AGGREGATE STABILITY IN RELATION TO HYDROLYSABLE ORGANIC CARBON IN A HUMID TROPICAL SOIL UNDER MANURE-FERTILIZER AMENDMENTS

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ABSTRACT

Manure and fertilizer applications influence soil aggregate stability and soil organic carbon (SOC). This study aims to assess the effect of poultry manure (PM) and inorganic fertilizers (IFs) on SOC fractions, aggregate stability, and their interrelationships in southwestern Nigeria. The impact of PM (0, 5, 10 t/ha) and IFs (0, 50, 100, 150% of 400 kg/ha NPK 20:10:10 plus 150 kg/ha Urea) on soil aggregate stability and SOC fractions was evaluated for three years. Soil samples were collected at maize maturity. Results showed that Fertilizer treatments did not affect the mean weight diameter (MWD), potential structural enhancement index (PSEI), dispersion ratio (DR), aggregated silt plus clay (ASC), or aggregate density (AD). However, PM reduced the clay dispersion index (CDI). Combining PM and IFs increased bulk soil SOC (SOCb) and non-hydrolysable carbon (NHC), but hydrolysable SOC (HOC) remained unchanged compared to the control. NHC positively correlated with AD and CDI, while HOCnegatively correlated with AD (r = -61 – 79) and DR (r = –0.71), but positively with ASC (0.68). PM and IFs did not improve macro aggregate stability but did enhance CDI. Increased NHC could impair soil structure, whereas increased HOC might improve colloidal stability. To better soil aggregate stability, using organic materials with low NHC and high degradability is recommended.

Keywords: *Poultry manure, inorganic fertilizers, colloidal stability*

INTRODUCTION

Soil organic carbon (SOC) plays a crucial role in sequestering atmospheric CO2, enhancing food security, and promoting sustainable soil management (Zhang et al., 2012; Sandeep *et al*., 2016). SOC contributes to soil aggregate stability, which in turn affects soil hydraulic properties, erodibility, and carbon sequestration (Shi *et al*., 2017; Toosi *et al*., 2017; Zhang *et al.*, 2014; Lal, 2001; Schmidt *et al.*, 2011; Berhe and Kleber, 2014).

Declines in SOC and aggregate stability have been linked to inherent soil fertility, poor agronomic practices, and continuous cultivation. Fertilization is a common method to boost soil organic matter (SOM) and fertility in intensive agro-ecosystems (Majumder *et al.,* 2007; Zhang *et al.,* 2014). Poultry manure (PM) can improve soil physical properties by enhancing SOC and aggregation (Atakora *et al*., 2014; Farhard *et al.,* 2011; Deksissa *et al*., 2008; Plaza-Bonilla *et al*., 2013; Adeyemo *et al*., 2019). However, due to its bulkiness, inorganic fertilizers are often used alongside PM (Vanlauwe *et al*., 2010). Research has shown that inorganic fertilizers can lead to increased soil dispersion, aggregate breakdown, and declines in soil pH and biological functions (Guo *et al*., 2019). Consequently, combining fertilizer sources can leverage the benefits of both.

Studies have indicated that PM, alone or combined with inorganic fertilizers, can improve mean weight diameter (MWD) (Udom *et al*., 2018; Sadiq, 2018; Selvi *et al*., 2005; Karami *et al*., 2012), aggregate density (Watts and Dexter, 1997; Munkholm and Kay, 2002), and micro-aggregate stability as measured by clay dispersion index (CDI), dispersion ratio (DR), and aggregated silt and clay (ASC) (Mba and Idike, 2009; Nweke *et al*., 2013; Ogunwole *et al*., 2010). Lower CDI and DR, and higher ASC indicate improved micro-aggregate stability.

Contrarily, some studies have reported that artificial fertilizers can increase SOC (Álvaro-Fuentes *et al*., 2012; Halvorson *et al*., 1999). Plaza-Bonilla *et al*. (2013) found that organic or mineral fertilizers might not always improve macro-aggregate stability in the short term, while Macheldo and Rodrigues (2015) noted potential soil structure damage from manure, depending on type and dosage.

This study hypothesizes that combining PM with inorganic fertilizers will enhance aggregate stability (AS) and SOC content in Ikole, southern Nigeria. Recent research has shifted focus from bulk SOC (SOCb) to soil organic carbon fractions (SOCFs), recognizing their varied roles based on composition, residence time, and stabilization mechanisms. SOC can be divided into hydrolysable (HOC) and non-hydrolysable carbon (NHC) fractions through acid hydrolysis. HOC includes labile and slow pools that are more responsive to management practices, while NHC is more stable and recalcitrant (Helfrich *et al*., 2007; Belay-Tedla *et al*., 2009; Bell and Lawrence, 2009).

Few studies have explored the effects of fertilization on both passive and active SOC fractions (Duval *et al*., 2013; Sahoo *et al*., 2019). Therefore, this study aims to evaluate how PM and inorganic fertilizers affect SOC fractions and aggregate stability in sandy-loam Alfisols of southwest Nigeria.

Materials and Methods

Study Location

The research was conducted at Ikole in the rainforest agro-ecological zone of Southwestern Nigeria, located at latitude 7°48' N, longitude 5°31' E, and an elevation of 571 meters above sea level (masl). The area experiences an average annual rainfall of 1600 mm and a mean temperature of 25°C, with an average relative humidity of 80%. The soils are Alfisols derived from granitic Precambrian basement complex (Bolarinwa *et al*., 2017). The site had been cultivated for fifteen years prior to this study, with common crops including maize, yam, cocoyam, and vegetables.

Experimental Design and Treatment

The study spanned three years (2013-2015) and employed a randomized complete block design (RCBD), replicated four times with twelve fertilizer treatments. The treatments were combinations of three rates of poultry manure (0, 5, and 10 t ha^{-1}; PM0, PM5, and PM10) with four rates of inorganic fertilizer (0, 50, 100, and 150% of the recommended dose; IF0, IF50, IF100, and IF150). The recommended dose for hybrid maize is 400 kg ha^{-1} NPK 20-10-10 (providing 80 kg N, 40 kg P_2O_5, and 40 kg K_2O ha^{-1}) plus 150 kg ha^{-1} Urea (providing 69 kg N ha^{-1}). Poultry manure, sourced from deep litter poultry houses, was analyzed for N, P, K, Ca, Mg, Na, and organic C, as shown in Table 2.

Field Work, Soil Sampling, and Laboratory Analysis

The experimental area was cleared and divided into plots measuring 1.5 m x 3.6 m, separated by 1 m buffer strips, totaling 30 m x 18.4 m. Poultry manure was applied in 2013 and 2014, one week before planting. Hybrid maize seeds (Zea mays L. var. M9211 Yellow) from Manoma Seed Company, Abuja, Nigeria, were sown on September 2, 2013, May 23, 2014, and June 3, 2015, at two seeds per hole, with a 60 cm inter-row spacing and 25 cm plant-to-plant distance. Inorganic fertilizers were applied in three splits: 400 kg ha^{-1} NPK 20:10:10 at 0, 50, 100, and 150% of the recommended rate was applied one week after planting; 150 kg ha^{-1} Urea at 0, 50, 100, and 150% was applied in two equal splits at four weeks after planting and at tasseling. Fertilizer was placed 5-8 cm away from each plant and 2-3 cm below the soil surface. In 2015, only residual effects of previous treatments were assessed, with no re-application.

Thinning was performed two weeks after sowing, leaving one seedling per stand (36 plants per plot, equivalent to 66,666 plants per hectare). Weeding was carried out four and seven weeks after sowing by hand pulling and hoeing.

Soil samples were collected before bed preparation from 20 random points at a 0-20 cm depth, mixed to form a composite sample, air-dried, and sieved through a 2 mm mesh. Samples were analyzed for available phosphorus, exchangeable calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), soil organic carbon (SOC), total nitrogen, pH, and particle size distribution. Bulk density was determined using ten core samples. At maize maturity each season, soil samples were collected from the net plot at three points in a zig-zag pattern, mixed, air-dried, and sieved through 8 mm, 4.75 mm, and 2 mm meshes for various analyses.

Soil Analysis

Particle size distribution was measured using the hydrometer method (Kalra and Maynard, 1982). Bulk density was determined using the core method. Soil pH was measured in a 0.10 N potassium chloride solution at a 1:2.5 soil-to-water ratio. Soil organic carbon was determined by the Walkley-Black method as modified by Nelson and Sommers (1982). Total nitrogen was analyzed using the micro Kjeldahl digestion-distillation method.

Available phosphorus was assessed using the Mehlich-3 extractant method. Exchangeable bases (K^+, Ca^{2+}, Mg^{2+}, Na^+) were extracted with ammonium acetate (NH_4OAc) solution, and their concentrations were measured with a flame photometer and atomic absorption spectrophotometer.

Determination of SOC and SOC Fractions

Soil Organic Carbon was quantified by the Walkley and Black method as modified by Nelson and Sommers (1982). SOC was fractionated into hydrolysable (HOC) and non-hydrolysable carbon (NHC) using the method of Silveira *et al*. (2008). Two grams of soil (< 2.00 mm) were treated with 6 M HCl, heated at 105°C for 3 hours, washed, centrifuged, dried, and analyzed for organic carbon to obtain NHC. HOC was calculated as the difference between total SOC and NHC (McLauchlan *et al*., 2004).

Bulk Density and Aggregate Density

Bulk density was measured using the core method. Aggregate density (AD) was assessed using the clod method (Grossman and Reinsch, 2002). Aggregates (5-8 mm) were weighed (Ma), coated with wax, weighed again (Ma+w), immersed in distilled water at 20°C, and reweighed (Ma1). The density (ρ) was calculated as:

$$AD = \frac{Ma}{\left(\frac{\mathrm{Ma}}{\mathrm{Pw}}\right) - \frac{(Ma - Ma + w)f}{Ps}}$$

Where Pw is density of water at 20 ^{0}C and Ps is density of wax coating (0.93 Mg m$^{-3.}$).

The value of f was taken as 0.3 for 5 to 8mm aggregates (Munkholm and Kay, 2002).

Assessment of Macro-Aggregate Stability

Macro-aggregate stability was assessed using the wet sieving technique (Kemper and Rosenau, 1986). Aggregates (> 4.75 mm) were pre-soaked in water, sieved through a series of sieves (2 mm, 1 mm, 0.25 mm, < 0.25 mm), and oscillated vertically. Aggregate mass on each sieve was oven-dried at 105°C for 24 hours. The mean weight diameter (MWD) was calculated as:

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

Where, xi is mean diameter of aggregates within a specific size range and wi is the weight of aggregates in that size range as a fraction of the total dry weight of the analyzed sample.

The Potential Structural Enhancement Index (PSEI) was computed as:

Assessment of Particle Size Distribution and Micro-Aggregate Stability

The PSEI is used to measure the effect of the treatments on aggregate stability (Mbagwu and Bazzoffi 1989), and was computed as follows:

$$PSEI = 1 - \left(\frac{MWDc}{MWDt}\right) x\,100 \qquad 3$$

Where MWDc is mean weight diameter for control and MWDt is mean weight diameter of treated soil.

Particle size distribution of fine earth (< 2 mm) was measured using the hydrometer method (Kalra and Maynard, 1991). Micro-aggregate stability indices were determined using similar procedures with water instead of calgon. Indices were calculated as follows:

DR = % clay + % silt (water) /% clay + % silt (calgon) x 100 4

CDI = % clay (water) / % clay (calgon) 5

ASC = % clay + % silt (calgon) - % clay + % silt (water)

CR = %Sand+% silt/ % clay.

DR, Dispersion Ratio, CDI, Clay Dispersion Index and ASC, Aggregated Silt plus Clay

Statistical Analysis

Data were analyzed using GENSTAT Release 7.2 DE software. Treatment means were separated using Fisher's least significant difference at a 5% probability level. Simple linear correlations between soil organic carbon fractions and aggregate stability indices were computed using Spearman's correlation coefficient (Rs).

RESULTS AND DISCUSSION

Initial Soil Properties

The initial soil properties at Ikole are presented in Table 1. The texture was sandy loam and the bulk density value was below the critical limit required for root growth (Morris and Lowery 1988). The soil pH (6.8) was slightly acidic. Soil chemical properties were above the critical value required for maize production except for nitrogen. (FMANR, 1990).

Table 1: Initial soil properties in experimental location

Parameter	Unit	Ikole
Soil organic C	g/kg	13.99
Total N	%	0.14
Mehlich-3 Available P	mg/kg	22.22
Exchangeable. K	cmol/kg	0.50
Exchangeable.Ca	cmol/kg	4.29
Exchangeable Mg	cmol/kg	0.84
Exchangeable Na	cmol/kg	0.16
Ph	,	6.80
Bulk density	Mg/m^3	1.54
Sand	%	67.00
Silt	%	16.00
Clay	%	17.00
Texture		SL

Table 2 Selected chemical properties of poultry manure

	2013	2014
Parameter	Ikole	Ikole
% Organic carbon	36.77	38.33
% Nitrogen, N	2.08	2.21
% Phosphorus, P	0.73	0.82
% Potassium,K	1.39	1.40
% Calacium, Ca	1.47	1.42
% Magnesium, Mg	0.50	0.53
% Sodium, Na	0.15	0.16
pH	7.50	7.40

The Effect of Poultry Manure and Inorganic Fertilizers on Soil Properties

Mean weight diameter, potential structural enhancement index, and aggregate density

The effects of poultry manure (PM) and inorganic fertilizers (IF) on soil properties, including mean weight diameter (MWD), potential structural enhancement index (PSEI), and aggregate density (AD), are shown in Table 3. Over three years (2013-2015), MWD varied significantly among treatments, but all fertilizers were statistically similar to or worse than the control. Consequently, PSEI values were negative, indicating that these amendments did not enhance soil structural stability. No significant changes in AD were observed. The study did not determine why macro aggregation decreased. Previous research suggests that changes in soil solution chemistry due to amendments may cause clay dispersion (Macheldo and Rodrigues, 2015). SOM can either enhance or reduce aggregation (Mbagwu and Bazzoffi, 1998), and short-term use of organic or mineral N fertilizers often does not improve macro-aggregate stability (Plaza-Bonilla *et al.*, 2013).

Table 3: Effect of poultry manure and inorganic fertilizers on mean weight diameter, potential structural enhancement index and aggregate density

Year	2013			2014			2015		
Parameter	MWD	PSEI	AD	MWD	PSEI	AD	MWD	PSEI	AD
Treatment	Mm		$Mgm^{-3.}$	Mm		$Mgm^{-3.}$	mm		$mgm^{-3.}$
$PM_0 + IF_0$	2.18	0.00	1.32	1.22	0.00	1.44	0.82	0.00	1.52
$PM_5 + IF_0$	1.94	-0.12	1.35	1.04	-0.18	1.32	0.68	-0.32	1.47
$PM_{10} + IF_0$	2.12	-0.02	1.37	0.88	-0.38	1.36	0.71	-0.17	1.58
$PM_0 + IF_{50}$	1.84	-0.1	1.43	1.01	-0.22	1.58	0.71	-0.16	1.61
$PM_5 + IF_{50}$	1.98	-0.1	1.45	0.99	-0.24	1.38	0.59	-0.37	1.49
$PM_{10} + IF_{10}$	1.89	-0.17	1.48	0.83	-0.32	1.35	0.69	-0.19	1.42
$PM_0 + IF_{100}$	2.01	-0.08	1.46	1.07	-0.15	1.59	0.71	-0.15	1.64
$PM_5 + IF_{100}$	1.98	-0.1	1.50	0.94	-0.5	1.45	0.64	-0.38	1.48
$PM_{10} + IF_{100}$	2.09	-0.04	1.45	1.11	0.1	1.57	0.64	-0.28	1.43
$PM_0 + IF_{150}$	1.83	-0.19	1.43	1.28	0.05	1.48	0.73	-0.13	1.55
$PM_5 + IF_{150}$	1.94	-0.15	1.38	1.24	0.01	1.42	0.79	-0.03	1.48
$PM_{10} + IF_{150}$	1.91	-0.14	1.42	1.25	0.02	1.43	0.81	-0.01	1.53
LSD (0.05)	0.37		NS	0.16		NS	0.11		NS

MWD, Mean weight diameter, AS, Aggregate stability, AD, Aggregate density.

PM0, PM5, PM10 is poultry manure at 0, 5, 10 t ha-1, respectively; IF0, IF50, IF100, IF150 is inorganic fertilizer at 0%, 50% 100% and 150% recommended fertilizer dose, respectively, being 400 kg ha-1 NPK-20:10:10 plus 150 kg ha-1 Urea

Clay dispersion index, Dispersion ratio and Aggregated silt plus clay

Table 4 presents the effects of fertilizer treatments on the clay dispersion index (CDI), dispersion ratio (DR), and aggregated silt plus clay (ASC) over three years. Significant CDI variations were observed among treatments each year. In 2013, all treatments with poultry manure (PM) alone or combined with inorganic fertilizer (IF) reduced CDI compared to the control (37.7%). In 2014, reductions were notable only in treatments PM10 + IF0 (40.3%) and PM5 + IF100 (40.6%). By 2015, CDI reduction was observed in treatments PM5 + IF50 (44.3%) and PM10 + IF100 (44.6%). The decrease in CDI is attributed to the soil organic matter's aggregating effect from PM. However, CDI increased each year (2015 > 2014 > 2013), suggesting that continuous cultivation may enhance clay dispersion, leading to soil erosion and degradation.

Conversely, in 2013 and 2014, fertilizer treatments had no significant impact on DR and ASC. This implies that CDI may be a better index than DR and ASC for predicting soil micro-aggregate stability in this context. Igwe and Obalum (2013) found that colloidal stability indices vary in their effectiveness for predicting micro-aggregate stability, supporting our findings. Macheldo and Rodrigues (2015) noted that certain organic fertilizers could affect soil structure and chemistry, potentially increasing DR. In 2015, while DR and ASC showed significant effects among treatments, only high doses of IF led to a notable increase in DR compared to the control (59%). Increased soil acidity from IF may cause silt and clay dispersion, contributing to soil sealing, impaired water infiltration, and erosion.

Table 4: Effect of poultry manure and inorganic fertilizers on Clay dispersion index, Dispersion ratio and Aggregated silt plus clay

Year	2013			2014			2015		
Parameter	CDI	DR	ASC	CDI	DR	ASC	CDI	DR	ASC
Fertilizer Trt	%	%	g/kg	%	%	g/kg	%	%	g/kg
$PM_0 + IF_0$	37.7	43.7	185	44.7	54.8	145	47.7	59.6	129.1
$PM_5 + IF_0$	34.5	41.6	195	42.2	53.6	149	47.2	55.5	141.6
$PM_{10} + IF_0$	34.5	41.2	198	40.3	52.2	159	47.9	58.1	136.6
$PM_0 + IF_{50}$	34.5	42.4	188	44.1	53.9	151	47.3	63.4	117.3
$PM_5 + IF_{50}$	34.5	40.0	200	42.2	54.2	149	44.4	57.6	139.1
$PM_{10} + IF_{10}$	35.6	40.9	200	42	53.0	160	45.3	58.7	137.0
$PM_0 + IF_{100}$	37.7	43.7	185	46.5	54.1	144	48.3	64.4	111.6
$PM_5 + IF_{100}$	34.5	44.6	190	40.6	53.6	154	45.7	60.9	136.6
$PM_{10} + IF_{100}$	34.7	42.4	195	42.8	54.2	152	44.6	58.2	134.1
$PM_0 + IF_{150}$	36.8	43.9	185	46.3	56.0	141	48.3	66	109.1
$PM_5 + IF_{150}$	34.5	40.7	195	43.7	53.6	159	48.3	62.4	121.6
$PM_{10} + IF_{150}$	34.5	40.0	200	43.6	53.1	157.	48.1	62.2	122.1
LSD (0.05)	1.8	NS	NS	3.6	NS	NS	2.81	4.75	19.2

CDI, Clay dispersion index, DR, Dispersion ratio, ASC, Aggregated silt plus clay

PM0, PM5, PM10 is poultry manure at 0, 5, 10 t ha-1, respectively; IF0, IF50, IF100, IF150 is inorganic fertilizer at 0%, 50% 100% and 150% recommended fertilizer dose, respectively, being 400 kg ha-1 NPK-20:10:10 plus 150 kg ha-1 Urea

Soil organic carbon in bulk soil, non-hydrolysable soil organic carbon and hydrolysable soil organic carbon

Figure 1 shows the impact of fertilizer treatments on soil organic carbon in bulk soil (SOCb). In 2013, significant increases in SOCb were observed only in the treatments PM5 + IF0 (5 t/ha PM plus 0% IF) and PM5 + IF100 (5 t/ha PM plus 100% IF) compared to the control. By 2014, all fertilizer treatments increased SOCb, with the highest increase in PM10 + IF50 (10 t/ha PM plus 50% IF). This increase is likely due to the contribution of underground biomass, as noted by Álvaro-Fuentes *et al*. (2012) and Quansah (2010), who reported similar positive effects from combining poultry manure with inorganic fertilizers.

In 2015, SOCb ranged from 9.62 g/kg (PM0 + IF0) to 12.75 g/kg (PM10 + IF100). All treatments significantly increased SOC compared to the control, except the sole applications of IF (PM0 + IF50 and PM0 + IF100) and PM at 10 t/ha (PM10 + IF0). The highest SOCb was observed in PM10 + IF100, similar to PM10 + IF50, suggesting no additional benefit from higher IF levels with 10 t/ha PM. The decrease in residual SOCb in 2015 compared to previous years indicates that continuous organic fertilizer application is necessary to replenish nutrients removed by crops and sustain soil productivity (Kidinda *et al*., 2015).

Figure 2 illustrates the effect on non-hydrolysable carbon (NHC). All fertilizer treatments significantly increased NHC compared to the control. The highest NHC in 2013 was in PM0 + IF150 (0 t/ha PM plus 150% IF, 9.74 g/kg), while in 2014, it was in PM10 + IF50 (9.63 g/kg). Residual NHC was best in PM0 + IF150 (7.5 g/kg), higher than other treatments but similar to PM0 + IF100. This suggests that higher rates of inorganic fertilizer might lead to higher NHC.

In contrast, the effects on hydrolysable organic carbon (HOC) were mixed (Figure 3). In 2013 and 2014, plots with 10 t/ha PM alone or in combination with IF (except PM10 + IF50 in 2014) showed significant declines in HOC compared to controls (7.38 and 6.06 g/kg). Lower PM rates (5 t/ha) did not decrease HOC except with high IF doses (PM5 + IF150). This decline might be due to the breakdown of aggregates caused by higher PM rates (Macheldo and Rodrigues, 2015), which can accelerate mineralization and loss of HOC. Sole IF applications also significantly reduced HOC in 2013 and 2014, likely due to increased acidity and mineralization of SOC.

In 2015, no improvement in HOC was observed with PM treatments, and a sharp decline was seen with sole IF applications compared to the control (5.2 g/kg). This suggests that PM is crucial for maintaining HOC, while sole IF applications are less effective. Further research is needed to better understand these responses, especially in sandy loam soils with limited previous studies.

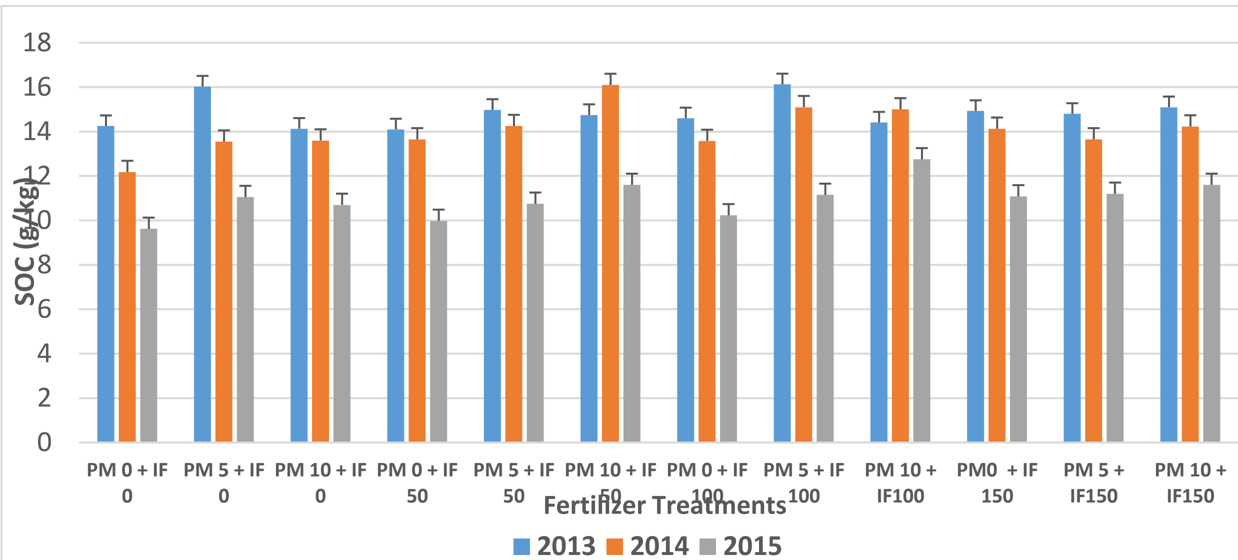

Figure 1: Effect of poultry manure and inorganic fertilizers on soil organic carbon in bulk soil

PM0, PM5, PM10 is poultry manure at 0, 5, 10 t ha-1, respectively; IF0, IF50, IF100, IF150 is inorganic fertilizer at 0%, 50% 100% and 150% recommended fertilizer dose, respectively, being 400 kg ha-1 NPK-20:10:10 plus 150 kg ha-1 Urea

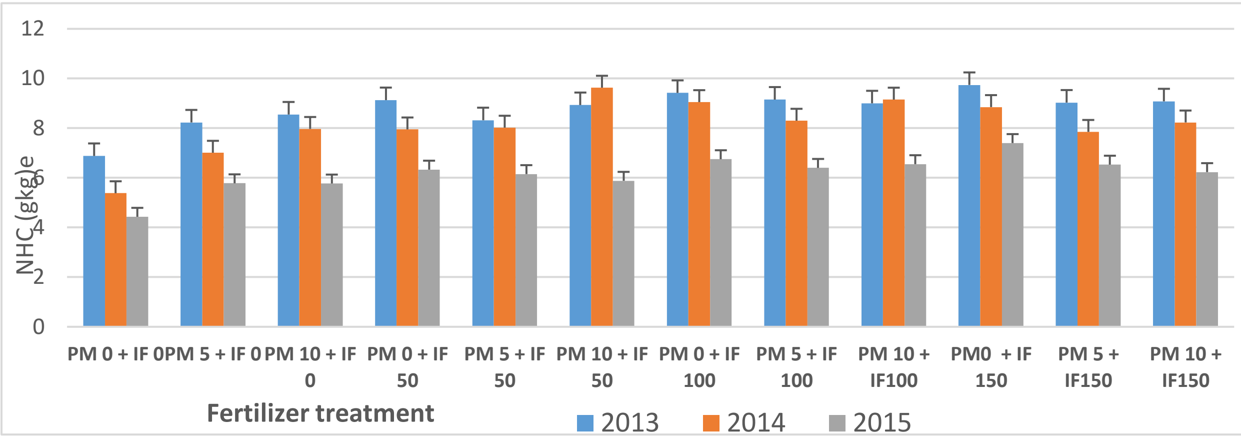

Figure 2: Effect of poultry manure and inorganic fertilizers on non-hydrolysable soil organic carbon

See details in Fig.1

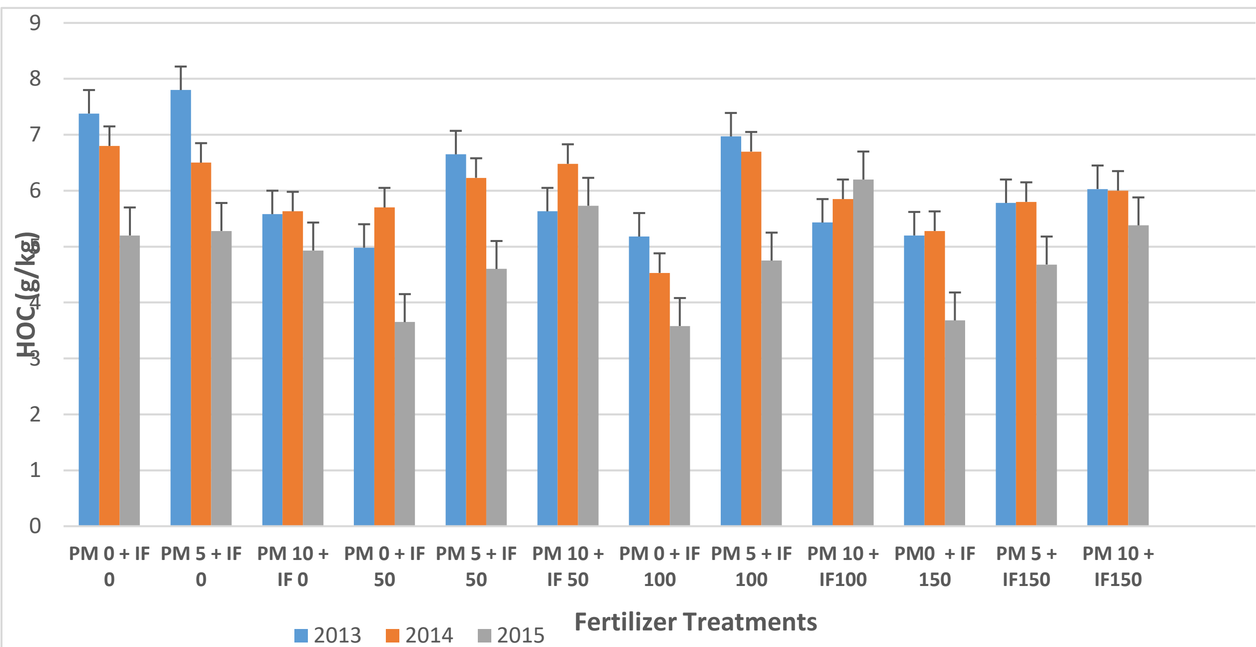

Figure 3: Effect of poultry manure and inorganic fertilizers on hydrolysable soil organic carbon

See details in Fig.1

Correlation of aggregate stability indices with soil organic carbon fractions

The study assessed the correlation between soil organic carbon fractions (SOCFs) and soil properties at Ikole over three cropping years, as detailed in Table 5. HOC and NHC showed no significant correlation with mean weight diameter (MWD) or potential structural enhancement index (PSEI) throughout the years, indicating that manure-fertilizer management had no notable effect on macro-aggregate stability. In 2013, NHC was positively correlated with aggregate density (AD), suggesting reduced porosity and limited root growth. Conversely, HOC exhibited a significant negative correlation with AD in 2014, a trend that strengthened in 2015 when amendments were withdrawn, indicating that increased HOC improved AD, thereby enhancing aggregate porosity and soil hydraulic properties.

There were no significant correlations between SOCFs and micro-aggregate stability indices in 2013 and 2014, confirming limited effects on dispersion ratio (DR) and aggregated silt plus clay (ASC). However, in 2015, NHC was positively correlated with clay dispersion index (CDI) (r = 0.62), indicating increased clay dispersion. HOC showed a negative correlation with DR (r = 0.71) and a positive one with ASC (r = 0.68), suggesting improved micro-aggregate stability when amendments were withdrawn. This supports Mbagwu *et al*. (1989), who noted that manure can influence aggregate stability both positively and negatively.

CONCLUSION

The study found that neither macro-aggregate stability indices nor micro-aggregate stability indices showed improvement with manure and inorganic fertilizer applications compared to unfertilized plots, except for the clay dispersion index (CDI), which improved with poultry manure. Therefore, CDI is the only reliable indicator for predicting micro-aggregate stability under these treatments.

Non hydrolysable carbon (NHC) increased significantly with both sole and combined fertilizer applications, with the highest increase in sole inorganic fertilizer plots. Conversely, hydrolysable organic carbon (HOC) showed minimal or negative effects relative to the control.

There was no significant correlation between SOCFs and macro-aggregate stability indices over the three years, or with micro-aggregate indices in 2013 and 2014. However, in 2015, NHC correlated positively with CDI and aggregate density (AD), suggesting potential soil structure impairment. HOC correlated negatively with dispersion ratio (DR) and positively with aggregated silt plus clay (ASC), indicating improved colloidal stability. To enhance aggregate stability, it is recommended to reduce inorganic fertilizer rates and use easily degradable organic materials with lower NHC.

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