IJAAR 1 (2013) 92-101 ISSN 2053-1265

International Journal of Advance Agricultural Research
www.bluepenjournals.org/ijaar

Infiltration and organic carbon pools under the long term use of farm yard manure and mineral fertilizer

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Article History
Received 28 June, 2013
Received in revised form 05 August, 2013
Accepted 10 August, 2013

Key words:
Farmyard manure, Mineral fertilizer, Organic carbon, Infiltration.

Full Length Research Article

ABSTRACT

Farmyard manure (D) in combination with inorganic fertilizer (NPK) trial was started at Samaru in 1950 to assess nutrient imbalances resulting from increasing use of mineral fertilizer on some poorly buffered soils as well as to improve and optimize productivity of these soils under intensive agricultural land use. Soil physical and chemical properties were studied in selected plots, with the aim of identifying treatment(s) that best improve soil quality over a long-term period. A total of ten treatments were evaluated namely: Inorganic fertilizer (NPK) in combination with farmyard manure (D), that is, (D+NPK), NPK only, D only, D + phosphorus (P), D + potassium (K), D + nitrogen (N), N only, K only, P only and a Control receiving neither NPK nor D. The results obtained show that long term application of manure with or without NPK increased aggregate stability and mean weight diameters (MWD) of the water stable aggregates for soils amended with D+P, D+K and NPK. Soils amended with D+P and D+NPK sequestered more total soil organic carbon than all other treatments. The soil organic carbon of aggregate fractions was very low. Higher soil bulk densities were observed for the no amendment (Control) plot, D+K, and NPK treated soils. However, the D+P, D+N and N treatments recorded a lower soil bulk density. Soils treated with D+P and NPK recorded higher infiltration rate than the control. Treatments with D only also generally had higher plant available water than the other treatments. Hence, on the basis of soil quality considered, the long term D+P treatment provides the most sustainable agricultural practice.

INTRODUCTION

Soil is a natural resources, it provides the basis of food chain that ends with human consumptions and waste disposal. However, increase in pressure on soils due to demographic changes coupled with the activities of humans in the present civilization has led to decline in the capacity of soils to produce food, feed and fibre that will cater for the needs of human.

Soils of the savanna are mainly classified as Alfisols, Ultisols, Entisols and Inceptisols. They are derived from precambian crystalline basement complex rocks (Harpstead, 1973), coarse textured with pH (water) ranging from 5.5 to near neutral, low soil surface organic matter with total nitrogen content of about 0.1% and low to moderate CEC (Jones and Wild, 1975). The soils have low fertility status, weak aggregation, low water holding capacity shallow depth and low organic matter content (El–Swaify et al., 1987) therefore fragile and easily degraded under continuous cultivation. Continuous cultivation which had replaced the traditional shifting cultivation causes soil nutrient and fertility depletion,

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structure degradation, reduced water infiltration, increased run off and erosion (Bationo et al., 1997; Odunze, 2003; Lawal, 2012) thus, crop production is not profitable without soil nutrition.

To ameliorate these problems for the purpose of sustainable yields, agronomists are faced with the challenge of coming up with possible solutions that will mitigate effects of soil degradation, this led to the search for soil conditioners and amendments; with the most prevalent being application of cow dungs. The application of cow dung or farm yard manure amendment to soil has been practiced for a long time, due to the constraints of high cost of procurements, shortage or late supply of inorganic fertilizer. Furthermore, inorganic fertilizer causes soil fertility degradation such as reduction in soil pH, reduction in organic matter content and exchangeable cations (Jones and Wild, 1975), non-replacement of trace mineral elements and over fertilizations amongst others.

The use of organic manure to improve soil fertility is considered to be more beneficial than inorganic fertilizer. This is because of its potential to modify physical condition of soils by improving its water holding capacity, aeration, drainage, friability and its ability to provide energy for microbial activity (Goladi and Agbenin, 1997). Inorganic fertilizer provides crops with its immediate and ready to use nutrients while organic fertilizer (slow–release element) provides the later requirements, there by sustaining crops with its need throughout its life. The complementary use of organic and inorganic fertilizer is believed to have a major beneficial effect on soil aggregation (Ogunwole and Ogunleye, 2004), as well as carbon sequestration through improved microbial activity.

The long term use of cow dung improves soil organic matter content (Goladi and Agbenin, 1997). Therefore; soil quality indicators like infiltration rate, water holding capacity, structure, soil texture etc. are enhanced. Soil organic matter has been documented to separate into various pools over time due to roots growth, litter falls and microbial decomposition (Christensen, 1992), therefore quantifying various pools of carbon is a useful approach to assessing soil quality indicators. In addition, total organic carbon has not always been good indicators for evaluating soil organic matter content (Lawal, 2010; Lawal et al., 2012).

Good quality soil is important for sustainable crop production especially under continuous cultivation. The complementary application of organic and mineral fertilizers to agricultural soil has been viewed as excellent way to recycle nutrients and organic matter that can support crop production and maintain or improve soil quality. However, in spite of the benefits accruable from the use of cow dung, there exists a dearth of research information on the quantification of organic carbon pools under the complementary use of organic and mineral fertilizer in a continuously cultivated system. Therefore the objectives of this study were to:

1. evaluate the effect of cow dung, mineral fertilizer and their combinations on soil organic carbon pools and aggregate stability;
2. establish a relationship between organic carbon pools, water infiltration and aggregate stability.

MATERIALS AND METHODS

Site Description

Soil samples were collected from the long-term farmyard manure (D)-NPK plots of the Institute for Agricultural Research (IAR) at Samaru (Latitude 11° 11’ N and longitude 7° 38’ E, altitude 686 m), in the northern Guinea savanna ecological zone of Nigeria. The DNKP trial was initiated in 1950 on a leached tropical ferruginous soil classified as Typic Haplustalf (Ogunwole et al., 2001), with a uniformly gentle slope (<0.5% slope). The trials consisted of ten treatments, namely: Inorganic fertilizer (NPK) in combination with farmyard manure (D), that is, (D+NPK), NPK only, D only, D + phosphorus (P), D + potassium (K), D + nitrogen (N), N only, K only, P only and a Control receiving neither NPK nor D; laid out in a randomized complete block design replicated three times. Each plot size was 220 m^2 with adequate discard of 0.91 m surrounding it, each of these plots were divided into three homogeneous sub-plots of 72 m^2 each and soil samples collected from three sites in each sub-plot, bulked and considered a replicate. In the selected plots, for this study, dung was applied at the rate of 5 tonnes/ha, nitrogen 67 kg/ha, phosphorus 27 kg/ha and potassium 58 kg/ha. The trial had been under natural fallow from 1997 to 2008. However the cultivation of the field resumed from September 2008, it was cropped to cowpea in 2008 and maize in 2009 prior to collection of soil samples in December 2009. Urea, single super phosphate and muriate of potash were sources of N, P, and K, respectively.

Soil sampling

Surface soil (0–15 cm) of some selected plots was sampled in three replications after dividing each plot into three parts. Soil samples (disturbed and undisturbed) were collected from ten chosen plots. The samples were appropriately labeled for easy identification. The plots sampled for this study are shown in Table 1.

The soil samples collected were divided into two parts; one part was passed through 5 mm mesh sieve and stored in polythene bags for soil aggregate stability

Table 1. Plots sampled.

Serial number	Plot number	Treatment
1	3	N (0200)
2	4	D+NPK (2222)
3	14	Control–No amendment (0000)
4	32	P (0020)
5	47	D+P (2020)
6	56	D (2000)
7	64	K (0002)
8	71	D+N (2200)
9	75	D+K (2002)
10	78	NPK (0222)

determination and the second part was grinded with porcelain mortar and pestle then passed through 2 mm sieve for subsequent routine physical and chemical analysis.

Field study

Infiltration

A double ring infiltrometer (Eijkelkamp Agrisearch Equipment) consisting of an inner ring of 300 mm in diameter and an outer ring of 550 mm in diameter both of 300 mm in height were inserted 100 mm into the ground. The rings were then pounded with water and the depth of water percolated into the ground/soil was recorded at the first 5 min, then 15, 30, 60 and 120 min to give a total of 120 min for one spot of each of the three replicate locations within each plot. The measurement was carried out during the dry season. However, for each time the infiltration reading taken, the antecedent moisture content was also noted. This was done by picking samples from spot and taking them to the laboratory to determine the initial moisture content of the field.

Bulk Density (BD) was determined by the core method Blake and Hartge, (1986).

Laboratory analysis

Aggregate size distribution (Wet sieving)

To determine aggregate size distribution through wet sieving method, 200 g of 5 mm soil was sieved in a bucket ¾ filled with water by slaking (rapid immersion) using sieve sizes of 2 mm (2000 um), 0.25 mm (250 um) and 0.05 mm (50 um) for 60 s, with an average strokes of 41, 28 and 3, respectively for each sieve. The less than 0.05 mm (<50um) filtrate was allowed to settle down overnight and the water was gently decanted. Soils retained in the sieves were labeled >2 mm, >0.25 mm, >0.05 mm and <0.05 mm, respectively. The various aggregate fractions were transferred into cans. The samples in cans were oven dried at 60°C to a constant weight for 48 h and samples weights were obtained using a weighing balance (Citizen electronic balance MP600) and then corrected for sand.

The proportional weight of soil aggregate was calculated as:

$$\frac{\text{Weight of sol retained in sieve - its percentage sand content}}{\text{Weight of bulk soil taken - its percentage sand content}}$$

The stability of the soil aggregate was characterized by mean weight diameter (MWD) which was determined as:

$$MWD = \sum_{i=1}^{n} X_i W_i$$

Where,
X_i = proportional weight of sand free aggregate;
W_i = mean diameter of sieve proceeding and preceding.

Particle size distribution in soil aggregate fractions

Hydrometer method was used in determining particle size distribution (Gee and Bauder, 1986) of the aggregate fractions >2, >0.25 and >0.05 mm, respectively. Briefly, known grams of these aggregate fractions were dispersed in 4% sodium hexametaphosphate solution, to allow aggregates separate into individual particles of sand, silt and clay.

Soil organic carbon fraction

Soil organic carbon content was determined in the various aggregate fractions separated during the wet sieving by the dichromate oxidation method (Nelson and Sommers, 1982). Briefly, 1 g of soil was oxidized with 1 N potassium dichromate and concentrated sulphuric acid, then titrated with 0.5 N ammonium ferrous sulphate solution.

Non-hydrolysable carbon

Non-hydrolysable carbon NHC was determined by acid hydrolysis (Tan et al., 2004). 1 g of bulk soil sample passed through a 250 um sieve was placed in a 50 ml digestion flask, 25 ml of 6 N HCl (Paul et al., 2001) was added to this flask and shaken thoroughly by hand. A digestion block was used to heat the soil sample at 100°C until only soil residue was left. The soil residue was transferred to a 50 ml centrifuge tube with 40 ml of distilled water and then centrifuge for 30 min, after which the supernatant was discarded. HCl was then removed by washing twice with 40 ml distilled water through centrifuging. Finally the residue was dried at 60°C over night after which organic carbon was determined in the acid hydrolyzed soil by dichromate oxidation.

Soil pH

Soil pH was determined, both in water and 0.01 M $CaCl_2$ solution, using a soil to solution ratio 1:2.5 (Rhoades, 1982).

Soil electrical conductivity (EC)

This was determined by the saturated soil paste method (Rhoades, 1982). Soil to distilled water ratio of 1:2.5 was allowed to stand overnight then it was read on a conductivity measuring Bridge M.C.3 model EBB/10.

Total nitrogen

Total nitrogen was determined by the micro Kjeldahl digestion method as described by Bremner (1982). 1 g of soil was heated with mixed catalyst (Selenium + $CuSO_4$ + Na_2SO_4) and concentrated sulphuric acid at temperature of 400°C then distilled into 2% boric acid and afterwards titrated with 0.025 N sulphur.

Soil moisture retention

This was determined using the pressure plate apparatus, at suction points of 0.3 bars (field capacity) and 15 bars (permanent willing point).

Total organic carbon

Total organic carbon was determined by dichromate oxidation method (Nelson and Sommers, 1982).

Data analyses

Data collected in this study were subjected to statistical analysis of variances(ANOVA) as described by Snedecor and Cochran (1967), using the SAS computer package (SAS, 1989) the differences among treatment means was evaluated using Duncan's multiple range test (DMRT) (Duncan, 1955). The magnitude and type of relationship between treatments were assessed through simple correlation analysis in accordance with the procedures of Steel and Torrie (1984).

RESULTS AND DISCUSSION

Effect of farm yard manure and mineral fertilizer on particle size distribution

The effect of farm yard manure (D) and mineral fertilizer (NPK) on soil particle size distribution was highly significant ($P<0.01$) on all the particle sizes except clay (Table 2). Higher sand fraction was recorded in plots treated with D+N although statistically similar with the other treatment plots except for N, D+NPK and Control plots. Soils treated with N recorded the least sand fraction. Soil plots amended with D+NPK recorded the highest silt fraction even though similar to plots receiving N and the Control.

Though the clay fraction was not significantly ($P>0.05$) affected by D and NPK, plots amended with D+NPK recorded the highest mean clay fraction and plots amended with K recorded the least mean clay fraction.

The high sand fraction in D+N amended plots may probably be an indication of higher resistance to frequent cultivation.

Table 3 shows the effect of manure and mineral fertilizer on soil infiltration rate. The difference among treatment means was highly significant ($P<0.01$) with plot treated with dung and their combination possessing better rate than the no amendment plots except for D+NPK plot which was equal statistically with the Control. This shows that application of farm yard manure is a valuable source of organic matter and plant nutrient (Farage et al., 2003) which has the tendency of promoting stable macro aggregates (Whalen and Chang, 2002), thus, maintaining surface integrity of soil, and

Table 2. Effect of farm yard manure and mineral fertilizer on soil particle size distribution.

Treatment	Clay (%)	Silt (%)	Sand (%)
Nitrogen (N)	22.21	39.333[ab]	35.147[d]
FYM+NPK (DNPK)	14.88	42.667[a]	43.120[cd]
Control	10.21	37.333[abc]	52.527[bc]
Phosphorus (P)	9.55	35.333[bc]	55.120[abc]
FYM+phosphorus (DP)	9.55	34.000[bcd]	56.453[ab]
FYM (D)	10.21	32.667[cde]	57.120[ab]
Potassium (K)	7.55	32.667[cde]	59.787[ab]
FYM+Nitrogen (DN)	8.88	24.000[f]	67.120[a]
FYM+potassium (DK)	8.21	28.000[ef]	63.787[ab]
NPK	8.88	28.960[def]	62.160[ab]
S.E ±	16.623	2.4917	5.8053
Significance	NS	**	**

Means with the same letters within a column are not significantly different at 5% level of probability.
FYM, Farm yard manure; NS, not Significant; **, significant at 1% level of probability; S.E ±, standard error.

Table 3. Effect of farm yard manure and mineral fertilizer on soil infiltration rate and moisture retention.

Treatment	Infiltration (cm/hr)	Moisture Regime		
		FC (30 KPa)	PWP (1500 KPa)	PAW
Nitrogen (N)	5.20[cd]	0.095	0.051[a]	0.044
FYM+NPK (DNPK)	3.08[d]	0.14	0.052[a]	0.088
Control	3.80[d]	0.12	0.036[de]	0.084
Phosphorus (P)	14.53[bcd]	0.13	0.033[e]	0.097
FYM+Phosphorus (DP)	52.05[a]	0.08	0.039[cde]	0.041
FYM (D)	13.00b[cd]	0.1	0.044[bc]	0.056
Potassium (K)	29.97[abc]	0.10	0.042[cd]	0.058
FYM+Nitrogen (DN)	12.45[bcd]	0.072	0.032[e]	0.040
FYM+potassium (DK)	22.58[bcd]	0.070	0.037[e]	0.033
NPK	37.33[ab]	0.126	0.041[cd]	0.085
S.E ±	10.85	0.037	0.00 34	
Significance	**	NS	**	

Means with the same letter within same column are not significantly different at 5% level of probability.
FYM, Farm yard manure; NS, not significant; **, significant at 1% level of probability; FC, field capacity; PWP, permanent wiling point; PAW, plant available water; S. E±, standard error.

facilitating infiltration rather than runoff (Franzluebbers et al., 2000). The least mean of infiltration recorded in plot treated with D+NPK might be as a result of high tillage operation over a long period of time that led to the pulverization of the soil.

On the effect of farmyard manure and mineral fertilizer on soil moisture content, Table 3 shows that the farmyard manure and mineral fertilizer have no significant effect on the soil moisture retention capacity at 30 kPa (field capacity). However plot amended with D+NPK retained the highest mean moisture at field capacity relative to the other treatments plots, D+K recorded the least mean moisture retention capacity among others. But at 1500 kPa, the effect of farmyard manure and mineral fertilizer on soil moisture retention capacity is highly significantly (P<0.01). Plot treated with N and D+NPK recorded the highest mean moisture retention relative to the soil plot with no amendment. Soil plot treated with D+K, D+N and

P recorded the least mean moisture retention at 1500 kpa. This result shows that more water was available to plants in plots treated with combination of mineral fertilizer and farmyard manure (D+NPK, D+P and D+K) far more than the plot with no farmyard manure at all (P and Control plots). This confirms the proportional relationship between soil organic matter and soil moisture as reported by Ekwue (1990). Sommerfeldt and Chang (1986) also reported that water retention increases with increasing organic matters content in sandy soils and decreases with increasing organic matter in clayey soil. Organic matter may increase water retention in soils with a clay content <15% (Macrea and Mehuys, 1985).

Effect of farmyard manure and mineral fertilizer on soil organic carbon pools

The effect of farmyard manure and mineral fertilizer on total organic carbon was highly significant (P<0.01). Table 4 revealed that plots treated with D+P recorded the highest mean total organic carbon. It was significantly equal with soils treated with D and D+NPK but however statistically better than all other treatment plot evaluated. Soils treated with K only and no amendment plots recorded the least mean total organic carbon along with soil receiving P, D+N, D+K and NPK. The inference could be as a result of increase soil fertility and moisture retention as a result of added manure resulting in increasing plant and weed growth and therefore accumulated plant biomass over the years from the plant litter deposition since plot was left fallow for several years. Furthermore, manure influences increase root growth therefore will add organic matter to the soil upon decomposing. Increasing the total organic carbon content of the soil most of which are retained in the macro aggregate fraction (Tisdall and Oades; 1982). Agbenin and Goladi (1997) recorded higher organic matter content with an addition of farmyard manure.

Analysis of data presented no significant difference among the treatment means with respect to unprotected particulate organic carbon (UPOC) intra-aggregate particulate organic carbon (IPOC) and silt plus clay associated carbon (Table 4). However in the UPOC aggregates, plots treated with D and D+NPK recorded the highest mean of organic carbon relative to the other treatment while the plot receiving no amendment had the least mean value. The UPOC are readily decomposable due to their accessibility to microbes and therefore may not last long in soil as at end of seasons when the soil samples were taken; such as to create significant difference amongst treatment imposed. In the IPOC, higher mean of organic carbon was recorded in soil treated with no amendment and NPK respectively and soil plot treated with D+N recorded the least mean soil organic carbon. Since plots had been on fallow over the years, it may be possible that IPOC which is stored or protected inside the soil aggregate and only usually lost during cultivation, became stable and thus was maintained at identical level irrespective of treatments (nutrient sources) applied. In the silt+clay associated carbon, soil receiving NPK treatment recorded the highest mean of soil organic carbon and plot receiving P recorded the least mean soil organic carbon.

The principal importance of manure application as promoting the formation and stabilization of soil macro–aggregates thereby facilitating soil organic carbon sequestration (Farage et al., 2003), thus, the higher organic carbon content in D and D+NPK amended soil.

The effect of farmyard manure and mineral fertilizer on the soil non-hydrolysable carbon (NHC) was highly significant (P<0.01) (Table 4). Soil plots treated with NPK, D+K and D+P recorded the highest mean non-hydrolysable carbon, although statistically the same as plot treated with D+N, K and P, but better than the other treatment. The plot amendment with D only recorded the lowest mean NHC, even though it was statistically the same as plot treated with N and D+NPK. The concentration of the NHC in the soil is affected by soil management and ecosystem properties such as land use, tillage and soil texture (Anderson and Paul, 1984). The NHC of soil can be increased by conversion from conventional tillage to no tillage in the entire aggregate soil fractions (Tan et al., 2004).

Effect of farmyard manure and mineral fertilizer on soil aggregate characteristics

The effect of farmyard manure and mineral fertilizer on soil aggregate characteristics was highly significant for the entire aggregate fraction as observed in Table 5. In the large macro aggregate (2000 µm), soil plot treated with D only recorded higher mean relative to the other treatment, although statistically the same as plot treated with K and no amendment. The plot receiving D+K recorded the least mean along with soil receiving N. The effect of the farmyard manure and mineral fertilizer on small macro aggregate revealed significantly higher stability of small macro aggregate in plots treated with (D+K, D+N and D+P) although plots treated with combination of dung and mineral fertilizer were statistically at equal with NPK treated plots. However plot treated with no amendment (Control) recorded the least mean of small macro aggregate. No significant effect was recorded on the micro aggregates (50 µm) in all the plots. In the <50 µm aggregates, higher mean was recorded in plot receiving D+NPK treatment while plot treated with D+N recorded the least mean.

The effect of farmyard manure and mineral fertilizer on

Table 4. Effect of farm yard manure and mineral fertilizer on soil organic carbon pools.

Treatment	TOC	UPOC 250μm	IPOC 50 μm g/Kg	Silt+Clay <50μm	NHC
Nitrogen (N)	7.40^{c}	0.508	0.535	0.949^{ab}	1.11^{c}
FYM + NPK (DNPK)	8.08^{ab}	0.666	0.402	0.778^{ab}	1.54^{bc}
Control	5.63^{cd}	0.272	0.622	0.710^{ab}	1.79^{abc}
Phosphorus (P)	5.97^{cb}	0.507	0.0423	0.634^{b}	2.40^{ab}
FYM + phosphorus (DP)	9.37^{a}	0.384	0.561	1.030^{ab}	2.98^{a}
FYM (D)	8.07^{ab}	0.695	0.500	0.768^{ab}	0.947^{c}
Potassium (K)	5.16^{d}	0.443	0.443	0.771^{ab}	2.28^{ab}
FYM + Nitrogen (DN)	5.90^{cd}	0.380	0.395	0.850^{ab}	2.25^{a}
FYM + potassium (DK)	6.99^{bcd}	0.587	0.464	0.749^{ab}	2.83^{a}
NPK	6.31^{bcd}	0.353	0.613	1.157^{a}	2.95^{a}
SE ±	0.799	0.2101	0.162	0.207	0.512
Significance	**	NS	NS	NS	**

Means with the same letter within the same column are not significantly different at 5% level of probability.
FYM, Farm yard manure; NS, not significant; **, significant at 1% level of probability; TOC, total organic carbon; NHC, non-hydrolysable carbon; UPOC, unprotected particulate organic carbon; IPOC, intra particulate organic carbon.

Table 5. Effect of farm yard and mineral fertilizer on soil aggregate characteristics.

Treatment	Largemacro Aggregate (>2000μm)	Smallmacro Aggregate (>250μm)	Micro Aggregate (>50μm)	Silt+Clay Aggregate (<50μm)	MWD
Nitrogen	0.0181^{b}	0.276^{e}	0.0725^{a}	0.00667^{b}	0.373^{c}
FYM+NPK	0.0280^{ab}	0.235^{e}	0.0708^{a}	0.00738^{a}	0.339^{c}
Control	0.0432^{a}	0.263^{e}	0.0733^{a}	0.00663^{b}	0.386^{bc}
Phosphorus	0.0286^{ab}	0.379^{bcd}	0.0709^{a}	0.00457^{cd}	0.483^{bc}
FYM+Phosphorus	0.0267^{ab}	0.428^{ab}	0.06670^{a}	0.00417^{cd}	0.525^{ab}
FYM	0.321^{ab}	0.369^{cd}	0.0709^{a}	0.00477^{c}	0.477^{abc}
Potassium	0.0420^{a}	0.356^{d}	0.074^{a}	0.00447^{cd}	0.477^{abc}
FYM+Nitrogen	0.0227^{b}	0.420^{abc}	0.072^{a}	0.00353^{d}	0.389^{bc}
FYM+Potassium	0.0158^{b}	0.471^{a}	0.0447^{b}	0.0042^{dc}	0.535^{a}
NPK	0.0280^{ab}	0.460^{a}	0.0633^{a}	0.00403^{cd}	0.555^{a}
SE ±	0.00772	0.0232	0.0085	0.000455	0.0606
Significance	**	**	*	**	*

Mean with the same letter(s) within the same column are not significantly different at 5% level of probability.
FYM, Farm yard manure; MWD, mean weight diameters; NS, not significant;**, significant at 1% Level of probability; *, Significant at 5% Level of probability.

MWD was significant (P<0.05) as presented in Table 5. Soil treated with farmyard manure, mineral fertilizer and their combination (D+P, NPK, D+K and D) recorded the highest MWD than the Control plot. While soil treated with D+NPK and N recorded the least MWD (Table 5). This corresponds with the result obtained by Ogunwole (2008). A probable reason for the least MWD may be that most of the large macro aggregates fraction in the dry soil degraded when rapidly immersed in water, a situation consistent with natural wetting by intense rain (Unger, 1997). The higher MWD might be as a result of increase in organic materials on the soil resulting from increase in organic manure as reported by Ogunwole (2008).

Table 6. Effect of farm yard manure and mineral fertilizer on selected soil properties.

Treatment	Soil Properties			
	Bulk Density (g/cm^{-3})	Electrical Conductivity (dsm^{-1})	pH	
			Water	$CaCl_2$
Nitrogen (N)	1.403^{b}	0.05^{6b}	5.817^{b}	5.227^{b}
FYM+NPK(DNPK)	1.440^{ab}	2.821^{a}	5.837^{b}	5.440^{ab}
Control	1.530^{a}	0.052^{b}	6.123^{a}	5.400^{b}
Phosphorus (P)	1.447^{ab}	0.163^{b}	6.033^{ab}	5.343^{b}
FYM+phosphorus (DP)	1.357^{b}	0.327^{b}	6.253^{a}	5.307^{b}
FYM (D)	1.447^{ab}	0.072^{b}	6.090^{ab}	5.680^{a}
Potassium (K)	1.430^{ab}	0.267^{b}	6.040^{ab}	5.360^{b}
FYM+Nitrogen (DN)	1.400^{b}	0.050^{b}	0.023^{ab}	5.320^{b}
FYM+potassium (DK)	1.50^{a}	0.061^{b}	6.150^{a}	5.423^{ab}
NPK	1.547^{a}	0.045^{b}	5.850^{b}	5.300^{b}
S.E ±	0.0500	1.1402	0.1156	0.1222
Significance	*	NS	*	NS

Mean with the same letter(s) within the same column are not significantly different 5% level of probability.
FYM, Farm yard manure; NS, not significant; **, significant at 1% Level of probability; *, significant at 5% Level of probability; S.E ±, standard error.

Effect of farmyard manure and mineral fertilizer on some soil properties

Soil bulk density

The effect of farmyard manure and mineral fertilizer significantly (P<0.05) affected soil bulk density (Table 6). Plots treated with NPK and D+K recorded statistically the same bulk density as plot with no amendment (Control). The least bulk density was in D+P, D+N and N treatment plots. However, it was observed that all the plots receiving dung either solely or together with mineral fertilizer except for D+K had better soil bulk density relative to the no amendment plot (Control). This indicates that farmyard manure reduces soil bulk density and this may improve plant root penetration into soil. Better plant root penetration may cause good root growth and establishment in soil which may improves plants' ability to take up water and nutrient required for proper plant growth and development. This may consequently stimulate good crop biomass and yield. Sommerfeldt and Chang (1986) reported reduced surface soil bulk density with increase rate of manure application. Also reduction in soil bulk density and increase in soil water retention as a result of cow dung application have been reported by Ohu et al., (1985) to be a possibility.

These findings revealed that the long term application of farmyard manure alone or in combination with other mineral fertilizers would reduce soil bulk density of a land under continuous cultivation.

Soil pH

The effect of farmyard manure and mineral fertilizer on soil pH in water was significantly (P<0.05) recorded. All the plots treated with dung either solely or in combination with one element of the mineral fertilizer recorded higher mean soil pH (Table 6). Thus plots amended with D+P, D+K and Control recorded the highest mean soil pH. Soil plots receiving N, NPK and D+NPK recorded the least mean soil pH (Table 6). This may also mean less risk of soil acidity with the use of organic nutrient sources either solely or in combination with inorganic fertilizers. But the effect of farmyard manure and mineral fertilizer on soil pH ($CaCl_2$) was not significantly (P<0.05) recorded. However, soil plot treated with D recorded the highest mean pH relative to the other treatments. Soil amended with D+P recorded the least mean soil pH although statistically the same as soil treated with N, Control, P, D+P, K, D+N and NPK.

The increase in soil pH (water) as recorded in Table 6 was not unexpected as pH is associated with organic manure application (Bache and Heathcote, 1969, Lopez, 1980). Agboola and Odeyemi, 1972 reported average soil pH 6.0 for plots receiving farmyard manure in combination with mineral fertilizer as opposed to 4.5 for fields treated with mineral fertilizer alone. Bache and Heathcote, 1969; also reported that plots receiving cow dung treatment had high soil pH and reduced Al and Mn concentration relative to those treatment with mineral fertilizers. However the pH ranges are adequate for proper nutrient uptake by plant.

Variation amongst treatment means of electrical conductivity (EC) were not significantly affected by the use of farmyard manure, mineral fertilizer and its combination. Generally the EC values are by far <4 dsm^{-1}. Therefore, this is an indication that the field is not tending towards salinity.

Conclusion

Application of chemical fertilizer is the only means of enriching the soil for quick nutrient availability for crop use. But there are some problems associated with the use as sole source of soil amendment among which are the exorbitant cost, scarcity and adverse effect on the soil when the soil is exposed to it for a long period of time and ecosystem pollution especially on water.

This study evaluated the long term complementary utilization of organic and mineral fertilizer on soil organic carbon pools and infiltration rate of the soil and the effect of this on soil quality indicators for sustainable crop production especially under continuous cultivation. The complementary application of the organic and mineral fertilizers to agricultural soil has been viewed as excellent way to recycle nutrients and organic matter that can support crop production and maintain or improve soil quality by improving the soil quality indicators such as bulk density, infiltration rate, soil moisture retention capacity, soil organic carbon content, soil pH, soil aggregate stability, soil structure and texture.

The natural recycling of animal droppings (particularly cow dung) through its disposal on cultivable land for crop -production, is a good agricultural practice in the tropics from the stand point of improving soil's productive capacity and reducing the use of mineral fertilizers. Analysis of the long term D+NPK trial revealed lower soil bulk density, higher level of soil aggregation and soil organic carbon content, good soil moisture retention capacity and lower susceptibility to water erosion, when there is complimentary utilization of organic (farmyard manure) and mineral fertilizers (NPK). Furthermore, the complimentary use of organic and inorganic fertilizer, over a long term display a near neutral pH, low electrical conductivity and relatively high non-hydrolysable carbon in the soil; thereby, improving the quality of such soils. This study also shows that the application of farmyard manure with or without NPK as soil amendment improves the soil structure by increasing the proportion of macro aggregate fraction and soil organic concentration.

For sustainable production in savanna Alfisols, there is a need to design policies that will promote soil aggregate stability and long term carbon sequestration under continuous cultivation. Such policies must give attention to soil management practices that not only maintain higher level of soil organic carbon concentration but also take into consideration other soil quality indicators such as infiltration rates, moisture retention capacity, soil pH and electrical conductivity, soil structure, texture and bulk density.

REFERENCES

Agbenin J. O. & Goladi J. T. (1997). Long-term soil fertility trend in the savanna as influenced by farm yard manure and inorganic fertilizer. Proceeding soil fertility management. 21-29.

Agboola A. A. & Odeyemi O. (1972). The effects of land use on soil nutrient status in the forest zone of western Nigeria. Niger. Agric. J. 9(2):161–169.

Anderson D. W. & Paul E. A. (1984).Organomineral complexes and their study by radiocarbon dating. Soil Sci. Soc. Am. J. 48:298-301.

Bache B. W. & Heathcote (1969). Long-term effects of fertilizers and manure on soil and leaves of cotton in Nigeria. Exp. Agric. 5:241-247

Bationo A., Williams T. O. & Mokwunye A. U. (1997). Soil fertility management for sustainable agricultural production in semi-arid West Africa. P 349-367.

Blake G. R. & Hartge K. K. (1986). Bulk density. In Klute A. (Ed), Methods of soil analysis, Part 1 . Agronomy Monographs No. 9, 2nd edition, American Society of Agronomy and Soil Science. Madison, WI.

Bremner J. M. (1982). Inorganic nitrogen. In: Page A. L., Miller R. H. & Keeney D. R. (eds) Methods of Soil Analysis. Part II, 2nd ed. American Society of Agronomy. Madison 595–624 pp.

Christensen B. T. (1992). Physical fractionation of soil and organic matter in primary particle size and density separates. Adv. Soil Sci. 20:2–90.

Ekwue E. J. (1990). Organic matter effects on soil strength properties. Soil Till. Res. 16:289-297.

El-Swaify S. A., Singh S. & Pathak P. (1987). Physical conservation constraints and management components for semi-arid tropics (SAT) Alfisols. In: Alfisols in the semi and tropics. Proceedings of consultants' Workshop on the state of art and management alternative s for optimizing the productivity of SAT Aifisols and relate soils. ICRISAT centre, Patancheru, India.

Farage P., Pretty J. & Ball A. (2003). Biophysical aspects of carbon sequestration in drylands. Seminar paper presented at University of Essex, UK.; pp.1-24.

Franzluebbers A. J., Wright S. F. & Stuedemann J. A. (2000). Soil aggregation and glomalin under pastures in the southern Piedment USA. Soil Sci. Soc. Am. J. 64:1018-1026.

Gee G. W. & Bauder J. W. (1986). Particle size analysis. In: A Klute (ed). Methods of soil analysis 2nd. No.9 ASA Inc. SSSA Inc. Madison, Washington D.C. pp 383–409.

Goladi J. D. & Agbenin J. O. (1997). The cation exchange properties and microbial carbon, nitrogen and phosphorus in savanna Alfisol under continuous cultivation. J. Sci. Food Agric. 75:412-418.

Jones M. J. & Wild A. (1975). Soil of the West African savanna; technical communication of the Common Wealth Bureau of soils No. 55; Common Wealth Agricultural Bureau; Harpenden. UK.

Lawal H. M. (2010). Relationship between aggregate stability and organic carbon pools: Carbon sequestration. Lambert Academic Publishing. ISBN: 978-3-8443-0048-2. 126PP.

Lawal H. M. (2012). Soil aggregation and organic carbon sequestration under three land use types. Niger. J. Soil Environ. Res. 10:1-7.

Lawal H. M., Ogunwole J. O. & Uyovbisere E. O. (2012). Reciprocal relationships between aggregate stability and organic carbon characteristics in a forested ecosystem of northern Nigeria. Trop. Subtrop. Agroecosyst. 15:481-488.

Macrea R. J. & Mehuys G. R. (1985). Effects of green manuring on soil physical properties of temperate area soils. In: Stewart, B.A. (ed) Advances in soil science. Springer-verlag. New York. Vol. 3. P 71-94

Nelson D. W. & Sommers L. E. (1982). Total carbon, organic carbon and organic matter P. 539-577.
Odunze A. C. (2003). Effect of forage legume incorporation on selected soil chemical properties in the northern Guinea savanna of Nigeria. J. Sustain. Agric. 22(1):101-112.
Ogunwole J. O., Babalola O. A., Oyinlola E. Y. & Raji B. A. (2001). A pedological characterization of soils in the Samaru area of Nigeria. Samaru J. Agric. Res. 17:71-77.
Ogunwole J. O. & Ogunleye P. O. (2004.) Surface soil aggregation, trace and heavy metal encichment long-term application in soil science and plant analysis. Vil. 35, Nos.1 and 12. Pp. 1505-1516.
Ogunwole, J. O. (2008). Soil aggregate characteristics and organic carbon concentration after 45 annual applications of manure and inorganic fertilizer. Biol. Agric. & Horticult. 25(3):223-233.
Ohu J. O., Raghavan G. S. V., McKyes E. & Mehuys G. (1985) The shear strength of compacted soils with varying organic matter content. Am. Soc. Agric. Eng. 85:139-141.
Paul E. A. Collins H. P. & Leavitt S. W. (2001). Dynamics of resistant soil carbon of Mid-western agricultural soils measured by naturally occurring C abundance. Geoderma 104:239-256.
Rhoades J. D. (1982). In: Page A. K, Miller R. H. & Kenny D. R. (eds). Methods of soil analysis, part 2. Chemical and mineralogical properties second edition. Agronomy No. 9, 1159pp.
SAS institute (1989). Statistical analysis system (SAS) users guide inst Cary. N.C.
Snedecor G. W. & Cochran W. G. (1967). Statistical Methods. The Iowa State University Press, Ames. U.S.A. p.507.
Sommerfeldt T. G. & Chang C. (1986). Soil water properties as affected by twelve annual applications of cattle feedlot manure. Soil Sci. Soc. Am. J. 51:7-9.
Steel R. G. & Torrie J. W. (1984). Priinciples and procedure of statistics: A biometrical approach. 2nd Ed. MacGraw-Hill Inter. Book Auckland. pp. 633.
Tisdall J. M. & Oades J. M. (1982). Organic matter and water stable aggregates. J. Soil Sci. 33:141-163.
Tan Z. X., Lal R., Izaurralde C. & Post W. M. (2004). Biochemically protected soil organic carbon at the North Applalachian experimental watershed. Soil Sci. 169(6):1-10.
Unger, P.W. (1997). Aggregate and organic carbon concentration inter-relationships of a torrerttic paleustoll. Soil Till. Res. 42:95-13.
Whalen J. K. & Chang A. (2002). Macroaggregate characteristics in cultivated soils after 25 annual manure applications. Soil Sci. Soc. Am. J. 66:1637-1647.