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Full Length Research Paper

Physico-chemical properties of a Haplic Acrisol in Southeastern Nigeria amended with rice mill waste and NPK fertilizer

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The effect of rice mill waste (RMW) in combination with or without NPK 15:15:15 on some physico-chemical properties of a Haplic Acrisol in Umudike, Southeastern Nigeria, was studied. The experiment comprised 10 treatments (20, 10, 5 and 2.5 t/ha RMW combined with 200 or 400 kg/ha NPK, 30 t/ha RMW alone, 400 kg/ha NPK alone and a control). They were laid in a randomized complete block design replicated 3 times. Data collected were subjected to analysis of varience. Results showed that relative to the control, application of RMW alone at 30 t/ha increased total porosity (P_t), saturated hydraulic conductivity (K_{sat}) and mean weight diameter (MWD) of water stable aggregates significantly by 41.1, 368.2 and 155.8%, respectively, and resulted in 20.9% significant decrease in bulk density (B_D). Improvements by other treatments in the physical parameters when compared to the control were not statistically significant except the application of 20 t RMW + 200 kg NPK/ha on B_D and P_t. Similarly, a combination of 20 t/ha RMW with NPK at 200-400 kg/ha and application of 30 t/ha RMW had significant increase in percent organic matter (OM) over the control treatment, indicating the potentials of RMW in improving physico-chemical properties of poor soils.

Key words: Rice mill waste, porosity, hydraulic conductivity, aggregate stability.

INTRODUCTION

The soils of Southeast agro-ecological zone of Nigeria have high erodibility and structurally unstable aggregates with limited capacity for water retention. They are also coarse-textured with low organic matter (OM) contents (Igwe et al., 1995; Mbagwu et al., 1993). However, they have well drained, deep profile with high infiltration rates and rapid saturated hydraulic conductivity (Piccolo and Mbagwu, 1994). Since the soils suffer multi-nutrient deficiencies, application of NPK fertilizer has become mandatory to increase crop yields. Mineral fertilizers are scarce and costly, and their use could exacerbate the problem of soil acidity.

Application of organic residues could increase soil organic matter (SOM), buffer the soil, improve aggregate stability and enhance water-retention capacity (Spaccini et al., 2002). Repeated applications of organic residues on soils have long- lasting positive effects on physico-chemical properties (Mbagwu and Piccolo, 1989).

Objective of this study was to evaluate the effects of applying RMW, with or without NPK fertilizer, on some physico-chemical properties of a coarse-textured soil in the Southeast agro-ecological zone of Nigeria.

MATERIALS AND METHODS

Site characteristics

The study was conducted at Umudike, (latitude 05° 29′ N and longitude 07° 33′ E), typical of degraded rainforest. It is

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Table 1. Some properties of the soil and the rice mill waste (RMW) used in the study.

Property	Value	
	Soil	RMW
Sand (%)	93.5	-
Silt (%)	2.3	-
Clay (%)	4.2	-
Textural class	Sand	-
Bulk density (kg m^{-3})	1.77	-
Total porosity (%)	33.33	-
Available water capacity (%)	11.11	-
pH (H_2O)	4.98	5.76
pH (KCl)	3.81	-
OC (%)	0.51	23.5
Total N (%)	0.05	0.43
C/N	10.2	54.7

characterized by a mean annual rainfall of 2238 mm, maximum and minimum temperatures of 32 and 23°C, respectively, and a relative humidity of 63-80%.

Experimental design and soil sampling

The experiment comprised 10 treatments set up in a randomized complete block design with 3 replications. Plot size was 5 m x 4 m. The RMW was applied by incorporation in ridges before it was cropped with cocoyam. NPK fertilizer (15:15:15) was applied six weeks after planting.

Undisturbed core samples were collected from each plot at 0-15 cm depth while auger samples were collected at 0-30 cm depth. The auger samples were dried at room temperature and a portion was passed through a 4.7 mm sieve for wet sieving to determine the mean weight diameter (MWD) of water-stable aggregates. The other portion was crushed and passed through a 2 mm sieve. A portion of the 2 mm - sieved soil was ground in a mortar and passed through a 0.15 mm sieve for total N and OM determinations.

Laboratory analyses

Particle size distribution was determined by the hydrometer method (Bouyoucos, 1951) using calgon, and also water as dispersants. Dispersion ratio (DR) and aggregated silt + clay (ASC) were computed as

$$DR = \frac{\%\ \text{silt + clay in water}}{\%\ \text{silt + clay in calgon}} \times 100 \quad (1)$$

$$AS = [\%\ \text{clay + silt (calgon)}] - [\%\ \text{clay + silt (water)}] \quad (2)$$

Saturated hydraulic conductivity (K_{sat}) was determined by the constant head method (Stolte, 1997). Bulk density (B_D) was determined according to Anderson and Ingram (1993) while total porosity (P_t) was calculated from bulk density (B_D) data assuming particle density to be 2.65 kg m^{-3} (Anderson and Ingram, 1993). Available water capacity (AWC) was computed as the difference between moisture retained at field capacity (FC) and wilting point (WP) (Mbagwu, 1991). Mean weight diameter (MWD) of water stable aggregates was determined by the procedure of Kemper and Chepil (1965) as modified by Mbagwu et al. (1994). Soil pH was measured electrometrically with a pH meter both in water and in KCl using a soil : liquid suspension ratio of 1:2.5. Organic carbon was determined by the Walkley-Black procedure of Nelson and Summers (1982) while total N was determined by the micro-kjeldahl digestion method (Bremner and Mulvaney, 1982). Some properties of the soil studied and the RMW used are shown in Table 1.

Data analysis

Data collected were analyzed using analysis of varience. Significant means were detected using the Fischer's Least Significant Difference (F-LSD) at 5% probability level.

RESULTS AND DISCUSSION

Bulk density, total porosity and saturated hydraulic conductivity

Table 2 shows the effect of the treatments on B_D, P_t and K_{sat}. Relative to the control, B_D decreased with increasing rate of RMW amendment. However, only the application of 30 t/ha RMW and the application of 20 t RMW + 200 kg NPK/ha decreased B_D significantly (P=0.05) by 20.9 and 15.2%, respectively. Similar observations were reported by Anikwe and Nwobodo (2002).

Significant improvement of 41.1% in P_t over the control was achieved when RMW was applied alone at 30 t/ha. The K_{sat} was significantly (P=0.05) improved by over 368% over the control by the application of 30 t/ha RMW. Although, other treatments improved the K_{sat}, such improvements were not statistically significant. These improvements support the findings of Mbagwu (1989) that incorporation of organic waste significantly increased soil hydraulic conductivity, the magnitude of which depended on the application rate. The higher K_{sat} in the amended soil implies reduced run-off and less erosion. The general rapid K_{sat} observed even in the control could be attributed to the coarse nature of the soil which confers on it, high macroporosity.

Aggregate stability and Available water capacity (AWC)

Aggregated silt + clay and MWD varied directly with each other while each of them showed an inverse relationship with dispersion ratio (DR) (Table 2). This indicated an improvement in the amount of aggregated clay as well as a decrease in the percent dispersible clay, implying that

Table 2. Some physical properties of soil amended with rice mill waste (RMW) and NPK fertilizer.

Treatment	B_D (kg m^{-3})	P_t (%)	K_{sat} (cm min^{-1})	DR (%)	ASC (%)	MWD (mm)	AWC (%)
Control	1.77	33.33	0.22	82.47	1.03	0.77	11.11
30 t/ha RMW	1.72	34.97	0.25	81.70	1.63	0.93	12.19
400 kg/ha NPK	1.40	47.04	1.03	63.63	3.30	1.97	13.40
20 t/ha RMW + 400 kg/ha NPK	1.63	38.49	0.86	65.87	2.47	1.42	13.11
10 t/ha RMW + 400 kg/ha NPK	1.68	36.48	0.48	70.76	2.30	1.20	12.74
5 t/ha RMW + 400 kg/ha NPK	1.63	38.24	0.40	71.55	2.13	1.07	12.74
2.5 t/ha RMW + 400 kg/ha NPK	1.64	38.11	0.26	74.28	1.83	1.00	12.29
20 t/ha RMW + 200 kg/ha NPK	1.50	43.52	0.84	65.67	2.70	1.61	13.38
10 t/ha RMW + 200 kg/ha NPK	1.56	42.89	0.66	67.23	2.30	1.35	12.84
5 t/ha RMW + 200 kg/ha NPK	1.57	41.32	0.42	71.80	1.95	1.13	12.75
F-LSD $_{(0.05)}$	0.26	9.73	0.78	25.83	2.72	0.80	7.73

Table 3. Some chemical properties of soil amended with rice mill waste (RMW) and NPK fertilizer.

Treatment	PH		Total N (%)	OM (%)
	H_2O	KCl		
Control	4.98	3.81	0.05	0.88
30 t/ha RMW	4.95	3.35	0.08	1.25
400 kg/ha NPK	5.19	4.25	0.13	2.50
20 t/ha RMW + 400 kg/ha NPK	5.14	4.04	0.10	1.93
10 t/ha RMW + 400 kg/ha NPK	5.08	4.02	0.10	1.08
5 t/ha RMW + 400 kg/ha NPK	5.07	3.97	0.10	1.47
2.5 t/ha RMW + 400 kg/ha NPK	5.04	3.94	0.09	1.47
20 t/ha RMW + 200 kg/ha NPK	5.09	4.04	0.12	2.22
10 t/ha RMW + 200 kg/ha NPK	5.08	4.03	0.10	2.13
5 t/ha RMW + 200 kg/ha NPK	5.04	3.98	0.09	1.54
F-LSD$_{(0.05)}$	0.24	0.49	0.52	0.92

the micro aggregates were stable. This could be attributed to the role of OM since it can penetrate clay domain to form complex chelates with polyvalent cations (Theng, 1976). Consequently, weakly bound clay particles are likely to be displaced, resulting in increased dispersion. This mechanism is usually expected at high level of soil organic matter (Whitbread et al., 1998), which the RMW amendment conferred on the soil studied (Table 3). All the RMW amended plots had lower DR values relative to the control. The trend in ASC values was similar to DR values, suggesting that the OM from RMW was able to induce aggregation of the soil particles.

The MWD of water-stable aggregates ranged from 1.00 to 1.97 mm in the amended soil representing 29.9 to 155.8% improvement in aggregation over the control. This corroborates the findings of Whitbread et al. (1998) who reported a significant correlation between macro aggregates and total carbon.

The AWC followed the same trend as ASC and MWD (Table 2), supporting the report of Mbagwu et al. (1994). Organic matter is hydrophilic; therefore, the increase in AWC in the RMW amended plots over the control was not a surprise.

pH, organic matter and total nitrogen

There were improvements in soil pH, OM and total N in the RMW amended plots over the control (Table 3). Similar result was reported by Oguike and Mbagwu (2001) for soil pH due to organic soil amendment. pH values in the RMW amended plots range from 5.04 to 5.19 representing 1.20 - 4.22% decrease in soil acidity.

This was not significant. However, the application of 400 kg/ha NPK increased soil acidity slightly over the control.

In all RMW treated plots, soil OM increased with increases in the application rates of RMW irrespective of NPK combinations. Similar results have been reported (Oguike and Mbagwu, 2001, 2004). A value of 1.93% was observed when 20 t/ha RMW + 400 kg/ha NPK was applied while 2.22% was recorded for 20 t/ha RMW + 200 kg/ha NPK suggesting that lower rates of NPK in combination with RMW amendments could be required to have significant and long-lasting improvement on fragile tropical soils.

There was a non-significant improvement in total N in all treatments relative to the control (Table 3). Nevertheless, the N status of all the treatments was generally low. This could be attributed to the high C/N ratio of the RMW used. Probably there was loss of soil N due to leaching resulting in the low total N recorded in all the RMW amended plots.

Conclusion

Soil amendment with the RMW has the potential to improve the physico-chemical properties of Haplic Acrisols. The use of RMW alone at 30 t/ha was found to have a higher significant (P=0.05) improvement over the control than other rates of RMW combined with 200 or 400 kg/ha NPK fertilizer (15:15:15) in the parameters assessed.

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