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Effect of Conservation Tillage on Soil Chemical Properties in Rice-Maize Cropping System

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Abstract

Soil organic matter, nitrogen (N), phosphorus (P) and potassium (K) nutrition of rice-maize cropping systems are important for sustaining crop productivity and food security. An experiment was conducted to determine the effects of tillage practices and residue retention on soil chemical properties in rice-maize cropping system. Conventional tillage, single pass wet tillage in rice (rotated with zero tillage in maize), bed planting (unpuddled rice transplanting) and strip tillage (unpuddled rice transplanting) in vertical plots and residue retention (0, 50 and 100%) in horizontal plot were tested for three consecutive years (2009-12). Rice was grown as transplanted irrigated crop and maize as upland crop. After third crop, strip tillage increased soil organic matter compared to bed and zero tillage at 0–7.5 cm soil depth. After three years, retention of crop residues, irrespective of tillage treatments, increased soil organic matter (SOM) at 7.5–15.0 cm soil depth. Tillage practices (puddled or unpudled) showed no significant changes in SOM. Neither tillage nor residue management had any significant effect on soil pH, total nitrogen, available phosphorus and exchangeable potassium.

Keywords: Tillage, residue retention, pH, organic matter, nitrogen, phosphorus, potassium

1. Introduction

Organic matter differs in stage of decomposition and degree of association with mineral material (Kay and VandenBygaart, 2002). These different forms of soil organic matter (SOM) collectively represent a reservoir of nutrients that are critical for plant growth. The tillage impacts on SOM varied due to soil type, cropping system, residue management and climatic conditions (Marschner *et al*., 2008). Tillage systems that reduce soil disturbance and residue incorporation have generally been observed to increase SOM content (Mrabet *et al*., 2001). Ismail *et al.* (1994) concluded that conservation tillage systems results in significant and positive effects on several chemical soil properties. SOM content declined when soil was tilled to a depth of 10 cm (Stockfisch *et al.*, 1999). Carter (1992) reported that conservation tillage practices may lead to high soil organic carbon (SOC) contents in surface soil than conventional tillage system or mould board plough. The loss of SOM due to tillage may be considered to be a function of soil type, climatic condition and cropping practice (Lal *et al*., 1998). Short term influence of tillage on transfer of soil carbon to atmospheric CO_2 in semi-arid soil is small (Ellert and Janzen, 1999). Therefore, long term conservation tillage practices were highly effective in improving SOC under semi-arid environment (Moreno *et al.*, 1997). The conversion to no-till may increase

SOC pool by about 10 Mg ha^{-1}in 5-20 years (Paustian *et al*., 1997). Conflicting results also exist regarding tillage practices and SOM content in surface soil. Dick (1983) reported higher organic C and N contents in no-tillage than conventional tillage system. Conventional tillage practices have resulted in lower carbon contents of agricultural soils due to increased decomposition rates and carbon redistribution (Christensen, 1996).

The SOM largely contributes to nutrient cycling and thus supply of N, S and other elements as well (Saleque*et al.,* 2009). Soil cultivation reduces organic matter and alters distribution and stability of soil aggregates (Six *et al.,* 1999). The decreased soil crusting, bulk density, runoff and erosion are also attributed for increased SOM levels. The most common method to enhance SOM is crop rotation, residue management and the application of farm manure (Kirchmann and Witter, 1992). The ability of soil to retain nutrients is increased by addition of organic materials and this play a major role in reducing soil erosion and maintaining long term soil health and productivity. Improved nutrient management and soil conservation practices are gaining importance in research and policy communities (Khan *et al.,* 2007). Soil pH influenced the solubility of phosphorus, iron, manganese, zinc and many other nutrients (Lindsey, 1979). Verma and Bhagat (1992) reported that the incorporation of rice straw in wheat caused a slight increase in an availability of P, Mn and Zn and a marked increase in the availability of K. There is a need to combine tillage practices with nutrient management practices, including recycling of crop residues in energy conscious world.

The effects of tillage systems and residue retention on soil properties are to be investigated, because there is little information on this subject in Bangladesh. Physical conditions are quite reverse for rice-maize system. Maize is grown in dry conditions whereas rice is grown in wet land conditions. Rice grown in minimum tillage under unpuddled transplanting conditions decreased the production cost and increased the profitability (Islam *et al.,* 2014). Unpuddled transplanting is gaining attention to the rice growing farmers in Bangladesh. It was hypothesized that minimum tillage with residue retention under dry and wet conditions would change the chemical properties in rice-maize cropping systems. The present investigation was therefore undertaken to determine the effects of tillage and residue management on soil chemical properties in rice-maize cropping systems.

2. Materials and Methods

This experiment was conducted in the regional station of Bangladesh Rice Research Institute, Rajshahi during 2009-2012. The soil is classified as high Ganges river flood plain – soil type is calcareous dark grey and soil texture sandy loam (Brammer, 1996). Field experiment involved conventional tillage (CT), single pass wet tillage (SPWT), zero tillage (ZT), bed planting (BP) and strip tillage (ST) with three levels of residue retention (100%, 50% and 0%). In maize season, SPWT was changed to ZT. Rice was grown in wet season (Aman) and maize in dry season (Rabi). The experiment was laid out in a strip plot design with tillage options as main plot and crop residue retention as subplot with three replications.

In rice cultivation, CT consisted of 2 passes primary tillage by 2 WT (wheel tractor) and exposed to sun for two days followed by inundating whole plot and puddling by 2 WT with 2 passes to complete land preparation. In SPWT, one pass tillage by 2 WT after inundating the field. ST and BP were done by Versatile Multi-crop Planter (VMP) in single pass operation before inundating the field. The land was fully inundated one day before transplanting in unpuddled plots. Seedlings were transplanted in puddled conditions (CT and SPWT) and unpuddled conditions (BP and ST).

In maize cultivation, CT consisted of 2 passes primary tillage by 2 WT and exposed to sun for two days, followed by 2 passes secondary tillage by 2 WT to complete land preparation. ZT, BP and ST were done in single pass operation by VMP. As per treatment sequence, previous crop residue was spread in between rows of rice and maize at 20 days after transplanting/seeding. Residue incorporation was started after first rice crop. Rice variety BR11 and maize variety NK40 were grown as indicator crops. Soil samples were taken randomly in three places in subplots between rows of crops and top of bed at a depth of 0-7.5 cm and 7.5-15 cmbefore starting the next crop. Chemical analysis was done in Soil Resource Development Institute (SRDI) laboratory, Rajshahi.

2.1. Measurement of soil pH in water

First 10 g soil was taken into a small beaker, 25 ml water was added and frequently stirred for 50 minutes. Then the beaker was left for 10 minutes without stirring. The pH meter electrode was ringed with soil suspension and the electrode was immersed in soil suspension and measurement was taken when display was stable. For each 10-soil sample or less: pH meter was checked in one of the buffer solutions. Calibration procedure was repeated as and when necessary

2.2. Determination of organic matter

In soil samples without $CaCO_3$, the content of total carbon was determined with the help of LECO C-200 Analyzer. In soil samples with a content of $CaCO_3$, a correction of total carbon content, as determined with LECO C-200 Analyzer, is required to obtain the content of organic carbon. All soil samples to be analyzed for organic carbon were checked for $CaCO_3$ by adding a small amount of the soil to a dish or beaker containing 10 % hydrochloric acid. If effervescence occurs, the soil contains $CaCO_3$ and the content of $CaCO_3$ must be determined. The content of organic carbon was calculated as:

% organic C = % total C - 0.12 x % $CaCO_3$....(1)

% organic matter = % organic C x 1.724.......(2)

2.3. Determination of potassium

Soil extraction: First, 2.50 g soil was taken into a dry conical flask. Then 25 ml 1 M ammonium acetate was added (using a pipette). Shaking for 30 minutes and left for overnight. Care was taken to avoid evaporation from the flask. Using filter paper whatman no. 42, the extract was filtered using a dry funnel into a dry beaker or flask.

Calculations

Cmol (+) K per kg soil = meq K per 100 g soil =

$$\frac{a\ x\ 25}{g} \text{ .... (1)}$$

Where,

a = cmol (+) K per l measured on the flame photometer,

g = g soil used for the analysis

2.4. Determination of phosphorus

The content of available P was determined by Olsen method (Olsen *et al.,* 1954). All P was determined colorimetrically (Murphy and Riley, 1962) after neutralization, when necessary with dilute HCl and NaOH and the neutral pH indicated by the light yellow color of the solution in the presence of P-nitro phenol indicator. Absorbance for P was determined at a wavelength of 710 nm by double beam spectrophotometer.

2.5. Determination of total nitrogen

Three steps processes were followed to determine total nitrogen. First digestions of the soil sample second distillation of the sample and third step titration of the sample.

Digestion: First, 3 g soil was taken into a tube. Then, one-gram catalyst mixture and 5 ml conc. H_2SO_4 was added to the tube. Digestion was continued for 2 hours at 390^oC temperature. The exhaust pump was started and the regulating valve was opened fully. After about 5 minutes the suction rate was reduced by almost closing the regulating valve. The digester was turned off, the rack with the tubes was removed from the digester and was placed beside the digester for cooling. Suction was continued for 5 minutes, the exhaust manifold was removed from the tubes, and the exhaust pump was turned off.

Distillation of Samples: 20 ml 0.05 M HCl was taken/measured into a conical flask from a burette or a dispenser, and the flask was placed on the platform in the distill. The platform was pushed up. 25 ml water was added to the digestion tubes from the digestion rack. The addition of water was done carefully while shaking because the mixture becomes very hot. 25 ml 33 % NaOH was dispensed into the digestion tube. The content in the flask which was removed from the distill was titrated with 0.05 M NaOH as described below.

Titration: After removal of the receiver flask from the distill, 4 drops of indicator solution was added to the content in the flask, and titrate with 0.05 NaOH until the colour changes from violet to green.

Calculations

% N in the soil

$$= \frac{a \ x \ M_{HCL} - bxM_{NaOH}}{c} x \, 1.401 \quad \text{.............(2)}$$

Where,

a = ml HCl measured into the conical flask in the distill (usually 20.00 ml),

b = ml NaOH used for titration of the content in the conical flask,

M_{HCl} = molarity of the HCl measured into the conical flask,

M_{NaOH} = molarity of the NaOH used for titration,

c = g soil used for the analysis.

If $M_{HCl} = M_{NaOH} = 0.0500$ and if 20.00 ml 0.0500 M HCl is measured into the conical flask, the calculation will be simplified to:

$$\text{\% N in the soil} = \frac{(20.00 - b) \ x \ 0.07005}{c} \quad \text{........(3)}$$

3. Results and Discussion

3.1. Soil pH

At the end of three-year trial, soil pH was compared to initial value for all tillage practices (Table 1). There was no influence of tillage practices on pH due to variations in soil depth. Apparently, pH values were the lowest in unpuddled treatment (BP and ST) than puddled ones (CT and SPWT). The effect of residue incorporation on soil pH was also insignificant. In top layer, pH values were the lowest with 100% residue incorporation than no residue use after first maize crop. However, reverse trend was observed in second maize and third rice crop.

3.2. Soil organic matter

The effect of tillage on l SOM was insignificant after crop harvest (Table 2). There was a decline in SOM with soil depth irrespective of tillage practices. SOM was increased in the succeeding crop harvest in both the layers. After third crop, strip tillage increased soil organic matter compared to bed and zero tillage at 0–7.5 cm soil depth. Initially, soil of the experimental plot contained less amount of organic matter. The values measured at the end of the trial showed that there was an improvement in soil organic matter in all the tillage trials. Staley *et al*. (1988) reported that intensive tillage operations result in more or less even distribution of SOM in topsoil, but in minimum tillage the concentration of organic matter was in the surface (0-5 cm) soil. Paustian *et al*. (1997) reported increased organic matter content with conservation tillage. Conventional tillage practices have resulted in lower carbon contents of agricultural soils due to increased decomposition rates and carbon redistribution (Christensen, 1996).

Cultivation also stimulates soil carbon losses due to accelerated oxidation of soil carbon by microbial action. In conventionally tilled soils, the organic matter was fairly distributed throughout the plow layer due to incorporation of crop residues evenly in the plowed layer. Examining the depth effect under tillage practices there was a decline in SOM with depth. Accumulation of organic carbon in the upper soil layer is evident under long-term no-tillage conditions (Singh *et al.,* 1994). After three years, retention of crop residues, irrespective of tillage treatments, increased SOM at 7.5–15.0 cm soil depth. Increase in organic matter in the 7.5-15 cm compared to upper layer may be attributed to the restricted decomposition.

Table 1. Effect of tillage and residue retention on soil pH at two soil depths

Tillage	Aman 2009				Maize 2010				Aman 2010			
	CR_{100}	CR_{50}	CR_0	Mean	CR_{100}	CR_{50}	CR_0	Mean	CR_{100}	CR_{50}	CR_0	Mean
0-7.5 cm depth												
CT				8.63	7.37	8.07	7.37	7.60	8.46	8.28	8.40	8.38
SPWT/ZT				8.63	7.40	7.57	8.03	7.67	8.41	8.46	8.46	8.44
BP				8.67	7.27	7.30	7.60	7.39	8.33	8.41	8.43	8.39
ST				8.63	7.30	7.30	7.70	7.43	8.39	8.42	8.43	8.41
Mean					7.34	7.56	7.68		8.40	8.39	8.43	
$LSD_{0.05}$	Tillage (T) = NS				Tillage (T) = NS Residue (CR) = NS T × CR = NS				Tillage (T) = NS Residue (CR) = NS T × CR = NS			
CV (%)	0.75				8.50				0.65			
	Maize 11				Aman 11							
CT	8.27	8.30	8.30	8.29	8.33	8.33	8.30	8.32				
SPWT/ZT	8.30	8.20	8.30	8.27	8.37	8.30	8.37	8.34				
BP	8.30	8.30	8.33	8.31	8.33	8.33	8.27	8.31				
ST	8.30	8.27	8.17	8.24	8.33	8.33	8.33	8.33				
Mean	8.29	8.27	8.28		8.34	8.32	8.32					
$LSD_{0.05}$	Tillage (T) = NS Residue (CR) = NS T × CR = NS				Tillage (T) = NS Residue (CR) = NS T × CR = NS							
CV (%)	1.13				0.65							
7.5-15 cm depth												
	Aman 2009				Maize 2010				Aman 2010			
CT				8.57	8.27	8.20	7.97	8.14	8.18	8.29	8.50	8.32
SPWT/ZT				8.67	8.10	8.23	7.53	7.96	8.31	8.49	8.50	8.43
BP				8.60	8.23	7.97	8.30	8.17	8.27	8.44	8.47	8.39
ST				8.63	7.97	8.23	8.30	8.17	8.11	8.39	8.45	8.32
Mean					8.14	8.16	8.03		8.22	8.40	8.48	
$LSD_{0.05}$	Tillage (T) = NS				Tillage (T) = NS Residue (CR) = NS T × CR = NS				Tillage (T) = NS Residue (CR) = NS T × CR = NS			
CV (%)	1.28				4.24				2.30			
	Maize 2011				Aman 2011							
CT	8.33	8.33	8.40	8.36	8.47	8.53	8.53	8.51				
SPWT/ZT	8.30	8.33	8.33	8.32	8.53	8.50	8.50	8.51				
BP	8.40	8.33	8.37	8.37	8.50	8.47	8.43	8.47				
ST	8.30	8.40	8.40	8.37	8.50	8.50	8.50	8.50				
Mean	8.33	8.35	8.38		8.50	8.50	8.49					
$LSD_{0.05}$	Tillage (T) = NS; Residue (CR) = NS; T × CR = NS				Tillage (T) = NS; Residue (CR) = NS;T × CR = NS							
CV (%)	1.36				0.63							

CT = Conventional tillage, SPWT = Single pass wet tillage, ZT = Zero tillage, BP = Bed planting, ST = Strip tillage, CR = Previous crop residue retention, CR_{100}, CR_{50} and CR_0 corresponds to 100%, 50% and 0% previous crop residue retention, NS = Non-significant

Table 2. Effect of tillage and residue retention on soil organic matter (%) at two soil depths

Tillage	Aman 2009				Maize 2010				Aman 2010			
	CR_{100}	CR_{50}	CR_0	Mean	CR_{100}	CR_{50}	CR_0	Mean	CR_{100}	CR_{50}	CR_0	Mean
0-7.5 cm depth												
CT				1.10	1.41	1.52	1.25	1.39	1.58	1.50	1.55	1.54
SPWT/ ZT				1.20	1.20	1.25	1.59	1.35	1.59	1.50	1.51	1.53
BP				1.24	1.49	1.26	1.52	1.42	1.70	1.37	1.47	1.51
ST				1.10	1.33	1.29	1.36	1.33	1.61	1.54	1.62	1.59
Mean					1.36	1.33	1.43		1.62	1.48	1.54	
$LSD_{0.05}$	Tillage (T) = NS				Tillage (T) = NS Residue (CR) = NS T × CR = NS				Tillage (T) = 0.06 Residue (CR) = NS T × CR = NS			
CV (%)	12.70				16.50				12.55			
	Maize 2011				Aman 2011							
CT	1.39	1.30	1.30	1.33	1.42	1.30	1.49	1.40				
ZT/SPWT	1.38	1.28	1.28	1.31	1.23	1.40	1.61	1.41				
BP	1.27	1.25	1.29	1.27	1.17	1.42	1.35	1.31				
ST	1.32	1.18	1.43	1.31	1.56	1.57	1.59	1.57				
Mean	1.34	1.25	1.33		1.35	1.42	1.51					
$LSD_{0.05}$	Tillage (T) = NS Residue (CR) = NS T × CR = NS				Tillage (T) = NS Residue (CR) = NS T × CR = NS							
CV (%)	14..32				17.23							
7.5-15 cm depth												
	Aman 2009				Maize 2010				Aman 2010			
CT				0.50	0.81	1.02	0.81	0.88	1.33	1.12	0.82	1.09
SPWT/ ZT				0.52	0.67	0.88	0.59	0.71	0.88	0.92	1.14	0.98
BP				0.48	0.80	0.72	0.74	0.75	1.12	1.22	0.95	1.10
ST				0.45	0.74	0.81	0.69	0.75	1.00	0.99	1.28	1.09
Mean					0.76	0.86	0.71		1.08	1.06	1.05	
$LSD_{0.05}$	Tillage (T) = NS				Tillage (T) = NS Residue (CR) = NS T × CR = NS				Tillage (T) = NS Residue (CR) = NS T × CR = NS			
CV (%)	39.40				22.95				32.19			
	Maize 2011				Aman 2011							
CT	0.86	0.77	1.13	0.92	1.25	0.92	1.10	1.09				
ZT/SPWT	1.26	1.39	1.17	1.27	1.08	1.20	0.95	1.08				
BP	1.08	0.94	1.24	1.09	1.10	1.17	0.95	1.07				
ST	0.76	0.31	1.13	0.73	1.17	1.23	0.95	1.12				
Mean	0.99	0.85	1.17		1.15	1.13	0.99					
$LSD_{0.05}$	Tillage (T) = NS; Residue (CR) = NS;T ×CR = NS				Tillage (T) = NS; Residue (CR) = 0.12; T × CR = NS							
CV (%)	55.77				15.28							

CT = Conventional tillage, SPWT = Single pass wet tillage, ZT = Zero tillage, BP = Bed planting, ST = Strip tillage, CR = Previous crop residue retention, CR_{100}, CR_{50} and CR_0 corresponds to 100%, 50% and 0% previous crop residue retention, NS = Non-significant

SOM value was the highest in all the tillage treatment receiving 100% residue incorporation than no residue incorporation except in second and fifth crop. It was because organic matter increased due to decomposition of crop residue. Tillage systems (no tillage or minimum tillage) that reduce soil disturbance and residue incorporation have generally been observed to increase SOM (Mrabet *et al.,* 2001). The findings of the study showed benefits by the application of residue incorporation. Ghoshal and Singh (1995) largely attributed these beneficial effects to enhanced microbial activity and soil organic matter.

3.3. Nitrogen

The effect of tillage and residue incorporation on soil N at two depths is shown in Table 3. Interaction effect of tillage and residue retention on N was not significant at two depths in all the crop harvest. Tillage practices had insignificant effect on soil N after all the crop harvest. The total N content was the highest in top layer than bottom layer. The total N concentration was fairly similar in all the tillage treatment. Soil N was not affected significantly by residue incorporation in three years study. After three years crop production, residue retention showed no influence on total nitrogen in the top layer. However, residue incorporation increased total nitrogen in the bottom layer. Increase in total N may be explained by the fact of increase in soil organic matter.

Balesdent *et al.* (2000) concluded that mineralizable nitrogen in the surface soil (0-10 cm) was more in case of no-tillage as compared with CT. The higher amount of mineralizable nitrogen under no-till than under conventionally till may be attributed to greater pool of labile nitrogen with a slow decomposition rate (Germon *et al*., 1991; Balesdent *et al.*, 2000) related this to higher biomass production.

3.4. Phosphorus

Table 4 showed the effect of tillage and crop residue retention on P concentration. Before hosting the trial, the soil enjoyed poor amount of P concentration. The data demonstrate that soil phosphorus was not affected significantly by the combined action of tillage systems and residue retention at two depths in all the crop harvest. The phosphorus level was the highest in top layer than bottom layers.

Effect of tillage on soil phosphorus concentration was not significant after crop harvest. Irrespective of tillage practices, phosphorus level was increased from initial condition to the end of the experiment. Effect of CR on soil P was not significant after crop harvest. At the end of three-year trial, P concentration was also increased irrespective of level of residue incorporation at 0-7.5 cm depth.

3.5. Potassium

Effect of tillage and residue retention on soluble K of soil was shown in Table 5. The tillage practice × residue incorporation demonstrated insignificant effect on K concentration. Effect of tillage on soluble K concentration was not significant in both layers. Effect of CR on soil K concentration was not significant at two depths in all the crop harvest. In each crop season, the incorporation of crop residue did not influence the available K concentrations significantly. At the end of the three-years' trial, zero tillage increased K concentration at both layer. These results are supported by the earlier findings of Mahboubi *et al*. (1993) of higher available K concentrations in no-till soils.

In the present findings, the K concentration was higher in ZT. Yin and Vyn (2002) also observed more soil K in case of no-tillage as compared to deep tillage. The repeated no-tillage has resulted in vertical stratification of soil K (Holanda *et al*., 1998; Yin and Vyn, 2002). Only change of the exchangeable K could not capture the full story of the K history. Because incorporation of crop residues added a huge amount of K, some of which may have incorporated into the non-exchangeable form to maintain K equilibrium in soil.

Table 3. Effect of tillage and residue retention on soil nitrogen (%) at two depths

Tillage	Aman 2009				Maize 2010				Aman 2010			
	CR_{100}	CR_{50}	CR_0	Mean	CR_{100}	CR_{50}	CR_0	Mean	CR_{100}	CR_{50}	CR_0	Mean
0-7.5 cm depth												
CT				0.05	0.07	0.08	0.06	0.07	0.08	0.07	0.08	0.08
SPWT/ ZT				0.06	0.06	0.06	0.08	0.07	0.08	0.07	0.07	0.07
BP				0.06	0.07	0.06	0.08	0.07	0.08	0.07	0.07	0.07
ST				0.05	0.06	0.06	0.06	0.06	0.08	0.08	0.08	0.08
Mean					0.07	0.07	0.07		0.08	0.07	0.08	
$LSD_{0.05}$	Tillage (T) = NS				Tillage (T) = NS Residue (CR) = NS T × CR = NS				Tillage (T) = NS Residue (CR) = NS T × CR = NS			
CV (%)	13.55				16.33				13.72			
	Maize 2011				Aman 2011							
CT	0.07	0.06	0.06	0.06	0.07	0.06	0.07	0.07				
ZT/SPWT	0.07	0.06	0.06	0.06	0.06	0.07	0.08	0.07				
BP	0.07	0.06	0.06	0.06	0.07	0.07	0.06	0.07				
ST	0.06	0.06	0.07	0.06	0.08	0.08	0.08	0.08				
Mean	0.07	0.06	0.06		0.07	0.07	0.07					
$LSD_{0.05}$	Tillage (T) = NS				Tillage (T) = NS Residue (CR) = NS T X CR = NS							
CV (%)	14.13				24.84							
7.5-15 cm depth												
	Aman 2009				Maize 2010				Aman 2010			
CT				0.03	0.04	0.05	0.04	0.04	0.06	0.05	0.04	0.05
SPWT/ZT				0.03	0.03	0.05	0.03	0.04	0.04	0.05	0.05	0.05
BP				0.03	0.04	0.04	0.04	0.04	0.05	0.06	0.05	0.05
ST				0.03	0.04	0.04	0.03	0.04	0.05	0.05	0.06	0.05
Mean					0.04	0.05	0.04		0.05	0.05	0.05	
$LSD_{0.05}$	Tillage (T) = NS				Tillage (T) = NS Residue (CR) = NS T × CR = NS				Tillage (T) = NS Residue (CR) = NS T × CR = NS			
CV (%)	35.90				21.15				32.62			
	Maize 2011				Aman 2011							
CT	0.04	0.04	0.05	0.04	0.06	0.04	0.05	0.05				
ZT/SPWT	0.06	0.07	0.06	0.06	0.05	0.06	0.05	0.05				
BP	0.05	0.04	0.06	0.05	0.06	0.06	0.05	0.05				
ST	0.04	0.02	0.05	0.04	0.06	0.06	0.05	0.06				
Mean	0.05	0.04	0.06		0.06	0.05	0.05					
$LSD_{0.05}$	Tillage (T) = NS; Residue (CR) = NS; T × CR = NS				Tillage (T) = NS; Residue (CR) = 0.01; T × CR = NS							
CV (%)	14.13				17.12							

CT = Conventional tillage, SPWT = Single pass wet tillage, ZT = Zero tillage, BP = Bed planting, ST = Strip tillage, CR = Previous crop residue retention, CR_{100}, CR_{50} and CR_0 corresponds to 100%, 50% and 0% previous crop residue retention, NS = Non-significant

Table 4. Effect of tillage and residue retention on soil phosphorus (µg g soil^{-1})at two depths

Tillage	Aman 2009				Maize 2010				Aman 2010			
	CR_{100}	CR_{50}	CR_0	Mean	CR_{100}	CR_{50}	CR_0	Mean	CR_{100}	CR_{50}	CR_0	Mean
0-7.5 cm depth												
CT				11.77	14.50	17.90	25.03	19.14	18.80	18.13	20.10	19.01
SPWT/ ZT				12.70	9.67	15.60	13.47	12.91	18.90	13.20	14.83	15.64
BP				10.80	12.53	14.30	11.63	12.82	20.93	20.77	26.17	22.62
ST				11.00	12.13	6.47	7.77	8.79	20.93	15.87	16.97	17.92
Mean					12.21	13.57	14.48		19.89	16.99	19.52	
$LSD_{0.05}$	Tillage (T) = NS				Tillage (T) = NS Residue (CR) = NS T × CR = NS				Tillage (T) = NS Residue (CR) = NS T × CR = NS			
CV (%)	10.31				32.92				22.26			
	Maize 2011				Aman 2011							
CT	9.09	10.81	10.27	10.06	15.93	19.23	19.53	18.23				
ZT/SPWT	8.19	8.55	7.63	8.12	17.87	15.93	15.90	16.57				
BP	11.89	7.52	8.56	9.32	18.77	19.00	21.93	19.90				
ST	9.52	10.18	13.00	10.90	14.33	15.47	14.83	14.88				
Mean	9.67	9.27	9.87		16.73	17.41	18.05					
$LSD_{0.05}$	Tillage (T) = NS Residue (CR) = NS T × CR = NS				Tillage (T) = NS Residue (CR) = NS T × CR = NS							
CV (%)	24.38				14.37							
7.5-15 cm depths												
	Aman 2009				Maize 2010				Aman 2010			
CT				9.97	7.87	8.27	6.63	7.59	10.43	10.00	14.93	11.79
SPWT/ ZT				11.23	14.17	8.13	6.53	9.61	8.70	13.53	11.90	11.38
BP				10.30	6.77	6.00	8.00	6.92	11.00	10.57	14.23	11.93
ST				8.93	6.20	6.63	7.17	6.67	11.93	11.70	10.27	17.92
Mean					8.75	7.26	7.08		10.52	11.45	12.83	
$LSD_{0.05}$	Tillage (T) = NS				Tillage (T) = NS Residue (CR) = NS T × CR = NS				Tillage (T) = NS Residue (CR) = NS T × CR = NS			
CV,%	10.57				34.13				26.74			
	Maize 2011				Aman 2011							
CT	16.67	12.95	10.42	13.35	18.03	18.10	18.00	18.04				
ZT/SPWT	11.44	9.29	16.99	12.58	20.60	16.67	15.67	17.64				
BP	12.30	18.88	10.95	14.04	15.17	15.43	23.97	18.19				
ST	7.59	7.89	8.71	8.06	17.30	17.27	17.97	17.51				
Mean	12.00	12.25	11.77		17.78	16.87	18.90					
$LSD_{0.05}$	Tillage (T) = 4.41; Residue (CR) = NS; T × CR = 6.40				Tillage (T) = NS; Residue (CR) = NS; T × CR = NS							
CV (%)	26.68				31.20							

CT = Conventional tillage, SPWT = Single pass wet tillage, ZT = Zero tillage, BP = Bed planting, ST = Strip tillage, CR = Previous crop residue retention, CR_{100}, CR_{50} and CR_0 corresponds to 100%, 50% and 0% previous crop residue retention, NS = Non-significant

Table 5. Effect of tillage and residue retention on soil potassium (m equivalent 100 gm soil^{-1}) at two depths

Tillage	Aman 2009				Maize 2010				Aman 2010			
	CR_{100}	CR_{50}	CR_0	Mean	CR_{100}	CR_{50}	CR_0	Mean	CR_{100}	CR_{50}	CR_0	Mean
0-7.5 cm depth												
CT				0.18	0.23	0.21	0.21	0.22	0.20	0.21	0.21	0.21
SPWT/ ZT				0.19	0.17	0.20	0.18	0.18	0.20	0.21	0.20	0.21
BP				0.17	0.20	0.18	0.21	0.20	0.21	0.22	0.21	0.21
ST				0.17	0.19	0.17	0.15	0.17	0.20	0.20	0.19	0.20
Mean					0.20	0.19	0.19		0.20	0.21	0.20	
$LSD_{0.05}$	Tillage (T) = NS				Tillage (T) = NS Residue (CR) = NS T × CR = NS				Tillage (T) = NS Residue (CR) = NS T × CR = NS			
CV (%)	4.48				17.59				4.53			
	Maize 2011				Aman 2011							
CT	0.18	0.21	0.19	0.19	0.20	0.21	0.19	0.20				
ZT/SPWT	0.17	0.21	0.15	0.18	0.20	0.23	0.20	0.21				
BP	0.19	0.19	0.17	0.18	0.19	0.20	0.20	0.20				
ST	0.18	0.18	0.15	0.17	0.19	0.20	0.20	0.20				
Mean	0.18	0.20	0.17		0.20	0.21	0.20					
$LSD_{0.05}$	Tillage (T) = NS Residue (CR) = NS T × CR = NS				Tillage (T) = NS Residue (CR) = NS T × CR = NS							
CV (%)	16.03				8.98							
7.5-15 cm depth												
	Aman 2009				Maize 2010				Aman 2010			
CT				0.18	0.16	0.18	0.16	0.17	0.20	0.21	0.19	0.20
SPWT/ ZT				0.20	0.20	0.19	0.17	0.19	0.21	0.22	0.21	0.22
BP				0.20	0.16	0.16	0.16	0.16	0.21	0.21	0.20	0.21
ST				0.17	0.16	0.17	0.16	0.16	0.20	0.20	0.20	0.20
Mean					0.17	0.18	0.16		0.21	0.21	0.20	
$LSD_{0.05}$	Tillage (T) = NS				Tillage (T) = NS Residue (CR) = NS T ×CR = NS				Tillage (T) = NS Residue (CR) = NS T × CR = NS			
CV (%)	4.26				12.04				5.88			
	Maize 2011				Aman 2011							
CT	0.15	0.14	0.14	0.14	0.19	0.21	0.18	0.19				
ZT/SPWT	0.15	0.14	0.14	0.14	0.20	0.22	0.19	0.20				
BP	0.15	0.18	0.16	0.16	0.19	0.21	0.19	0.20				
ST	0.15	0.12	0.12	0.13	0.18	0.19	0.18	0.19				
Mean	0.15	0.15	0.14		0.19	0.21	0.19					
$LSD_{0.05}$	Tillage (T) = NS; Residue (CR) = NS; T × CR = NS				Tillage (T) = NS; Residue (CR) = NS; T × CR = NS							
CV (%)	17.33				6.64							

CT = Conventional tillage, SPWT = Single pass wet tillage, ZT = Zero tillage, BP = Bed planting, ST = Strip tillage, CR = Previous crop residue retention, CR_{100}, CR_{50} and CR_0 corresponds to 100%, 50% and 0% previous crop residue retention, NS = Non-significant

4. Conclusions

Tillage practices with crop residue retention had no significant effect on soil chemical properties such as pH, soil organic matter, potassium, phosphorus and nitrogen concentrations.

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