-1089.

Bationo A, Kimetu J, Ikerra S, Kimani S, Mugendi D, Odendo M, Silver M, Swift MJ, Sanginga N. 2004. The African network for soil biology and fertility: new challenges and opportunities. In: Bationo, A, Ed. Managing nutrient cycles to sustain soil fertility in Sub-Saharan Africa. Academy Science Publishers, Nairobi, Kenya.

Bhatt R, Kukal SS, Busari, MA, Arora S, Yadav M. 2016. Sustainability issues on rice-wheat cropping system. Intern. Soil and Water Conservation Research **4,** 64-74.

Byerlee D, Sheikh AD, Aslam M, Hobbs PR. 1984. Wheat in the rice-based farming system of the Punjab: Implications for research and extension. NARC/CIMMYT Reports Series No. 4. NARC/CIMMYT, Islamabad.

Chhokar RS, Sharma RK, Jat GR, Pundir AK, Gathala MK. 2007. Effect of tillage and herbicides on weeds and productivity of wheat under rice-wheat growing system. Crop Protection **26,** 1689-1696.

Davari MR, Sharma SN, Mirzakhani M. 2012. Effect of cropping systems and crop residue incorporation on production and properties of soil in an organic agro ecosystem. Biological Agriculture and Horticulture **28(3),** 206-222.

Dawe D, Frolking S, Li C. 2004. Trends in rice-wheat area in China. Field Crops Research **87**, 89-95.

Dotaniya ML. 2013. Impact of crop residue management practices on yield and nutrient uptake in rice-wheat system. Current Advances in Agricultural Science **5(2)**, 269-271.

Erenstein O. 2009. Adoption and impact of conservation agriculture-based resource conserving technologies in South Asia. In: 4th World Congress on Conservation Agriculture, New Delhi, India.

FAO. 1990. Integrated plant nutrient systems: State of the art. Commission on Fertilizers, 11th Session, 1990 Apr 4-6, Rome (Italy).

Gangwar KS, Singh KK, Sharma SK, Tomar OK. 2006. Alternative tillage and crop residue management in wheat after rice in sandy loam soils of Indo-Gangetic plains. Soil and Tillage Research **88,** 242-252.

Gathala MK, Ladha JK, Kumar V, Saharawat YS, Kumar V, Sharma PK, Sharma S, Pathak H. 2011a. Tillage and crop establishment affects sustainability of South Asian rice-wheat system. Agronomy Journal **103,** 961-971.

Gomez KA, Gomez AA. 1984. Statistical Procedures for Agricultural Research, 2nd ed. IRRI John Wiley & Sons Publication, New York.

Gopal R, Kumar R. 2010. Recent advances in resource conserving technologies for rice. Rice Knowledge Management Portal, Directorate of Rice Research, Rajendranagar, Hyderabad, India, p 13.

Government of Pakistan. 2011. Agricultural Statistics of Pakistan 2010-11, Statistics Division, Pakistan Bureau of Statistics Islamabad, Pakistan.

Gupta RK, Yadvinder-Singh, Ladha JK, Bijay-Singh, Singh J, Singh G, Pathak H. 2007. Yield and phosphorus transformations in a Rice-Wheat System with crop residue and phosphorus management. Soil Science Society of America Journal **71(5),** 1500-1507.

Helrich K. Ed. 1995. Official Methods of Analysis of the AOAC. Association of Official Analytical Chemists, Arlington, VA, USA.

Hobbs PR, Gupta RK. 2002. Rice-wheat cropping systems in the Indo-Gangetic plains: Issues of water productivity in resource conserving technologies. In: Proceedings of water productivity workshop, International Water Management Institute, Colombo, Sri Lanka, 12-14 November 2001.

Hobbs PR, Gupta RK. 2003. Resource-conserving technologies for wheat in the rice-wheat system. In: Ladha JK, *et al.*, Eds. Improving the productivity and sustainability of rice-wheat systems: Issues and impacts. ASA Spec. Publ. 65. ASA, CSSA and SSA, Madison, WI, 149-171.

Hobbs PR, Singh Y, Giri GS, Lauren JG, Duxbury JM. 2002. Direct-seeding and reduced-tillage options in the rice-wheat systems of the Indo-Gangetic plains of South Asia. In: Pandey S, Mortimer M, Wade L, Trough TP, Lopez K, Hardy B, Eds. Direct seeding: Research strategies and opportunities, Proceedings of the International Workshop on Direct Seeding in Asian Rice Systems: Strategic Research Issues and Opportunities. 25-28 January, 2000, Bangkok, Thailand. International Rice Research Institute, Los Banos, Philippines, 201-215.

JaiPaul, Dixit AK, Sharma AK, Kumar V. 2014. Nutrient recycling and its relationship with biofertility indicators of soil health and nutrient uptake in a rice (*Oryza sativa* L.)-Wheat (*Triticumaestivum*L. emend. Fiori & Paol) cropping sequence. Agroecologyand Sustainable Food Systems **38(4),** 445-459.

Jastrow JD. 1996. Soil aggregate formation and the accrual of particulate and mineral-associated organic matter. Soil Biology and Biochemistry **28**, 656-676.

Jat ML, Gathala MK, Ladha JK, Saharawat YS, Jat AS, Vipin Kumar, Sharma SK, Kumar V, Gupta R. 2009. Evaluation of precision land leveling and double zero-till systems in the rice-wheat rotation: Water use, productivity, profitability and soil physical properties. Soil and Tillage Research **105,** 112-121.

Khurana HS, Bijay-Singh, Dobermann A, Phillips SB, Sidhu AS, Yadvinder-Singh. 2008. Site-specific nutrient management performance in a rice-wheat cropping system. Better Crops **92(4),** 26-28.

Kirchhof G, Priyono S, Utomo WH, Adisarwanto T, Dacaney EV, So HB. 2000. The effect of soil puddling on the soil physical properties and the growth of rice and post-rice crops. Soil and Tillage Research **56,** 37-50.

Kone FJ, Kouadio Y, Yapo ES, 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. Journal of Applied Sciences Research **6,** 1581-1588.

Krishna GM, Misra AK, Hati KM, Bandyopadhyay KK, Ghosh PK, Mohanty M. 2004. Rice residue-management options and effects on soil properties and crop productivity. Food Agriculture and Environment **2(1),** 224-231.

Kukal SS, Aggarwal GC. 2003a. Puddling depth and intensity effects in rice-wheat system on a sandy loam soil. I. Development of subsurface compaction. Soil and Tillage Research **72,** 1-8.

Kukal SS, Aggarwal GC. 2003b. Puddling depth and intensity effects in rice-wheat system on a sandy loam soil II. Water use and crop performance. Soil and Tillage Research **74,** 37-45.

Kumar K, Goh KM. 2000. Crop residue management: Effects on soil quality, soil nitrogen dynamics, crop yield, and nitrogen recovery. Advances in Agronomy **68,** 197-319.

Kumar V, Ladha JK. 2011. Direct seeding of rice: recent developments and future research needs. Advances in Agronomy **111,** 297-313.

Ladha JK, Fischer KS, Hossain M, Hobbs PR, Hardy B. 2000. Improving the productivity and sustainability of rice-wheat systems of the Indo-Gangetic Plains: A synthesis of NARS-IRRI partnership research. IRRI Discussion Papers Series40. IRRI, Manila, Philippines, 1-31.

Ladha JK, Pathak H, Padre AT, Dawe D, Gupta RK. 2003. Productivity trends in intensive rice-wheat cropping systems in Asia. In: Ladha JK *et al.* Eds. Improving the productivity and sustainability of rice-wheat systems: Issues and impacts. ASA Special Publication 65. ASA, CSSA, and SSSA, Madison, WI, 45-76.

Ladha JK, Kumar V, Alam MM, Sharma S, Gathala MK, Chandna P, Sahrawat YS, Balasubramanian V. 2009. Integrating crop and resource management technologies for enhanced productivity, profitability, and sustainability of the rice-wheat system in South Asia. In: Ladha JK *et al.* Eds. Integrated crop and resource management in the rice-wheat system of South Asia. International Rice Research Institute (IRRI), Los Baños, Philippines, p 69-108.

Mandal KG, Misra AK, Hati KM, Bandyopadhyay KK, Ghosh PK, Mohanty M. 2004. Rice residue-management options and effects on soil properties and crop productivity. Food Agriculture and Environment **2(1),** 224-231.

Pathak H, Ladha JK, Aggarwal PK, Peng S, Das S, Singh Y, Singh B, Kamra SK, Mishra B, Sastri ASRAS, Aggarwal HP, Das DK, Gupta RK. 2003. Trends of climatic potential and on-farm yields of rice and wheat in the Indo-Gangetic Plains. Field Crops Research **80,** 223-234.

Pichot J, Sedogo MP, Poulain JF, Arrivets J. 1981. Evolution de la fertilite´ d'un sol ferrugineux tropical sous l'influence de fumuresmine´rales et organiques. Agronomie Tropicale **36**, 122-133.

Prasad R, Power JF. 1991. Crop residue management. Advances in Soil Science **15**, 205-251.

Prasad R, Gangaiah B, Aipe KC. 1999. Effect of crop residue management in a rice-wheat cropping system on growth and yield of crops and on soil fertility. Experimental Agriculture **35,** 427-435.

Ryan J, Estefan G, Rashid A. 2001. Soil and Plant Analysis Laboratory Manual. International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria, p 172.

Saharawat YS, Singh B, Malik RK, Ladha JK, Gathala M, Jat ML, Kumar V. 2010. Evaluation of alternative tillage and crop establishment methods in a rice-wheat rotation in North Western IGP. Field Crops Research **116,** 260-267.

Samra JS, Singh B, Kumar K. 2003. Managing crop residues in the rice-wheat system of the Indo-Gangetic Plains. In: Ladha JK *et al.* Eds. Improving the productivity and sustainability of rice-wheat systems: Issues and impact. ASA, Special Publication 65, Madison, WI, USA, 173-195.

Sarkar A. 1997. Energy-use pattern in sub-tropical rice-wheat cropping under short-term application of crop residue and fertilizer. Agriculture, Ecosystems and Environment **61,** 55-67.

Sarkar R, Kar S. 2011. Temporal changes in fertility and physical properties of soil under contrasting tillage-crop residue management for sustainable rice-wheat system on sandy-loam soil. Journal of Crop Improvement **25(3),** 262-290.

Sharma PK, De Datta SK. 1986. Physical properties and processes of puddled rice soils. Advances in Soil Science **5**, 139-178.

Sharma PK, Mishra B. 2001. Effect of burning rice and wheat crop residues: Loss of N, P, K and S from soil and changes in nutrient availability. Journal of Indian Society of Soil Science **49**, 425-429.

Sharma PK, Ladha JK, Bhushan L. 2003. Soil physical effects of puddling in rice-wheat cropping systems. In: Ladha JK *et al.* Eds. Improving the productivity and sustainability of rice-wheat systems: Issues and impacts. ASA Special Publication 65. ASA, CSSA and SSA, Madison, WI., p 97-114.

Sharma SN, Sharma SK. 2004. Role of crop diversification and integrated nutrient management in resilience of soil fertility under rice-wheat cropping system. Archives of Agronomy and Soil Science **50,** 511-519.

Sharma P, Tripathi RP, Singh S. 2005. Tillage effects on soil physical properties and performance of rice-wheat cropping system under shallow water table conditions of Tarai, northern India. European Journal of Agronomy **23(4),** 327-335.

Sharma SN, Prasad R, Dwivedi MK, Kumar S, Davari MR, Shukla L. 2010. Crop diversification and residue incorporation for making rice-wheat cropping systems sustainable. Journal of Sustainable Agriculture **34(4),** 342-364.

Sheikh AD, Zubair M, Asif M. 2000. Barriers in enhancing the productivity of the rice-wheat farming system of the Punjab. AERU, NARC, Technical Report, p 75.

Sidhu HS, Manpreet-Singh, Humphreys EJ, Yadvinder-Singh, Balwinder-Singh, Dhillon SS, Blackwell J, Bector V, Malkeet-Singh, Sarbjeet-Singh. 2007. The Happy Seeder enables direct drilling of wheat into rice stubble. Australian Journal of Experimental Agriculture **47,** 844-854.

Singh GP, Beri V, Sidhu BS. 1995. Humification of rice and wheat residues in soil. Journal of Indian Society of Soil Science **43(1),** 17-20.

Singh RB, Paroda RS. 1994. Sustainability and productivity of rice-wheat systems in Asia-Pacific region: Research and technology development needs. In: Paroda RS, Woodhead T, Singh RB. Eds. Sustainability of rice-wheat production systems in Asia. FAO, Bangkok. 1-35 p.

Six J, Elliott ET, Paustian K. 1998. Aggregate and SOM dynamics under conventional and no-tillage systems. Soil Science Society of America Journal **63,** 1350-1358.

Soltanpour PN, Workman SM. 1979. Modification of the NH_4HCO_3-DTPA soil test to omit carbon black. Communication in Soil Science and Plant Analysis **10,** 1411-1420.

Stevenson FC, van Kessel C. 1996. The nitrogen and non-nitrogen benefits of vegetable pea to succeeding crops. Canadian Journal of Plant Sciences **76,** 735-745.

Sudhir-Yadav, Gill G, Humphreys E, Kukal SS, Walia US. 2011. Effect of water management on dry seeded and puddled transplanted rice. Part 1: Crop performance. Field Crops Research **120,** 112-22.

Surekha K, Kumari APP, Reddy MN, Satyanarayana K, Cruz PCS. 2003. Crop residue management to sustain soil fertility and irrigated rice yields. Nutrient Cycling in Agroecosystems **67,** 145-154.

Tirol-Padre A, Ladha JK. 2006. Integrating rice and wheat productivity trends using the SAS mixed procedure and meta-analysis. Field Crops Research **95,** 75-88.

Tripathi RP, Gaur MK, Rawat MS. 2003. Puddling effects on soil physical properties and rice performance under shallow water table conditions of Tarai. Journal of Indian Society of Soil Science **51,** 118-124.

Tripathi RP, Sharma P, Singh S. 2007. Influence of tillage and crop residue on soil physical properties and yields of rice and wheat under shallow water table conditions. Soil and Tillage Research **92,** 221-226.

Utomo M., Frye WW, Blevins RL. 1990. Sustaining soil nitrogen for corn using hairy vetch clover crop. Agronomy Journal **82,** 979-983.

Verma TS, Bhagat RM. 1992. Impact of rice straw management practices on yield, nitrogen uptake and soil properties in a wheat-rice rotation in northern

India. Fertilizer Research **33,** 97-106.

Wright RJ, Stuczynski TI. 1996. Atomic absorption and flame emission spectrometry, in: Sparks, D.L., *et al*. (Eds.), Methods of Soil Analysis, Part 3: Chemical Methods. Soil Science Society of America, Madison, Wisconsin, USA, 65-90 p.

Yadav RL, Prasad K, Gangwar KS. 1998. Analysis of eco-regional production constraints in rice-wheat cropping system. PDCSR Bulletin No. 98-2. Project Directorate for Cropping Systems Research. Modipuram, India, 68 p.

Yadvinder-Singh, Bijay-Singh, Timsina J. 2005. Crop residue management for nutrient cycling and improving soil productivity in rice-based cropping systems in the tropics. Advances in Agronomy **85,** 269-407.