**Soil Properties as Affected by Crop Residue Management Practice at Minna, Niger State, Nigeria**

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**Abstract**

A field experiment was conducted at the Teaching and Research Farm, Federal University of Technology, Minna, in the Southern guinea savanna agro-ecological zone of Nigeria. The treatments consisted of method of crop residue application (surface application and incorporation) and rate of application (0, 10 and 15 t/ha), laid out in a randomized complete block design and replicated four times. Maize (Oba Super 1 variety) was used as the test crop. Soil samples were randomly collected at 0 – 15 and 15 – 30 cm depths after crop harvest. Soil physical and chemical properties were determined. Data collected were subjected to analysis of variance at 0.05 level of significance. Results obtained from this study indicated that incorporation of crop residue resulted in significantly (P ≤ 0.05) higher soil total porosity, organic carbon, available phosphorus, exchangeable calcium, magnesium, potassium and sodium content than surface application. Also, soil chemical parameters increased significantly with rate of application of crop residue. Fifteen t/ha application rate gave rise to the highest soil organic carbon, available phosphorus, exchangeable calcium, magnesium, potassium and sodium contents, while zero residue treatment produced the lowest amount of the soil chemical parameters determined in this study. Combination of incorporation of crop residue and 15 t/ha application rate gave rise to highest soil exchangeable potassium and sodium content. Thus, it could be concluded that returning crop residues back to the soil, especially by incorporation, increases soil nutrient status, and has potential to increase crop growth and yield for sustainable food security.

**Keywords:** Crop residue management, method and rate of application, soil chemical properties.

**Introduction**

Crop residues are the remains of plant parts after crop harvest. They are also wastes or by-products of processed crop materials such as grains, vegetables and tubers. Crop residues should be treated as soil organic amendments rather than agricultural wastes. This ideology could be adduced to research reports that noted that crop residues have the potential to improve soil biological, physical and chemical conditions (Linden *et al.*, 2000; Ewulo, 2005). However, the capacity of crop residues to affect the biological, physical and chemical properties of the soil depend on substrate quality (the nature of the crop residues and their inherent mineralogical content), prevailing climatic variables, activity levels of decomposers’ community (Kuruvilla *et al.*, 2014) and the management practices employed in processing and application or utilization of the crop residues. Crop residue management practices consists of the procedures associated with the processing of the residues, method and rate of application. It also includes the period of the year when the residue is applied and length of time over which application is carried out. According to Eze *et al.* (2018), crop residues utilized as soil organic amendments or as manure are often left on the field after crop harvest, applied as stover (whole plant parts excluding the roots) or chopped into smaller pieces before application. They could be applied on the soil surface as mulch or incorporated into the soil during or after land preparation. Organic residues are effective sources of plant nutrients (Adejare *et al.*, 2017a).

Minna is located in the Southern guinea savanna zone of Nigeria. Soils in Minna are generally poor in structure, low in organic matter content, and low in nutrient status. The poor physical and chemical condition of tropical soils is attributed to high annual temperatures and the fact that they are mostly sandy in texture (Adesodun and Adekorojo, 2011). The challenges posed by poor soil physical and chemical properties in respect of sustainable crop growth and yields necessitate the application of organic amendments that would improve soil physical and chemical condition for enhanced soil productivity and improve crop growth and yields. Eze *et al.* (2020) noted that application of rice husk-residue gave rise to taller maize crops and higher yields. These findings could be attributed to release of plant nutrients resulting from the decomposition of crop residues applied to the soil. Adejare *et al.* (2017b) reported that soil total porosity, moisture content, organic carbon, N, P, K, Ca and Mg increased with rate of application of plant residue, while bulk density decreased with it. These workers concluded that improvement of soil physical and chemical properties resulted from *Aspilla africana* residue applied as a soil amendment. Consequently, crop yield increased by a range between 81 and 86 % (Adejare, *et al.*, 2017a).

Rice husk-residue is the remains or by-product of paddy rice milling. It is commonly found lying waste around rice mills in millions of tons. In most cases, it is burnt at the point of disposal. This has the potential to adversely affect the aesthetic beauty of the environment and contribute to environmental pollution and climate change (Nwite, 2015). This crop residue is not usually appealing to livestock animals as feed, especially due to its very high fibre content and unpalatable nature. It is about the least utilized as feed after millet panicle residue. The minimal competition for rice husk-residue as feed for livestock animals has increased its potential for use as soil organic amendment because of its availability and relatively low cost of acquisition for use by farmers (Eze *et al.*, 2015b & 2018). However, a major limitation in the utilization of rice husk-residue to improve soil physical and chemical condition is its high C:N ratio, and resistance to easy decomposition due to its tough nature and high fibre content (Seta et al., 2016; Dhanya et al., 2013; Zhanq et al., 2008). Rice husk-residue could be applied on the soil surface as mulch or incorporated. The closer it is brought in contact with the soil and consequently soil microbes, the faster will be the rate of decomposition and the release of the nutrient elements it contains (Kuruvilla et al., 2014).

The objective of this study was to determine the effect of the method and rate of application of rice husk-residue on selected soil physical and chemical properties.

**Materials and Methods**

A field experiment was conducted under rainfed condition during the 2014 and 2015 cropping season at the Teaching and Research Farm, Federal University of Technology, Minna to determine the effect of crop residue management practice on selected soil physical and chemical properties. The experimental site is located at latitude 09º 32´ N and longitude 06º 29´ E, and elevation of 208 m above mean sea level. Minna is located in the Southern guinea savanna zone of Nigeria. It is characterized by a sub-humid climate with distinct dry (October to April) and wet (May to September) seasons. Annual rainfall in Minna is 1,284 mm, while average temperature is 32º C (NIMET, 2020). Soils in Minna are predominantly sandy in texture. They are developed from basement complex rocks consisting of granites, magnitites, gneiss and schists. The vegetation is characterized by few trees and shrubs with vast grassland. Major crops grown in Minna are maize, rice, millet, sorghum, cowpea, groundnut, soybean, yam and vegetables.

The field trial was a 2 x 3 factorial experiment laid out in a randomized complete block design. The treatments consisted of method of crop residue application (surface application and incorporation) and rate of application (0, 10 and 15 t/ha), replicated four times. The land was ploughed using a tractor. Plots (4 x 4 m each) with raised edges were marked out and leveled manually using a hand-hoe. Two weeks before planting, rice husk-residue was uniformly applied on the surface and also incorporated at a soil depth of 10 – 15 cm using a hand-hoe of about 30 cm in diameter. Other cultural practices carried out were sowing of maize (Oba Super 1 variety) seeds, thinning, weed removal, fertilizer application and crop harvest. After crop harvest, soil samples were randomly collected at 0 – 15 and 15 – 30 cm depths using a soil auger. The samples were bulked to obtain a composite sample. The bulked soil sample was air-dried, gently crushed and passed through 2 mm sieve in readiness for physicochemical analysis. Chemical analysis was carried out on the soil samples to determine soil organic carbon (Walkley and Black, 1934), available phosphorus (Bray and Kurtz, 1945) and exchangeable bases (Grant, 1982). Soil bulk density was determined by core method (Blake and Hartage, 1986). Total porosity was computed as stated by Ball-Coelho *et al.* (1998). Data collected were subjected to analysis of variance (ANOVA) at 0.05 level of significance to determine differences between means using Statistix (2005) software (8.0 version). Mean separation was done using Duncan’s multiple range test.

**Results and Discussion**

**Soil Physical Properties**

Results of the effect of method and rate of application of rice husk-residue on soil physical properties (soil bulk density and total porosity) at 0 – 15 and 15 – 30 cm depths during the 2014 and 2015 cropping seasons are presented in Table 1. Both method and rate of application treatments had no significant influence on soil bulk density. Unlike rate of application of crop residue, method of application had significant effect on soil total porosity at 15 – 30 cm depth. Incorporated rice husk-residue resulted in significantly (P ≤ 0.05) higher total porosity of soil samples compared with surface application by a range between 5 and 8 %.

Table 1: Effect of method and rate of application of rice husk-residue on soil bulk density (g/cm3) and total porosity (%) at 0 – 15 and 15 – 30 cm depths.

|  |
| --- |
| 0 – 15 cm 15 – 30 cm |
| Bulk density Total porosity Bulk density Total porosity |
| Treatment 2014 2015 Pooled 2014 2015 Pooled 2014 2015 Pooled 2014 2015 Pooled |
| Method of  application (A)  Surface 1.61a 1.59a 1.60a 40.7a 39.9a 40.3a 1.61a 1.67a 1.64a 39.3b 37.0a 38.1b  Incorporation 1.56a 1.63a 1.60a 41.0a 38.6a 39.8a 1.52a 1.65a 1.59a 42.4a 37.8a 40.1a    SE± 0.04 0.03 0.03 1.8 1.3 1.1 0.03 0.02 0.02 1.1 0.8 0.8  Rate of  application (B)  0 t/ha 1.60a 1.62a 1.61a 40.7a 39.0a 39.9a 1.60a 1.67a 1.63a 39.8a 36.9a 38.4a  10 t/ha 1.60a 1.60a 1.60a 40.5a 39.6a 40.1a 1.55a 1.63a 1.59a 41.4a 38.4a 39.9a  15 t/ha 1.56a 1.61a 1.58a 41.4a 39.1a 40.2a 1.55a 1.68a 1.61a 41.3a 36.7a 39.0a  SE± 0.05 0.04 0.03 2.2 1.6 1.3 0.03 0.03 0.02 1.3 1.0 0.9  Interaction  A x B NS NS NS NS NS NS NS NS NS NS NS NS |

Means with the same letter(s) in the columns are not significantly different according to Duncan’s multiple range test at 5 % probability level.

NS: Not significant

**Soil Chemical Properties**

Table 2 shows results of the effect of method and rate of application of rice husk-residue on soil chemical properties (soil organic carbon, available phosphorus, exchangeable calcium, magnesium, potassium and sodium) at 0 – 15 and 15 – 30 cm depths during the 2014 and 2015 cropping seasons and average data for the two years.

**Organic Carbon**

Results in Table 2 indicate that method of application of rice husk-residue significantly (P ≤ 0.05) affected organic carbon content of soil samples at 0 – 15 cm depth, whereas, rate of application of crop residue did not. In 2015 and in the pooled data, incorporation of rice husk-residue gave rise to significantly higher organic carbon content by as much as 57 and 39 %, respectively, than surface application treatment. Also, in 2015, soil samples collected from 15 – 30 cm depth had significantly higher organic carbon content by 51 % when rice husk-residue was incorporated than surface application of crop residue. Furthermore, 15 t/ha application of crop residue produced two times higher soil organic carbon content than 0 t/ha treatment during the 2015 cropping season and 36 % higher in the average data.

**Available Phosphorus**

Throughout the period of this study, available phosphorus content of soil samples obtained from 0 – 15 cm depth was not affected by method and rate of application of rice husk-residue. However, during 2014 cropping season, incorporation of crop residue resulted in significantly higher available phosphorus content of soil samples at 15 – 30 cm depth than surface application treatment by 11 %.

**Exchangeable Calcium**

In 2015 and in the pooled data, a similar trend was observed at all soil depths, whereby, incorporation treatment and application of rice husk-residue at 15 t/ha produced significantly higher soil exchangeable calcium content than surface application and zero application treatments, respectively.

Table 2: Effect of method and rate of application of rice husk-residue on soil chemical properties at 0 – 15 and 15 – 30 cm depths.

|  |
| --- |
| 2014 |
| 0 – 15 cm Depth 15 – 30 cm Depth |
| Org C Avail. P Exch. Ca2+ Exch. Mg2+ Exch. K+ Exch. Na+ Org C Avail. P Exch. Ca2+ Exch. Mg2+ Exch. K+ Exch. Na+ Treatment g/kg mg/kg ‹------------------- cmol/kg ----------------------› g/kg mg/kg ‹--------------------- cmol/kg -----------------------› |
| Method of  application (A)  Surface 1.94a 9.30a 3.44a 0.41a 0.13a 1.13a 2.45a 9.28b 3.00a 0.20a 0.16a 0.70a  Incorporation 2.34a 8.59a 3.33a 0.21a 0.13a 0.68a 2.42a 10.30a 3.44a 0.19a 0.13a 0.70a  SE± 0.47 0.92 0.68 0.12 0.01 0.31 0.33 0.45 1.05 0.04 0.01 0.12  Rate of  application (B)  0 t/ha 2.09a 8.61a 2.67a 0.25a 0.13a 0.77a 2.61a 9.66a 2.67a 0.18ab 0.15a 0.73a  10 t/ha 2.06a 9.19a 3.17a 0.28a 0.13a 1.44a 2.49a 10.04a 3.33a 0.15b 0.14a 0.67a  15 t/ha 2.28a 9.02a 4.33a 0.40a 0.13a 0.51a 2.19a 9.67a 3.67a 0.25a 0.15a 0.69a  SE± 0.58 1.12 0.83 0.15 0.01 0.37 0.41 0.55 1.29 0.04 0.02 0.15  Interaction  A x B NS NS NS NS NS NS NS NS NS NS \* \*  2015  Method of  application (A)  Surface 2.21b 1.83a 9.56b 2.12b 0.11b 1.25b 2.07b 1.20a 9.70b 2.76b 0.15b 1.32b  Incorporation 3.47a 1.14a 11.76a 4.76a 0.48a 2.11a 3.13a 1.43a 12.08a 4.12a 0.46a 2.06a  SE± 0.40 0.33 0.79 0.55 0.06 0.25 0.41 0.24 0.78 0.46 0.07 0.24  Rate of  application (B)  0 t/ha 2.51a 1.59a 7.77b 2.98a 0.22a 1.54a 1.64b 1..13a 7.71b 2.92b 0.21a 1.50a  10 t/ha 2.73a 1.29a 11.53a 3.70a 0.34a 1.71a 2.54ab 1.41a 11.85a 4.31a 0.39a 1.77a  15 t/ha 3.29a 1.58a 12.67a 3.63a 0.33a 1.79a 3.61a 1.40a 13.10a 3.10ab 0.32a 1.80a  SE± 0.49 0.41 0.96 0.67 0.07 0.31 0.51 0.30 0.96 0.56 0.08 0.29  Interaction  A x B NS NS NS NS \* NS NS NS NS NS \* NS  Pooled  Method of  application (A)  Surface 2.08b 5.57a 6.50a 1.27b 0.12b 1.19a 2.26a 5.24a 6.35b 1.48b 0.15b 1.01b  Incorporation 2.90a 4.86a 7.54a 2.48a 0.31a 1.40a 2.77a 5.86a 7.76a 2.16a 0.29a 1.38a  SE± 0.31 0.54 0.50 0.28 0.03 0.21 0.27 0.32 0.64 0.28 0.03 0.13  Rate of  application (B)  0 t/ha 2.30a 5.10a 5.22b 1.62a 0.17a 1.16a 2.13b 5.40a 5.19b 1.55a 0.18a 1.12a  10 t/ha 2.39a 5.24a 7.35a 1.99a 0.24a 1.58a 2.52ab 5.72a 7.59a 2.23a 0.26a 1.22a  15 t/ha 2.79a 5.30a 8.50a 2.02a 0.23a 1.15a 2.90a 5.53a 8.38a 1.68a 0.23a 1.25a  SE± 0.38 0.66 0.62 0.34 0.04 0.26 0.33 0.39 0.78 0.34 0.04 0.16  Interaction  A x B NS NS NS NS \* NS NS NS NS NS NS NS |

Means with the same letter(s) in the columns are not significantly different according to Duncan’s multiple range test at 5 % probability level.

\*: Significant at 5 % level of probability

NS: Not significant

**Exchangeable Magnesium, Potassium and Sodium**

In 2014, exchangeable magnesium, potassium and sodium contents of soil samples at 0 – 15 cm depth were not different, irrespective of the method and rate of application of rice husk-residue. However, in 2015 and in the pooled data, whereas, rate of application of rice husk-residue had no significant influence on soil exchangeable magnesium, potassium and sodium contents, method of application did at 0 – 15 cm depth. Incorporation of crop residue resulted in significantly higher soil exchangeable magnesium, potassium and sodium contents by two times, four times and 69 %, respectively, than surface application treatment. Soil exchangeable magnesium and potassium contents were significantly higher under incorporation treatment by a range between twice and two and a half times than surface application treatment in the average data for 2014 and 2015. At 15 – 30 cm depth, exchangeable magnesium content of soil samples did not differ significantly, irrespective of the method of application of rice husk-residue in 2014. However, application of 15 t/ha crop residue produced significantly higher soil exchangeable magnesium content than 10 t/ha application rate by 67 %. Incorporation of crop residue produced significantly higher soil exchangeable magnesium content than soil surface application in 2015 and in the average value by 49 and 46 %, respectively. Also, in 2015, rate of application of rice husk-residue significantly affected soil exchangeable magnesium at 15 – 30 cm depth. Application of 10 t/ha residue resulted in higher soil exchangeable magnesium than 0 t/ha treatment by 48 %. At 15 – 30 cm depth, method and rate of application of rice husk-residue had no significant influence on soil exchangeable potassium and sodium in 2014. In contrast, in 2015 and in the pooled data, results indicated that incorporation treatment resulted in significantly higher soil exchangeable potassium and sodium content than surface application treatment by as much as three times and 56 %, respectively. In the pooled data, incorporation treatment resulted in significantly higher soil exchangeable potassium and sodium contents than surface application treatment by as much as two times and 37 %, respectively. In the current study, significant (P ≤ 0.05) interaction relationships were observed. Interaction between method and rate of application of rice husk-residue had significant effect on soil exchangeable potassium and sodium content (Tables 3 and 4.). Combination of application of crop residue by incorporation and at 15 t/ha rate gave rise to highest soil exchangeable potassium and sodium content.

Results from this study indicated that higher crop residue application rates and crop residue incorporation resulted in higher soil total porosity and higher soil organic carbon, available phosphorus, exchangeable calcium, magnesium, potassium and sodium content than surface application The fact that application of crop residues and organic residues in general as organic amendment improves soil physical and chemical properties is widely documented. In line with the findings in the current study, Mohammed *et al.* (2017b), Eze *et al.* (2015 a & b), Ogbodo (2011) and Mbah and Nneji (2010) reported that soil physical and chemical conditions were better at higher crop residue application rates than at lower rates. It is worth mentioning that, the method of application of crop residues is also vital to the improvement of soil properties. Mohammed *et al.* (2017b) noted that incorporation of cowpea residue gave rise to higher soil organic carbon, organic matter, available phosphorus, total nitrogen and water soluble organic carbon. Ojeniyi and Falade (1997) reported that incorporation of crop residues improved soil condition compared with surface application. Mbah and Nkpaji (2009) reported that ash incorporation reduced soil acidity and increased availability of K, Ca and Mg. Maskena *et al.* (1993) noted that incorporation of crop residues improves soil water retention and availability for plant and microbial activity, and consequently, enhances nutrient cycling. According to Eze *et al.* (2020) and Mohammed *et al.* (2017a), application of crop residues as organic amendment at higher rates and by incorporation consequently translated to improved crop growth and higher yields.

Table 3: Interaction effect of method and rate of application of rice husk-residue on exchangeable potassium (cmol/kg) and sodium (cmol/kg) at 15 – 30 cm depth during the 2014 cropping season.

|  |
| --- |
| Exchangeable potassium Exchangeable sodium |
| Treatment Rate of application (t/ha) Rate of application (t/ha) |
| Method of application 0 10 15 0 10 15 |
| Surface 0.12bc 0.16ab 0.19a 0.51ab 0.69ab 0.89ab  Incorporation 0.17ab 0.12bc 0.10c 0.95a 0.64ab 0.49b  SE± 0.02 0.20 |

Means with the same letter(s) in the columns are not significantly different according to Duncan’s multiple range test at 5 % probability level.

Table 4: Interaction effect of method and rate of application of rice husk-residue on exchangeable potassium (cmol/kg) at 0 – 15 and 15 – 30 cm depths during the 2015 cropping season and at 0 – 15 cm depth for the 2014 & 2015 cropping seasons combined data.

|  |
| --- |
| (0 – 15 cm Depth, 2015) (15 – 30 cm Depth, 2015) (0 – 15 cm Depth, 2014 & 2015 combined) |
| Treatment Rate of application (t/ha) Rate of application (t/ha) Rate of application (t/ha) |
| Method of application 0 10 15 0 10 15 0 10 15 |
| Surface 0.19b 0.09b 0.06b 0.21b 0.18b 0.06b 0.16b 0.11b 0.10b  Incorporation 0.24b 0.60a 0.60a 0.22b 0.59a 0.57a 0.19b 0.37a 0.36a  SE± 0.10 0.11 0.05 |

Means with the same letter(s) in the columns are not significantly different according to Duncan’s multiple range test at 5 % probability level.

**Conclusion**

On the basis of the results obtained in this study, it could be concluded that:

1. incorporation of crop residue resulted in significantly higher soil total porosity, organic carbon, available phosphorus, exchangeable calcium, magnesium, potassium and sodium content than surface application,
2. soil chemical parameters increased significantly with rate of application of crop residue. Fifteen t/ha application rate gave rise to the highest soil organic carbon, available phosphorus, exchangeable calcium, magnesium, potassium and sodium contents, while zero application produced the lowest amount of the soil chemical parameters determined in this study, and
3. combination of incorporation of crop residue and 15 t/ha application rate gave rise to highest soil exchangeable potassium and sodium content.

Thus, returning crop residues back to the soil, especially by incorporation, increases soil nutrient status, and has potential to increase crop growth and yield for sustainable food security.

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