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EFFECT OF TILLAGE AND CROP RESIDUE ON SOIL CHEMICAL PROPERTIES AND RICE YIELDS ON AN ACID ULTISOL AT ABAKALIKI SOUTHEASTERN NIGERIA

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ABSTRACT

A study was conducted in 2008 and 2009 raining seasons, to evaluate the possibility of alleviating the degraded soil conditions at Abakaliki. The measures employed were combination(s) of different tillage methods [No-Tillage (NT), Hoe Tillage (HT), Ploughing (PL) and Ploughing and Harrowing (PH)] and crop residues [No Residue (NR), Rice Straw (RS), Burnt Rice Straw (BRS) and Legume Residue (LR)] treatments. Improved rice cultivars (ITA 257, Ex-China and ITA 315) were the test crops. The design of the experiment was a 4 x 4 x 3 factorial in a Randomized Complete Block Design replicated three times.. The results obtained showed that soil organic matter, pH, available P, exchangeable K, Ca, Mg and CEC significantly ($p<0.05$) improved in the plots that received crop residue across the four tillage methods compared to where crop residues were not applied. The soil chemical properties were also significantly ($p<0.05$) superior with the application of BRS across the four tillage methods compared to the application of the other residue treatments. Rice growth and grain yield were significantly ($p<0.05$) higher on the plots that received the combination of the different tillage methods and crop residues respectively than the combination of the different tillage methods without crop residues. There were grain yield increases of 1.47, 1.21 and 1.20 t/ha in the first year and 2.05, 1.64 and 1.53 t/ha in the second year with the application of NT+BRS, NT+RS and NT+LR respectively compared to the application of NT+NR. The application of HT+BRS, HT+RS and HT+LR brought about significant ($p<0.05$) grain yield increases of 1.65, 1.20 and 1.16 t/ha and 2.67, 2.45 and 2.42 t/ha in the first year and second year respectively. Grain yield significantly ($p<0.05$) increase by 1.91, 1.68 and 1.62 t/ha in the first year and 2.44, 1.95 and 1.91 t/ha in the second year respectively as a result of PL+BRS, PL+RS and PL+LR treatments compared to PL+NR. PH+BRS, PH+RS and PH+LR treatments led to significant ($p<0.05$) grain yield increases of 2.55, 1.54 and 1.52 t/ha respectively in the first year and 2.74, 1.72 and 1.71 t/ha respectively in the second year compared to the application of PH+NR treatment. The ITA 315 and Ex-China produced 0.55 and 0.47 t/ha, and 0.62 and 0.50 t/ha significantly ($p<0.05$) higher grains than ITA 257 in the first and second years respectively. The highest grain yield of 4.87 t/ha in the study was obtained from ITA 315 grown on soil that received PH+BRS treatment.

Key words: Tillage and Crop Residue, Soil Chemical Properties, Rice Yields, Acid Ultisol, Southeastern Nigeria

INTRODUCTION

Most tropical soils are known to suffer structural and fertility constraints. The soils of the Abakaliki Agro-ecological zone of Southeastern Nigeria, which falls under the tropical environment, have specifically been reported by several researchers to be very acidic, low in organic matter content and that consequently the soils have low levels of exchangeable bases, cation exchange capacity and buffer capacity (Enwezor *et al.*, 1985; FDALR, 1985 and Asadu and Akamigbo, 1990). The soils are therefore, of low fertility leading to low crop productivity. The use of tillage and crop residue has been advanced as part of the measures that could be used to manage the soil productivity problems and increase the yield of crops.

Rice production in Abakaliki area has been severely affected by the degraded soil conditions. The average yield of 2.5 t/ha normally obtained from the area is rather low compared to yields from other rice producing areas of the world. Efforts had been made to resolve the productivity constrains of the soil through the use of different tillage methods, or various organic manure sources and management methods (Nnabude and Mbagwu, 1999; Ogbodo, 2004; Ogbodo, 2005a,b; Ogbodo, 2009 and Ogbodo, 2010).

The present study is a combination of different tillage methods and crop residue sources to resolve the soil and crop productivity problems in the study area, using improved rice cultivars as the test crop.

MATERIALS AND METHODS

The experiments were carried out in the 2008 and 2009 raining seasons at the Research and Teaching Farm of the Faculty of Agriculture, Ebonyi State University, Abakaliki. The area is located within longitude 08^0 03^1 E and latitude 06^0 25^1 N in the derived savanna zone of Nigeria. The mean monthly temperatures ranged between 24 ^{0}C and 28 ^{0}C. The rainfall pattern was bimodal, with peaks in the months of July and September. Annual amounts of rainfall ranged between 1800 and 2000 mm. Rainfall stabilized around May and stopped around October, leaving a dry period between November and April during the study seasons. The soil is hydromorphic and has an isohypothermic soil temperature regime and belongs to the order ultisol derived from shale and classified as typic haplustult (FDALR, 1985). The description of the surface soil physical and chemical characteristics is shown in Table 1. The experimental site was previously used for rice cultivation, before it was used for the experiment.

Table 1: Pre-Planting Soil Texture and Chemical Properties

Soil Texture	
Sand (%)	44.80
Silt (%)	34.40
Clay (%)	20.80
Textural Class	Sandy Clay Loam
Chemical Properties	
pH (H_2O)	4.80
Organic Matter (%)	2.00
Total N (%)	0.12
Available P (gm/kg)	6.00
K (cmol(+)kg)	0.19
Ca (cmol(+)kg)	2.10
Mg (cmol(+)kg)	2.20
CEC (cmol(+)kg)	4.60

Experimental Design and Field Layout

The experimental design used was 4 x 3 x 4 split-split plot factorial in a Randomized Complete Block Design. The area of land used for the experiment measured 769.5 m^2. Each replicate measured 256.5 m^2 and comprised of four tillage methods, three rice cultivars and four crop residue sources. There were three blocks within each tillage treatment (made up of twelve treatment units) measuring 54 m^2. Each block comprised of 4 treatment units, each measuring 16 m^2. The replicates and tillage methods were separated by one another by 1m alleys respectively, whereas the individual plots were separated by 0.5 m alleys.

Treatments

Tillage methods were the main treatment, the rice cultivars were the sub treatment whereas crop residues were the sub-sub treatment. Each treatment was replicated three times. The tillage methods were: No – tillage (NT), Hoe – tillage (HT), Ploughing (PL) and Ploughing and harrowing (PH). The three rice cultivars were ITA 315, Ex-china and ITA 257, whereas the crop residue treatments were no residue (NR), Rice Straw (RS), Burnt Rice Straw (BRS) and legume residue (LR). The dry rice straw was from the previous year's harvest, whereas *Centrocema pubensis* was harvested from the ones growing widely in the surrounding bush. The improved rice cultivars used for the trials were foundation seeds sourced from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

Treatment Applications

The ploughing was carried out once for the PL plots, while the PH plots were ploughed once and harrowed twice. For the HT plots, the vegetation was slashed with a matchet and removed, while the soil was tilled manually with a hoe. A non selective herbicide, glyphosate (360g a.i) was sprayed on the vegetation on the NT plots at the rate of 5 litres per hectare two weeks before sowing the seed. The crop residues were applied as surface mulch on the appropriate plots. 5 ton per hectare (t/ha) equivalent of dry rice straw, freshly harvested *Centrosema pubensis* and burnt rice straw were applied on the appropriate plots respectively. For the NR plots, no crop residue was applied while the existing plant residues were removed. The rice seeds were direct seeded by dibbling; using sticks to create opening and the seeds covered after sowing. Three seeds were planted per hill at a spacing of 25 cm x 25 cm, and later thinned down to two seedlings per stand at 21 days after planting (DAP), giving a plant population of 320,000 stands per hectare.

Cultural Practices

Fertilizer was applied at the rate of 40 kg P / ha as single super phosphate, 40 kg K / ha as muriate of potash and 80 kg N / ha as urea to all the plots. One third of the N fertilizer was applied alongside the P and K basally before residue application; 4 days before planting the seeds, whereas the remaining two thirds of N were applied at 75 DAP.

Data Collection

Six soil auger samples were randomly collected from the experimental area at 0-20 cm depth for pre-planting soil analysis. At the end of each season's experiments, six auger samples were taken from each plot, mixed and a sub-sample taken for post harvest chemical analysis. Plant height and tiller number were measured at 75 DAP. Plant height was taken as the height from the base of the plant and the tip of the tallest tiller using a meter rule. At dry maturity, the rice panicles were harvested from a net plot of 2 m x 2 m in the middle of each plot, dried, threshed and the grain yield data adjusted to 14% moisture, and converted to t/ha.

Laboratory Methods

The pre-planting composite soil sample (taken at 0 – 20cm depth) was analyzed in the laboratory for the texture and chemical properties. The soil particle size distribution was determined by the hydrometer method (Gee and Bouder, 1986). The post harvest soil samples taken from each plot were subjected to chemical analysis. Total nitrogen was determined by the Macro Kjeldahl method (Bouycous, 1951). Available P was determined using Bray II method as outlined in Page *et al.* (1982). Organic carbon was determined by the Walkley and Black method (Nelson and Sommers, 1982). Soil pH (2:1 in water) was determined by the glass electrode pH meter (Maclean, 1982). Exchangeable bases were extracted using the ammonium acetate method (Tel and Rao, 1982)

DATA ANALYSIS

Analysis of variance and mean separation were done using least significant difference test for $P \leq 0.05$ procedure described as described by SAS (2006).

RESULTS

Soil chemical properties

The effect of tillage methods and crop residue treatments on soil chemical properties are presented in Tables 2a – b. Significantly ($p<0.05$) higher organic matter levels were detected on the rice straw and legume residue treated plots than on the no-residue and burnt rice straw treated plots across the four tillage methods. Application of the various crop residues raised the soil pH levels across the four tillage methods compared to where the soil was not treated with crop residue. Treating the soil with burnt rice straw significantly ($p<0.05$) increased soil pH compared to the other residue treatments across the tillage methods.

Significantly ($p<0.05$) higher N, P, K, Ca and Mg levels were also detected on the soils treated with crop residue than where crop residue treatment was not applied across the four tillage methods. The concentrations of exchangeable Ca and Mg were significantly ($p<0.05$) higher on the soils that received burnt rice straw treatment across the four tillage methods than where the soil was treated with rice straw and legume residue across the tillage treatments.

The soils that received tillage and crop residue treatments had significantly ($p<0.05$) higher cation exchange capacity than the soils that were treated with the various tillage methods but without crop residue application. The soils that specifically received burnt rice straw treatment across the various tillage treatments had significantly ($p<0.05$) higher cation exchange capacity compared to the ones that were treated with rice straw or legume residue across the four tillage methods.

Table 2a: Effect of Tillage and Crop Residue on Organic Matter, pH, Total Nitrogen and Available Phosphorus

First Year

Residue Type	Organic Matter (%)				pH (H_20)				Total Nitrogen (%)				Available Phosphorus (mg/ gm)			
	NT	HT	PL	PH	NT	HT	PL	PH	NT	HT	PL	PH	NT	HT	PL	PH
NR	2.00	1.00	2.00	2.02	4.80	4.70	4.70	4.50	0.12	0.12	0.11	0.14	6.00	5.80	5.50	6.60
RS	2.90	2.00	2.94	2.93	5.70	5.70	5.90	5.10	0.22	0.20	0.26	0.20	11.70	10.80	11.40	10.10
BRS	2.46	1.21	2.22	2.20	6.40	6.40	6.30	6.40	0.25	0.20	0.20	0.20	10.70	11.40	11.70	10.10
LR	2.87	2.00	2.63	2.62	5.70	5.80	5.70	5.60	0.22	0.22	0.24	0.21	9.50	8.10	9.70	8.50
$LSD_{(0.05)}$	0.40				0.65				0.09				2.53			

Second Year

Residue Type	Organic Matter (%)				pH (H_20)				Total Nitrogen (%)				Available Phosphorus (mg/ gm)			
	NT	HT	PL	PH	NT	HT	PL	PH	NT	HT	PL	PH	NT	HT	PL	PH
NR	2.03	0.95	2.08	2.06	4.40	4.00	4.50	4.70	0.17	0.12	0.15	0.16	5.50	5.10	4.80	8.20
RS	2.99	2.00	2.92	2.94	5.60	5.80	6.00	5.40	0.24	0.19	0.22	0.23	11.20	11.00	10.20	11.10
BRS	2.36	1.26	2.00	2.20	6.90	6.30	6.60	6.60	0.24	0.22	0.24	0.24	10.60	10.10	11.00	10.10
LR	2.97	1.98	2.82	2.82	5.40	5.70	5.70	6.20	0.27	0.25	0.25	0.24	7.90	9.00	8.00	10.70
$LSD_{(0.05)}$	0.36				0.68				0.06				2.26			

NT = No-Tillage; HT= Hoe Tillage; PL = Ploughing; PH = Ploughing and Harrowing; NR = No Residue; RS = Rice Straw; BRS = Burnt Rice Straw and LR = Legume Residue

Table 2b. Effect of Tillage and Crop Residue on Exchangeable K, Ca, Mg and Soil CEC

First Year

Residue Type	Exchangeable K (Cmol / kg)				Exchangeable Ca (Cmol / kg)				Exchangeable Mg (Cmol / kg)				Soil CEC (Cmol / kg)			
	NT	HT	PL	PH	NT	HT	PL	PH	NT	HT	PL	PH	NT	HT	PL	PH
NR	0.19	0.15	0.16	0.17	2.10	1.10	2.00	2.10	2.20	1.00	2.10	2.10	4.49	2.25	4.26	4.37
RS	0.43	0.34	0.51	0.50	4.10	3.70	4.80	4.60	4.00	2.50	4.10	4.40	8.53	6.54	9.41	9.50
BRS	0.45	0.42	0.46	0.48	6.00	5.70	6.00	4.10	5.20	3.90	5.60	5.80	11.65	10.02	12.06	10.38
LR	0.37	0.30	0.46	0.47	4.10	4.40	4.70	4.80	3.30	3.00	3.50	3.60	7.77	7.70	8.66	8.87
LSD $_{(0.05)}$	0.18				1.06				1.10					2.43		

Second Year

Residue Type	Exchangeable K (Cmol / kg)				Exchangeable Ca (Cmol / kg)				Exchangeable Mg (Cmol / kg)				Soil CEC (Cmol / kg)			
	NT	HT	PL	PH	NT	HT	PL	PH	NT	HT	PL	PH	NT	HT	PL	PH
NR	0.17	0.16	0.19	0.17	2.40	2.20	2.30	2.30	2.20	1.90	2.20	2.20	4.77	4.26	4.69	4.67
RS	0.45	0.34	0.42	0.40	4.40	4.10	4.90	4.80	4.20	3.20	4.00	4.90	9.05	7.64	9.32	10.10
BRS	0.46	0.47	0.47	0.40	6.70	6.30	5.80	6.30	5.80	4.90	5.60	5.60	12.96	11.67	11.87	12.30
N LR	0.34	0.30	0.40	0.42	4.00	3.80	4.40	4.80	3.90	3.20	3.80	3.60	8.24	7.30	8.60	8.82
T LSD $_{(0.05)}$	0.17				1.02				1.08					2.38		

= No-Tillage; HT= Hoe Tillage; PL = Ploughing; PH = Ploughing and Harrowing; NR = No Residue; RS = Rice Straw; BRS = Burnt Rice Straw and LR = Legume Residue

Rice Crop Growth

The growth response of the rice cultivars to soil tillage and crop residue treatments are shown in Tables 3 and 4. Generally, rice growth was significantly ($p<0.05$) better on the soil treated with the combination of crop residues and tillage method than on the soil tilled or untilled without crop residue treatment for the two years study. The growths of the crops were superior on tilled soil treated with crop residue than on the tilled soil without crop residue treatment. Growth was also superior on the untilled plots with crop residue treatment than untilled plots without residue treatment. The three rice varieties were significantly ($p<0.05$) taller when the soil was treated with crop residue than where the soil had no crop residue treatment across the four tillage methods. Ploughing, ploughing and harrowing the soil with crop residue significantly ($p<0.05$) increased plant height than when the soil was not tilled, or hoe –tilled with or without crop residue treatment. There were no significant differences in plant heights of the three varieties when under the same treatments. Tillering was significantly ($p<0.05$) higher in ITA 315 and Ex-china than in ITA 257. The three varieties produced significantly ($p<0.05$) higher number of tillers when the soil was tilled and treated with crop residue than when not; and when the soil was untilled with crop reissue treatment than when not. Ploughing, ploughing and harrowing the soil with crop residue treatment significantly ($p<0.05$) increased tillering compared to where the soil was not tilled or hoe-tilled with or without crop residue treatment. Tillerings of the three varieties were statically comparable when the soil received rice straw, legume residue and burnt rice husk treatments across the four tillage methods.

Specifically, the influence of the No-tillage method and residue treatment on the tillering of the three varieties for the two years was in the order: NT+BRS = NT+RS = NT+LR > NT+NR. The application of Hoe-tillage method and residue treatments to the soil led to significant differences in tillering of the three varieties in the order HT+BRS = HT + RS = HT+LR > HT+NR in the first year, and HT + BRS>HT+RS = HT+LR> HT+NR in the second year. When the soil was treated with ploughing and crop residue the rice tillering was in the order: PR > PL + RS > PL +LRI> PL+NR whereas in the second year it was in the order: PL+BRS>PL+LR>PL+RS>PL+NR. The influence of ploughing and harrowing with crop residue treatments on the rice tillering showed that in the first year PH+RS>PH+BRS>PH+LR>PH+NR in the first year, while in the second year the tillering was in the order PH + BRS = PH + LR = PH + LR > PH + NR.

The pooled result of the influence of the various tillage and different residue treatments on the tillering ability of the three varieties was in the order ITA 315 > Ex-China>ITA 257 in the first year and ITA 315 = Ex-China > ITA 257 in the second year.

The combination of the No-tillage and the different crop residues did not produce significant differences in plant height in both years of the study. Plant height was however, significantly ($p<0.05$) higher where HT+BRS treatment was applied compared to HT+NR treatment in both years of the study. For ploughing and crop residue combinations, the rice plants were significantly ($p<0.05$) taller where PL+BRS was applied to the soil compared to the application of PL+NR in the first year, while heights were comparable among the plants on soils treated with ploughing and the different crop residues in the second year. The rice crops were taller on soils treated with PH+BRS in the first year, whereas in the second year the rice plants were taller on soils treated with PH+BRS and PH+RS compared to the plants grown on soil treated with PH+NR.

Table 3. Effect of tillage and crop residue on rice plant height

	First Year				Second Year			
	Rice Varieties				Rice Varieties			
Tillage and Residue	**ITA 257**	**Ex-China**	**ITA 315**	**Mean**	**ITA 257**	**Ex-China**	**ITA 315**	**Mean**
NT+NR	52.53	42.33	55.67	50.18	42.23	47.33	45.67	45.10
NT+RS	45.67	52.33	55.33	51.11	47.67	52.33	56.67	52.22
NT+BRS	49.33	56.67	66.67	57.56	54.33	60.00	61.33	58.55
NT+LR	47.33	54.33	50.67	50.78	50.00	61.33	62.00	57.78
HT+NR	47.33	49.33	52.33	50.60	45.67	47.33	47.67	46.89
HT+RS	56.33	59.00	62.33	59.22	55.33	56.00	66.00	59.11
HT+BRS	52.67	63.33	74.33	63.44	56.67	64.67	69.33	63.56
HT+LR	50.67	60.67	62.00	57.78	50.33	61.33	68.00	59.89
PL+NR	52.33	52.33	50.55	51.74	49.67	52.67	52.33	51.56
PL+RS	54.33	60.00	61.33	58.55	55.33	66.00	71.00	64.11
PL+BRS	56.33	64.67	73.00	64.67	60.00	66.00	72.67	65.67
PL+LR	52.33	60.00	69.67	60.67	56.33	63.00	68.67	62.67
PH+NR	54.33	55.33	56.00	54.22	50.67	52.67	56.00	53.11
PH+RS	61.33	63.00	68.67	64.33	66.00	68.67	74.67	69.78
PH+BRS	66.00	71.00	72.67	69.89	71.00	78.67	84.67	78.21
PH+LR	61.00	66.00	68.67	65.22	64.33	69.33	70.67	68.11
Mean	53.74	58.98	62.50		54.70	60.46	64.21	
FLSD $_{(0.05)}$								
Tillage and residue	4.12				6.15			
Varieties	5.00				9.26			

NT+NR = No-Tillage + No Residue; NT+RS = No-Tillage + Rice Straw; NT+BRS = No-Tillage+ Burnt Rice Straw; NT+LR = No-Tillage + Legume Residue; HT+NR = Hoe Tillage + No Residue; HT+RS = Hoe Tillage + Rice Straw HT+BRS = Hoe Tillage + Burnt Rice Straw; HT+LR = Hoe Tillage + Legume Residue; PL+NR = Ploughing + No Residue; PL+RS = Ploughing + Rice Straw; PL+BRS = Ploughing + Burnt Rice Straw; PL+LR = Ploughing + Legume Residue; PH+NR = Ploughing and Harrowing + No Residue; PH+RS = Ploughing and Harrowing + Rice Straw; PH+BRS = Ploughing and Harrowing + Burnt Rice Straw; PH+LR = Ploughing and Harrowing + Legume Residue

Table 4. Effect of tillage and crop residue on number of rice tillers

	First Year				Second Year			
Tillage and Residue	**Rice Varieties**				**Rice Varieties**			
	ITA 257	**Ex-China**	**ITA 315**	**Mean**	**ITA 257**	**Ex-China**	**ITA 315**	**Mean**
NT+NR	4.00	11.00	11.00	9.00	6.00	8.00	8.00	9.00
NT+RS	6.00	14.00	13.00	12.00	11.00	12.00	12.00	11.00
NT+BRS	7.00	15.00	16.00	13.00	10.00	13.00	13.00	12.00
NT+LR	7.00	15.00	17.00	14.00	8.00	12.00	11.00	11.00
HT+NR	6.00	11.00	15.00	11.00	7.00	11.00	12.00	10.00
HT+RS	12.00	14.00	16.00	14.00	12.00	15.00	17.00	15.00
HT+BRS	10.00	16.00	17.00	14.00	13.00	21.00	18.00	17.00
HT+LR	11.00	10.00	13.00	13.00	12.00	17.00	14.00	14.00
PL+NR	10.00	10.00	13.00	11.00	10.00	12.00	13.00	12.00
PL+RS	15.00	19.00	16.00	17.00	14.00	19.00	18.00	17.00
PL+BRS	16.00	18.00	20.00	18.00	12.00	15.00	17.00	15.00
PL+LR	14.00	16.00	15.00	15.00	13.00	15.00	18.00	15.00
PH+NR	12.00	15.00	14.00	14.00	14.00	14.00	15.00	14.00
PH+AS	15.00	18.00	20.00	18.00	19.00	18.00	16.00	18.00
PH+BRS	13.00	19.00	18.00	17.00	14.00	18.00	20.00	17.00
PH+LR	14.00	15.00	19.00	16.00	15.00	18.00	20.00	18.00
Mean	10.00	16.00	16.00		12.00	15.00	15.00	
LSD $_{(0.05)}$								
Tillage and residue	2.71				2.00			
Varieties	2.75				3.00			

NT+NR = No-Tillage + No Residue; NT+RS = No-Tillage + Rice Straw; NT+BRS = No-Tillage+ Burnt Rice Straw; NT+LR = No-Tillage + Legume Residue; HT+NR = Hoe Tillage + No Residue; HT+RS = Hoe Tillage + Rice Straw HT+BRS = Hoe Tillage + Burnt Rice Straw; HT+LR = Hoe Tillage + Legume Residue; PL+NR = Ploughing + No Residue; PL+RS = Ploughing + Rice Straw; PL+BRS = Ploughing + Burnt Rice Straw; PL+LR = Ploughing + Legume Residue; PH+NR = Ploughing and Harrowing + No Residue; PH+RS = Ploughing and Harrowing + Rice

Rice grain yield

The effect of tillage and crop residue treatment on rice grain yield is presented in Table 5. Generally, there was significant increase in grain yield for the three varieties when the soil was tilled and treated with crop residue than when the soil was not tilled and without crop residue treatment. Grain yield was also significantly ($p<0.05$) higher when the soil was tilled and treated with crop residue than when tilled without crop residue treatment. Grain yield was also significantly ($p<0.05$) higher when the soil was treated with crop residue than when not across the four tillage methods. Ploughing, ploughing and harrowing the soil with crop residue treatment led to significantly ($p<0.05$) higher grain yield than when the soil was not tilled or hoe-tilled, with or without crop residue treatments. The combination of burnt rice straw and ploughing, and burnt rice straw and ploughing and harrowing operations led to significantly ($p<0.05$) higher grain yield than when the soil was not tilled or hoe-tilled with residue treatment. Generally, grain yield of ITA 315 and Ex-China were significantly ($p<0.05$) higher than grain yield of ITA 257. The highest grain yield of 4.87 t/ha was obtained from ITA 315 when the soil received combination of ploughing and harrowing with burnt rice straw treatment.

Specifically, the influence of the different tillage methods and crop residue treatments on the grain yields of the three rice varieties showed that under No tillage methods and residue management, grain yields were significantly higher in the order NT + BRS = NT + RS = NT+LR>NT+NR in the first year and NT+BRS > NT+RS= NT+LR> NT+NR in the second year, whereas under Hoe-tillage and crop residue combination treatments the order was: HT + BRS > HT + RS = HT + LR >HT+NR in the first year and HT + BRS = HT + RS = HT+LR>HT+NR in the second year. The order of influence of ploughing and residue combination treatments on grain yield was in the order: PL+BRS = PL + LR = PL + RS>PL+NR in the first year, and PL + BRS > PL + RS=PL+LR>PL+NR in the second year, while the order of influence for applying ploughing and harrowing with crop residue treatment to the soil on rice grain yield was PH+BRS>PH+RS=PH+LR>PH+NR in both years of the study.

The pooled result of the yield response of the different varieties to the treatments were in the order ITA 315 =Ex-China >ITA 257.

Quantitatively, grain yield significantly increased by 147, 1.21 and 1.20 t/ha as a result of the application of NTBRS, NT+LR and NT+RS in the first year compared to NT+ NR treatment. In the second year, there were 2.05, 1.64 and 1.53 t/ha significantly higher grain yields as a result of the application of NT + PRS, NT + LR and NT + RS treatments compared to NT + NR, whereas NT+BRS also led to 0.52 and 0.41 t/ha significantly ($p<0.05$) higher grain yield than NT+ RS and NT + LR. When the soil was tilled with hoe and treated with crop residues, significantly ($p<0.05$) higher grain yields of 1.65, 1.20 and 1.16 t/ha were obtained by the application of HT+BRS, HT+LR and HT+RS than HT+NR treatment, while grain yield significantly increased by 0.45 and 0.49 t/ha as a result of the application of HT + BRS compared to HT + LR and HT + RS respectively. In the second year, HT + BRS, HT + LR and HT + RS treatments brought about 2.67, 2.45 and 2.42 t/ha significantly ($p<0.05$) higher grain yields compared to the application of HT+ NR. Ploughing the soil and applying crop residues brought about significant grain yield increases of 1.91, 1.68 and 1.62 t/ha as a result of PL+BRS, PL+LR and PL+RS treatments respectively, compared to PL+NR in the first year. In the second year subjecting the soil to PL+BRS, PL+LR and PL+RS treatments significantly increased grain yield by 2.44, 1.95 and 1.91 t/ha respectively compared to PL+NR, whereas PL+BRS also significantly improved grain yield by 0.53 and 0.49 t/ha compared to PL+RS and PL+LR respectively. When the soil was ploughed and harrowed, and treated with the different crop residues, significantly ($p<0.05$) higher grain yields of

2.55, 1.54, 1.52 t/ha were obtained as a result of PH+BRS, PH+LR and PH+RS respectively compared to PH+NR in the first year. PH+BRS treatment also increased grain yield by 1.03 and 1.01 t/ha compared to treating the soil with PH+RS and PH+LR respectively. The Second year result showed that applying PH+BRS, PH+RS and PH+LR to the soil significantly increased rice grain yields by 2.74, 1.72 and 1.71 t/ha respectively than PH+NR treatment, whereas PH+BRS also brought about 1.03 and 1.02 t/ha significantly higher grains than treating the soil with PH+LR and PH+RS respectively.

The variety effect on grain yield valued across tillage methods and residue managements showed that in the first year, ITA 315 and Ex-China had 0.55 and 0.47 t/ha significantly higher grain yields respectively than ITA 257, while in the second year ITA 315 and Ex-China had 0.62 and 0.50 t/ha significantly higher grain yield than ITA 257. There were no significant differences in the grain yields of ITA 315 and Ex-China owing to variety effect in the two years.

Table 5. Effect of tillage and crop residue on rice grain yield

	First Year				**Second Year**			
Tillage and Residue	**Rice Varieties**				**Rice Varieties**			
	ITA 257	**Ex-China**	**ITA 315**	**Mean**	**ITA 257**	**Ex-China**	**ITA 315**	**Mean**
NT+NR	0.40	0.55	0.60	0.52	0.46	0.45	0.50	0.47
NT+RS	1.65	1.75	1.77	1.72	1.87	2.00	2.13	2.00
NT+BRS	1.75	2.23	2.00	1.99	2.40	2.53	2.63	2.52
NT+LR	1.70	1.75	1.75	1.73	2.00	2.10	2.23	2.11
HT+NR	0.50	0.68	0.67	0.62	0.60	0.67	0.68	0.65
HT+RS	1.68	1.80	1.85	1.78	2.40	3.30	3.53	3.07
HT+BRS	1.95	2.40	2.46	2.74	2.67	3.63	3.67	3.32
HT+LR	1.67	1.80	1.98	1.82	2.46	3.34	3.50	3.10
PL+NR	0.80	1.27	2.00	1.36	0.94	1.18	1.10	1.07
PL++RS	2.46	3.38	3.10	2.98	2.60	3.00	3.34	2.98
PL+BRS	2.60	3.58	3.63	3.27	3.00	3.62	3.92	3.51
PL+LR	2.59	3.34	3.20	3.04	2.68	3.10	3.28	3.02
PH+NR	1.42	1.69	1.87	1.66	1.28	1.77	1.83	1.63
PH+RS	2.68	3.34	3.53	3.18	2.83	3.56	3.67	3.35
PH+BRS	3.34	4.62	4.66	4.21	3.63	4.60	4.87	4.37
PH+LR	2.64	3.30	3.67	3.20	2.77	3.62	3.64	3.34
Mean	1.87	2.34	2.42		2.16	2.66	2.78	
FLSD $_{(0.05)}$								
Tillage and residue	0.42				0.40			
Varieties	0.43				0.45			

NT+NR = No-Tillage + No Residue; NT+RS = No-Tillage + Rice Straw; NT+BRS = No-Tillage+ Burnt Rice Straw;
NT+LR = No-Tillage + Legume Residue; HT+NR = Hoe Tillage + No Residue; HT+RS = Hoe Tillage + Rice Straw HT+BRS = Hoe Tillage + Burnt Rice Straw; HT+LR = Hoe Tillage + Legume Residue; PL+NR = Ploughing + No Residue; PL+RS = Ploughing + Rice Straw; PL+BRS = Ploughing + Burnt Rice Straw; PL+LR = Ploughing + Legume Residue; PH+NR = Ploughing and Harrowing + No Residue; PH+RS = Ploughing and Harrowing + Rice Straw; PH+BRS = Ploughing and Harrowing + Burnt Rice Straw; PH+LR = Ploughing and Harrowing + Legume Residue

DISCUSSION

The higher organic matter levels on the surfaces of residue treated plots were a product of the decomposed crop residue. The hoe-tilled soil had lower organic matter level than the soils with the other tillage methods with or without residue treatment because of the removal of the existing vegetation during land clearing. The lower organic matter on the burnt rice straw treated soils occurred because much of the organic carbon was lost during burning. The reduction in the acidity of residue treated soils was more of a result of organic matter level than the effect of tillage. The significantly higher pH of the burnt rice straw treated soils was also specifically because of the influence of Ca and Mg which are the major constituents of the burnt rice straw, and which had liming effect on the soil acidity. These elements displaced H ions in the exchange site which were leached down the soil profile, hence reducing the H ion concentration of the soil. Biederbeck *et al*. (1980) also reported that organic residue particularly the burnt type had liming effect on the soil. The improvement in soil chemistry in the study was very encouraging considering the poor fertility status of the soil reported earlier (FDALR, 1985) and the pre-planting chemical properties of the study site.

The differences in the basic cations between where residues were applied compared to where there was no residue application across the tillage methods was accounted for by the release of the organic elements in the residues after decomposition and mineralization. This might have been made possible by the increased activities of microbes which must also have increased in population due to the conducive environment for their survival provided by the residue mulch. The lower acidity on the residue treated soil also encouraged the mineralization and release of these elements. The organic residue might also have increased soil moisture levels and hence the solubilization and increased organic P availability. Blevins *et al.* (1983), equally reported that the behaviour of P is governed by soil water, which improves phosphorus availability in the soil.

The higher organic matter levels equally led to the increase in the soil nutrient elements and CEC because of the ones released from the organic matter reserve. Organic matter is known to be the natural reserve of the organic nutrients. The higher pH values on residue treated soils also encouraged the release of these elements in the soil exchange complex. Asadu and Akamigbo (1990), reported that reduced acidity would encourage the solubilization and release of the inorganic forms of nutrient elements into the soil. It is the reduction in the soils acidity and increased organic matter and accumulation of nutrients that brought about higher soil cation exchange capacity observed in the residue treated plots in the study.

The improved soil chemical properties under residue treatment made nutrients more available for plant growth whether the soil was tilled or not tilled. The higher levels of these nutrient elements increased crop productivity. The reduced acidity under crop residue treatment made more nutrients available and reduced the availability of trace elements that could have hampered crop growth. Also, improved soil structure and moisture under the tilled and residue treatment conditions made mobility of nutrient and gaseous exchange easier leading to improved nutrient availability and uptake by plants for growth.

The improved soil chemical properties resulting from the treatment including reduced acidity and higher soil organic matter and availability of nutrients raised the soil fertility status leading to significant increase in grain yield. This was accentuated by the improvement in grain yield tonnage harvested per hectare among the three varieties. The highest grain of 4.47 t/ha obtained in the study is a great improvement in the average yield of 2.5 – 3.5 t/ha reported in earlier studies in the area (Ogbodo and Nnabude, 2004; Ogbodo *et al*., 2009; Ogbodo, 2010). The reduced acidity of the plots treated with BRS across the tillage methods led to increased release of nutrient into the soil and subsequent uptake by plants for superior growth and yield compared to the other treatments. The soil physical environmental conditions provided by tillage also improved mobility of nutrients and root penetration to access the nutrients and water.

The superior plant size particularly the higher tillering of the plants where the soil was tilled and treated with crop residue enhanced the photosynthetic efficiency of the plants, leading to improved grain yield. The significantly higher grain yield obtained in ITA 315 and Ex-China plots across the whole tillage and crop residue treatments was a product of variety effect. Ogbodo and Nnabude (2004), had reported significantly higher yield of ITA 315 and Ex-China compared to ITA 257 which they attributed to the adaptability of the two varieties to the inherent environmental conditions of the study area.

CONCLUSION

The results of the study indicated that it is possible to bring about improvements in the fertility status of the soils of Abakaliki area with adequate tillage and crop residue management. These combination treatments provided conducive soil environment for nutrient availability and uptake by plant for growth and yield. The treatment combination of tillage and burnt rice straw provided particularly superior improvement in soil chemical properties, because the residue ash neutralized the soil acidity to a great extent as well as provided other nutrient needed by the rice crop for growth and yield, compared to the other residue sources. Ploughing and harrowing the soil and treating with burnt rice straw proved the most adequate measure in the study to combat the soils chemical constraints. It is apparent from the study that for a better improvement in rice grain yield in the study area that farmers are encouraged to plough and harrow their soils, and treat with burnt rice straw.

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