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Full Length Research Paper

Temporal variations in organic carbon, soil reactivity and aggregate stability in soils of contrasting cropping history

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We studied the effect of incorporating agricultural wastes on soil aggregate stability (AS), organic carbon (OC), and soil reactivity (pH) of similarly textured soils under different managements (vegetable, (VG) and Orchard (OR) farming), in South-eastern Nigeria. The agricultural wastes were cow dung (CD,) cassava peels (CP), and kola nut pods (KP). The air dried agricultural wastes were crushed and sieved using a 2 mm wire mesh and decomposed under shade for two weeks. The decomposed amendments were applied in combination (CD+CP, CD+KP), or alone (KP, CP, CD) at the rates of 100 and 200 Mg/ha. Samples for physical and chemical analysis were collected in triplicate after two and four weeks of incubation and analyzed for selected physiochemical properties. Results show that combinations of wastes of plant and animal origin (CD+CP or CD+KP) enhanced the soil properties better than their single applications. The immediate effect of agricultural wastes in improving the pH (20-40 or 30-50%, respectively, for vegetable and orchard farm management) gave corresponding increases in organic carbon and soil aggregate stability and suggested that decomposition of agricultural wastes prior to incorporation is necessary to sustain vegetable or orchard farming. Significant positive correlation coefficients of 0.893 and 0.911 for the first and second sampling times indicated that organic carbon accounted for 79.7 and 83% of the soil aggregate stability at both periods. For the vegetable farm, 70% of soil aggregate stability depended on the level of organic carbon while about 87% of soil aggregate stability is accounted for in the Orchard farm by organic carbon.

Key words: Agricultural wastes, management history, decomposition, aggregate stability, organic carbon.

INTRODUCTION

Disposal of agricultural or farm stead wastes emanating from traditional agricultural practice is a problem in most parts of the tropics. This is because these wastes, poorly managed, constitute environmental pollution (Eke, 1994), blocking sewages and water ways. These eventually lead to soil degradation by the process of erosion and desertification.

One of the most common methods of disposal and management of these wastes from household and farm stead is to plow them back into the farms. They may be burnt before they are incorporated into the soil, but in most cases are incorporated fresh into the soil as a way of improving the organic matter content of soils. This method of nutrient recycling is of common place with traditional farmers especially with small-holder farmers who supply the bulk of food for the large population. Persistence of this practice is attributed to the fact that inorganic or synthetic fertilizers are uneconomical due to its high cost and unavailability. Moreover, the practice of incorporating agricultural wastes into the soil has virtually replaced traditional soil fertility regeneration methods (shifting cultivation, crop rotation) because of increasing pressure on land resulting from rapid population growth and other uses to which land is put (Nwajiuba, 1997).

These agricultural wastes used as organic manure are rich in essential plant nutrients like nitrogen, phosphorus

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Table 1. Properties of the organic manure used in the study.

Properties	Cow dung (CD)	Cassava peel (CP)	Kola nut pod (KP)
Total N (%)	2.38	1.54	0.98
Available P (ppm)	0.75	0.41	0.40
K (cmol/kg)	0.68	1.85	0.45
Mg (cmol/kg)	0.43	0.49	0.37
Ca (cmol/kg)	0.80	0.20	0.80
Na (cmol/kg)	0.56	.056	0.56

Table 2. Treatments as applied in the study.

Treatments	Rates (Mg/ha)
CD_1	100
CD_2	200
CP_1	100
CP_2	200
KP_1	100
KP_2	200
$CD+CP_1$	50+50 each
$CD+CP_2$	100+100each
$CD+KP_1$	50+50 each
$CD+KP_2$	100+100each
C	Control

and potassium (Umuenweke, 1995). Also, the application of organic manure to soil maintains soil fertility for a longer time than the synthetic fertilizers (Alabi, 1990).

The availability of these wastes creates an urgent need for the development of alternative and integrated low–input soil fertility management strategies based on maximum use of local biological resource. Agricultural wastes such as cassava peels and kola nut pods are known to improve soil structure when used as soil amendments, while livestock wastes which are rich in plant nutrients promote the activities of soil microorganisms and improve soil fertility without resorting to expensive agrochemicals (Ikongwa, 1997). In this study, we examined the potentials of using decomposed cassava peels, kola nut pods and cow dung as soil fertility improvement agents of two soils at Micheal Okpara University of Agriculture, Umudike in south- Eastern Nigeria.

The objective was to determine the organic amendments or their combinations that are most suitable for soils in the study area in enhancing its physical and chemical properties.

MATERIALS AND METHODS

Study site

The experiment was carried out in Micheal Okpara University of Agriculture, Umudike located on latitude 5^o $28^'$ N and longitude 7^o $32^'$E with an elevation of 122 m above sea level. The area experiences two distinct seasons, the wet and dry. The rainy season starts in March and finishes in October while the dry season starts in November and ends in February. The distribution is bimodal with peaks in July and September and a brief break in August (August break). The area is characterized by a uniform mean temperature ranging between 27 - 35^o C all through the year. The soil samples used for the experiments were collected from orchard farm exposed to citrus with annual pruning and weeding as management practice, and a vegetable farm (Okro, Telferia and Amarantus) used for students' industrial training with normal agronomic practices such as organic matter addition, weeding and mulching. Some of the properties of the soils used in the experiment are shown in Table 3.

Organic amendments

The organic amendments comprised of cow dung (CD), cassava peels (CP) and kola nut pods (KP). The CD and CP were collected from Micheal Okpara University of Agriculture (MOUA) and the neighbouring National Root Crops Research Institute (NRCRI) both in Umuahia, Abia state while the KP was bought from Ndoro market in Ikwuano LGA of Abia state. The CD used was the feacal material only while the cassava peel is the external part of cassava (*Manihot esculenta*) roots. The kola nut pod is the thick external covering of kola nut. These organic amendments were air dried, crushed and passed through 2 mm sieve and composted under shade for about two weeks. Adequate moisture was ensured by adding water and turning every two days to provide sufficient aeration for microbial activities. The organic amendments were analyzed for chemical properties as listed in Table 1, and were applied at 5 and 10% rates corresponding to 100 and 200 Mg/ha. The control for the experiment received no amendment. The amendments were thoroughly mixed with the soil and each treatment replicated three times. The treatment combinations used in this study is shown on Table 2.

Soil sampling

Top soil samples were collected from 0-20 cm depth, air dried and sieved with 2 mm sieve. Four kilogram of the soil weighed into eight litre capacity plastic buckets was used for the incubation study. The samples with the added amendments were adequately moistened every two weeks and samples for physical and chemical properties were collected at two and four weeks of incubation.

Determination of soil physical properties

Particle size analysis was determined by the hydrometer method (Bouyoucos, 1951) using Calgon (sodium hexametaphosphate) as

Table 3. Properties of the soil (0-20 cm) used for the study.

Properties	Orchard farm (%)	Vegetable farm (%)
Sand	71.80	63.70
Silt	10.00	17.40
Clay	18.20	18.9
Texture	Sandy loam	Sandy loam
pH	5.08	4.90
Total N (%)	0.10	0.21
OC (%)	1.13	2.53
K (cmol/kg)	0.18	0.25
Mg (cmol/kg)	1.80	1.60
Ca (cmol/kg)	2.60	2.40
Na (cmol/kg)	0.10	0.10
Available P (ppm)	17.90	19.40
Exchangeable acidity (cmol/kg)	2.32	3.60
ECEC (cmol/kg)	5.02	7.95

the dispersant. The textural class was determined with the textural triangle. Soil aggregate stability was determined using the mean weight diameter (MWD) method as described by Kemper and Chepil (1965). A nest of three sieves of diameters 2, 1, and 0.6 mm was used.

Determination of soil chemical properties

Soil pH was determined in water (1:2.5 soils to water ratio) with the ELL glass-electrode pH meter (Maclean, 1965). Organic carbon (OC) was determined using dichromate wet oxidation method (Walkey and Black, 1934) as modified by Piper (1942). Total nitrogen (N) was determined using the macro Kjeldahl method as described by Jackson (1958). Available phosphorus (P) was determined using Bray II method as described by Bray and Kurtz (1945). Exchangeable acidity was determined by the titration method (IITA, 1979). Exchangeable cations (K, Ca, Mg, and Na) were extracted with ammonium acetate, while K, Na, Ca, were determined with a flame photometer and Mg was determined using the atomic absorption spectrophotometer (IITA, 1979). Effective cation exchange capacity (ECEC) was determined by summation of exchangeable metallic and acidic ions.

Data analysis

Data generated were subjected to a 5 X 3 X 2 analysis of variance test (Steel and Torrie, 1980). Where the F-values were significant at P = 0.05, the means were separated using the $F\text{-}LSD_{0.05}$. Simple linear correlation analysis was also used to determine the relationship between aggregate stability, soil pH and organic carbon.

RESULTS AND DISCUSSION

The physical and chemical properties of the soils prior to the study shown in Table 3, indicate that both soils are of medium texture, slightly acid and low in percent N, available P, Na, and Ca (cmol (+)/kg) and CEC. Soil samples from the vegetable farm had a very high content of organic matter. This is attributed to the fact that the farm is exposed to yearly inputs of organic matter from the organic manure used in the vegetable production contrary to the samples from the Orchard farm which is not so exposed.

Effects of organic amendments on soil aggregate stability

Aggregate stability of the orchard farm soil increased with increasing rate of organic amendment (Table 4). For this soil, at both sampling times, CD alone and CD+CP at 200 Mg/ha gave the greatest improvements in soil aggregate stability relative to the control. For all amendment treatments soil aggregate stability improved between two and four weeks. The highest improvement (88%) relative to the control was obtained 4 weeks after amendment incorporation, suggesting that mineralization of amendments progresses with time. Generally, higher rates of amendment resulted in higher soil aggregate stability. For the Orchard soil, the trend of soil aggregate stability at each sampling time was CD+CP>CD>CD+KP>CP>KP. The factors, type and rate of amendment and sampling time were very highly significant (P<0.01) in affecting changes in soil aggregate stability.

For the vegetable farm soil the soil aggregate stability improved with increased rate of application for all sampling times relative to the control. The amendment CD (at 200 Mg/ha) and CD+CP (200 Mg/ha) gave the highest increase just as was observed in the Orchard soil. Though CD alone (at 200 Mg/ha) performed better (62-72%) in the Vegetable soil compared to the Orchard

Table 4. Changes in soil aggregate stability (AS) as a result of organic manure amendment on the orchard (OR) and vegetable (VG) farm soil.

Treatment	Orchard farm				Vegetable farm			
	2wks		4wks		2wks		4wks	
	AS (%)	TF (%)	AS (%)	TF (%)	AS (%)	TF (%)	AS (%)	TF (%)
CD_1	58	45	65	59	52	37	67	63
CD_2	62	55	70	71	62	63	72	76
CP_1	52	30	59	44	50	32	56	37
CP_2	61	53	67	63	58	53	65	59
KP_1	51	28	59	44	48	26	55	34
KP_2	57	43	64	56	55	45	61	49
$CD+CP_1$	57	43	68	66	56	47	70	71
$CD+CP_2$	62	55	77	88	63	65	76	85
$CD+KP_1$	53	33	66	61	51	34	65	59
$CD+KP_2$	60	53	70	70	59	55	68	66
C	40	-	41	-	38	-	41	-
$F\text{-}LSD_{0.05}$	3.0	-	3.0	-	3.7	-	3.7	-

Treatment Factor TF (%) = (Va/Vc-1)100; Va - value from the manure amended soil, Vc - value from the control (C)

farm soil (55-71%) for two and four weeks sampling periods, respectively. Also the factors, (type and rate of amendment and sampling time) significantly ($P<0.01$) influenced the soil aggregate stability of the soil. There were indications that the treatments were of greater influence in the vegetable farm soil, confirming that management practices could influence the response ($P<0.01$) of the soil to organic manure inputs as found in this study. The observation in this study is similar to the reports of Mbagwu and Piccolo, (1998), who reported that addition of organic manure in the soil improves the degree of aggregation and aggregate stability. In this study, at the 200 Mg/ha rate of amendment, the level of improvement was higher irrespective of the management practice. However the vegetable farm responded more to the amendment, giving higher levels of improvements at both sampling times and the level of improvements were consistent, being highest at four weeks of sampling. This is attributed to comparatively better chemical properties of the Vegetable farm soil (Table 3).

Effects of farmstead manure on soil chemical properties

The changes in soil chemical properties (Table 5) were influenced by the type and rate of organic amendment as well as the incubation period for both soils. In the Orchard farm soil increases in organic carbon relative to the control for both sampling period was above 100% in most cases. CP at the lower rate (100 Mg/ha) gave the highest improvement (56%) relative to the control at two weeks.

Generally the trend in percent organic carbon at two weeks was CD+KP>KP>CD+CP>CD>CP and CD > KP + CD >CD+CP>KP>CP, and at four weeks the trend was CD+KP>CD+CP>KP>CD>CP and CD + KP > CD > KP > CD +CP>CP at 200 and 100 Mg/ha, respectively. The factors, type, rate and time of sampling were all statistically significant at $P<0.01$ for both soils.

Similar trend in percent organic carbon variation was observed for the vegetable farm (Table 5). The trend was CP>CD>CD+KP>CD+CP>KP and KP > CD + KP > CD + CP >CD>CP at two weeks of sampling, and at four weeks the trend was CD+CP>CD>CP>CD+KP>KP and KP>CD+CP>CD+KP>CD>CP at 200 and 100 Mg/ha, respectively. The increase in organic carbon observed here agrees with the observation of Gerzabek, et al. (1997) that the addition of organic manure especially of plant origin improves organic carbon. However, this study indicates that the differences in the level of organic carbon increase depend on the soil quality or management practice which is a product of the differences in organic carbon loss or decomposition. Hence there is a higher (120-440%) and consistent improvements in the Vegetable farm soil, while in the Orchard soil, improvements is as a result of application of plant manure alone or in combination depended on the application rate. The plant manure (KP) in combination with animal manure (CD) gave the highest improvement in organic carbon at two weeks for the Orchard farm soil while in the Vegetable farm soil the animal manure CD gave the highest improvement at 200 Mg/ha application rate.

The effects of amendments on soil pH (Table 5) for both soils show that the soil became less acidic with the

Table 5. Changes in soil organic carbon (OC) and soil reactivity pH of vegetable or orchard farm soils amended with organic manure.

Treatment	Orchard farm				Vegetable farm			
	OC (%)		pH		OC (%)		PH	
	2wks(TF)	4wks(TF)	2wks(TF)	4wks(TF)	2wks(TF)	4wks(TF)	2wks(TF)	4wks(TF)
CD_1	2.16 (96)	2.38(100)	6.20(35)	6.80(42)	2.14(263)	2.53(200)	6.30(26)	6.90(33)
CD_2	2.20(100)	2.68(129)	6.60(43)	7.50(56)	3.00(400)	3.31(273)	6.80(36)	7.20(38)
CP_1	1.72(56)	2.15(84)	6.40(39)	6.60(38)	1.76(198)	1.90(126)	6.30(26)	7.10(37)
CP_2	2.30(100)	2.59(121)	6.40(39)	7.40(54)	3.18(439)	3.13(273)	7.10(42)	7.30(40)
KP_1	1.91(74)	2.23(91)	6.50(41)	6.90(44)	2.70(358)	2.93(249)	6.30(26)	7.20(38)
KP_2	2.51(128)	2.87(145)	6.70(46)	7.40(54)	2.74(364)	3.01(258)	7.00(40)	7.50(44)
$CD+CP_1$	1.96(78)	2.23(91)	6.80(48)	7.00(46)	2.58(337)	2.80(233)	6.90(38)	7.40(42)
$CD+CP_2$	2.50(127)	2.89(147)	6.80(48)	7.60(58)	2.85(383)	3.24(286)	7.50(50)	7.80(50)
$CD+KP_1$	2.12(93)	2.47(111)	6.90(50)	7.20(50)	2.57(336)	2.70(220)	6.80(36)	7.40(42)
$CD+KP_2$	2.81(155)	3.03(159)	6.90(50)	7.50(56)	2.88(388)	3.02(260)	7.40(48)	7.90(50)
C	1.10(-)	1.17(-)	4.60(-)	4.80(-)	0.59(-)	0.84(-)	5.00(-)	5.20(-)
$F\text{-}LSD_{0.05}$	0.15	0.15	0.31	0.31	0.24	0.24	0.39	0.39

*TF as in Table 4.

Table 6. Simple linear correlation between percent organic carbon (OC) and aggregate stability (AS).

Dependent variable	Two weeks		Four weeks	
AS	r 0.893**	r^2 (%) 79.7	r 0.911**	r^2 (%) 83.0
	Orchard farm		Vegetable farm	
AS	r 0.932	r^2 (%) 86.9	r 0.844	r^2 (%) 70.6

addition of these amendments. The neutralizing effects of these amendments increased with increasing application rates. The Orchard farm soil experienced greater increase in soil pH, equivalent to 30 - 50% increases in soil pH relative to the control. In the Vegetable farm soil, the increases in pH units ranged from 20-40% relative to the control, indicating that the Orchard soil responded better to the treatments in terms of soil reactivity. Improvements in pH increased with sampling time, rising to neutral (7 and above) in all treatments for both soils at four weeks. Combinations of manure of plant and animal origins (CD+CP and CD+KP), at different rates, gave the highest increases in soil pH of both soils at each sampling period. The type of amendment significantly influenced the pH of the soil at $P<0.05$, while the rate and sampling time significantly influenced soil pH at $P<0.01$. The observation here is consistent with the findings of Opara-Nadi et al. (1987) and Arya et al. (1991) who reported pH increases with application of organic wastes. However, we suggest that a period of incubation of these materials be carried out before incorporating the manure into the soil as this takes care of evolution of CO_2 which normally accompany decomposition of these organic manures with a resultant increase in soil acidity. Also the incubation of organic manure prior to incorporation eliminated the need for lime application before incorporation of manures, such that the immediate (two weeks) effect of incorporating these amendments on soil pH was as high as 50% relative to the control for both the Orchard and Vegetable soils under study.

Simple linear correlation of organic carbon with soil aggregate stability showed a highly significant positive correlation ($P\leq0.01$) for both soils (Table 6). This is consistent with the results of several studies (Acton et al., 1963; Mehta et al., 1960; Nnabude and Mbagwu, 2001) which reported that organic carbon exerts positive influence on soil physical properties.

Conclusion

Conclusively therefore, we recommend from this study that combination of CD and CP or CD and KP is most effective in the improvement of soil physical and chemical properties if some period of decomposition is allowed before its incorporation into the soil. For the sandy loam soils of Umudike, a rate of 200 mg/ha is recommended.

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