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Influence of soil amendment with poultry droppings on the soil properties and productivity of cumbers (*Cucumis sativus L.*) on a degraded Ultisol in Nsukka Area, Southeast Nigeria

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ABSTRACT

Poultry manure (PM) input is globally utilized for enhancing and maintaining soil fertility in vegetable farming. In many tropical regions, however, 'site' specific PM rate for optimum crop yield is lacking. A three-year continuous cucumber cultivation with 0, 10, 20 and 30 t/ha PM rates in three replicates, were arranged in RCBD on an Ultisol. Soil physicochemical properties and cucumber yield responses to PM input rates were evaluated. The study soil was strongly acid and low in OC, N and exchangeable cations concentrations. The 20 and 30 t/ha PM input improved macro-aggregate stability by 91 and 99 %, respectively, and accordingly, increased the aggregates mean weight diameter. Poultry manure rates showed a lacking effect on cucumber length and girth, but the 20 and 30 t/ha PM rates significantly increased the number and weight of cucumber fruits in the first and third cropping years. Accordingly, the rates produced 10.53 t/ha cucumber fruits, corresponding to a three-fold yield increase. The overall soil chemical response to PM rates was a function of the PM quality. While improved P retention with 20 and 30 t/ha PM rates cut across the three cropping years, a significant increase in soil pH, Ca and K status was also evident with these rates in the third year. Also, the soil pH, C/N, P, Ca and K correlated positively to the number and weight of cucumber fruits. Based on 'agronomic' influence and convenience, 20 t/ha PM rate is therefore recommended for maintaining optimum cucumber yield in Ultisols.

1.0. Introduction

Cucumber (*Cucumis sativus* L.) is one of the most important members of the Cucubitaceae family (Eifediyi and Remison, 2009) that have been cultivated for over many thousands of years. Though cucumber can naturally thrive in both temperate and tropical environments, its production in tropical Africa has not been ranked (FAOSTAT, 2019). Howbeit, cucumber production in Nigeria has increased recently, probably due to awareness being created by its market demand and economic returns, short duration in maturity or due to its nutritional and medicinal values (Okoli and Nweke, 2015). Cucumber is a high nutrient demanding crop that performs poorly on nutrient-deficient soils and consequently, leads to low yields, bitter and misshapen fruits and reduced farmers' income (Grubben and Denton, 2004; Eifediyi and Remison, 2009).

Low cucumber yields have been attributed to declining soil fertility due to continuous cropping and disregard for soil amendment additions (Enujeke, 2013). The prevailing climatic factors as excessive precipitation and the high-temperature regime in Southeastern Nigerian also contribute to poor fertility status of the soil due to soil acidity, soil nutrient imbalance, and high rate of organic matter decomposition. In the face of declining soil productivity occasioned by climate change impacts, small-scale cucumber production may be enhanced with the application of organic manure. Organic fertilization is an essential component of soil fertility improvement strategy that often leads to increased crop yield. The use of organic manures has been recommended for long-term cropping in the tropics because their slow mineralization promotes crop yield for an extended period (Gambo et al., 2008).

Poultry manure (PM) is a source of plant nutrient that has been used since ancient times. The vital impact of PM on soil properties, as well as on crop productivity abound in the literature (Ewulo et al., 2008; Moyin-Jesu, 2015; Onyegbule and Asawalam, 2015; Olowokere and Odulate, 2019; Mangalassery et al., 2019). The effect of PM input on the growth and yield of cucumber has received much research attention, but most reports are based on only two-season experiments and are devoid of the effect of PM on soil properties (Eifediyi and Remison, 2010; Hamma et al., 2012; Ikeh et al., 2012; Enujeke, 2013; Okoli and Nweke, 2015). Due to possible changes in climatic variables, more than two seasons field trial may be necessary for proffering precise and reliable PM recommendation for farmers. Cucumber yield response to PM input is regionally variable given the vast heterogeneity in nutrient composition of the cultivated soil and the PM obtainable in a locality. So, while "site-specific" inorganic fertilizer recommendation has been strongly advocated (Soropa et al., 2019), same could be applied in proposing organic fertilizer recommendations, alongside specified per cent concentrations (ratios) of the significant primary nutrients (NPK) content of the organic input. Besides ascertaining and categorizing the grade of the organic input quickly, the NPK ratio may also be useful in assessing "organic input quality", an important measure to slide into obscurity. Moyin-Jesu (2015) attributed the improvement in soil fertility and cucumber yield to 'balanced nutrient composition' of PM. Okoli and Nweke (2015) however, never accounted for the PM nutrient composition nor the study soil characteristics (soil type, texture), making reproducibility of the experiment on cucumber yield difficult.

On the contrary, available PM recommendations are detailed in the following examples. For optimizing cucumber yields (fruit length, fruit diameter and fruit weight) within the rainforest agro-ecological zone of Nigeria, Ikeh et al. (2012) recommended 8t/ha PM (NPK 4.8:0.4:0.8) on sandy clay loam soil; Law-Ogbomo and Osaigbovo (2018) recommended 10t/ha PM (NPK 0.185:0.001:0.001) on sandy loam soil; and 6t/ha PM (NPK 4.3:0.04:9.7) performed excellently on sandy loam Alfisol (Moyin-Jesu, 2015). Enujeke (2013) recommended 20 t/ha PM (NPK 1.4:0.6:0.6) on sandy loam soil in the forest-savanna transition zone while 40 t/ha PM (0.0490:0.0001:0.0004) gave optimum yield response on sandy loam soil in the derived savanna zone (Agu et al., 2015). It does appear that the differences in PM nutrient composition contribute above and beyond soil type and agro-ecology, to the variations in PM recommendations.

Despite the increasing relevance of cucumber cultivation in the derived savanna agro-ecological zone, the area has limited information on PM recommended rate for optimizing cucumber yield. This has consequently raised scientific concern at the Faculty of Agriculture, University of Nigeria Nsukka (UNN) whose poultry farm produces large tonnes of PM from its deep litter management system. It thus becomes imperative to bridge the knowledge gap by evaluating the effect of PM on soil properties and cucumber yield in an Ultisol which dominates the University community and its environs. This would inform surrounding farmers of the optimum 'agronomic' rate for cucumber crop. It will also provide vital information on the soil fertility improvement trend of the PM input for maintaining and sustaining cucumber production in the area. The study aimed at investigating the changes in soil physicochemical properties, as well as cucumber yield response to varying PM rates in an Ultisol at Nsukka, Southeastern Nigeria.

2.0. Materials and Methods

2.1. Site description

The field experiments were conducted at the Department of Soil Science Teaching and Research Farm, University of Nigeria, Nsukka. The location falls within the Derived Savannah agro-ecological zone of Nigeria and on the latitude and longitude of 06^0 52´N and 07^0 24´E, respectively. The average elevation is about 436 m above sea level. The climate is humid tropical that is characterized by a bimodal rainfall pattern with peaks in July and September, and a short dry spell in August. The mean annual rainfall is about 1600 mm while the average minimum and maximum temperature are about 22 ^{0}C and 30 ^{0}C, respectively. The prevailing relative humidity of the location is rarely below 60 %. The soil originated from weathered Sandstone and has been classified as an Ultisol, with deep, permeable and well-drained characteristic structure (Nwadialo, 1989).

2.2. Treatment description

The poultry manure (PM) used for the experiment was gotten from the deep litter management system of the Poultry Unit of Department of Animal Science Teaching and Research Farm, University of Nigeria, Nsukka. The PM is made up of the beddings (sawdust), poultry feed droppings and the faeces of layers at laying stage (in 2015) or the faeces of broilers from a day old to about 12 weeks (in 2016 and 2017). After the sales of the broilers, the air-dried PM is usually bagged in 50 kg sacks and sold to farmers. Before application in the soil, the chemical properties of the PM, as presented in Table 1, were determined.

2.3. Field experimental setup and treatments

The experimental field was previously used for maize crop research and after that, was on two years bush fallow before the study establishment. In the year 2015, a land measuring 224.25m^2 was cleared, ploughed, harrowed and ridged by a tractor, and then the seedbeds (plots) were partitioned using a hand hoe. Twelve plots of 1.5 m x 3.75 m with 1 m spacing between blocks and plots were marked out, and four rates of PM (0, 10, 20, and 30 t/ha) laid out in a Randomized Complete Block Design (RCBD) with three replicates. The PM was evenly spread on the beds and incorporating within 0-20 cm soil depth using a hand hoe, two weeks before planting. The experiment was conducted on the same piece of land in 2015, 2016 and 2017 minor cropping seasons. Cucumber seeds (Ashley variety) gotten from the Department of Crop Science, UNN were sown two per hole at about 2.5cm depth and a spacing of 75 cm × 75 cm, given a population of twenty plants per bed. Weeding with hand hoe was done 3 weeks after planting while subsequent weed control was usually by hand-picking. Due to insufficient rainfall towards the fruiting stage, supplementary irrigation with 15 and 10 L of water on each bed was applied daily (usually in the evening) with the use of a watering can in 2015 and 2016, respectively. The watering continued until plant senescence.

2.4. Data collection

At physiological maturity (coinciding between 8 and 9 weeks after planting), the cucumber yield data collected from an area of 5.62 m^2 per bed were the fruit number, fruit length, fruit girth and fruit weight. The fruits were weighed using a sensitive weighing balance in grams and later estimated in tonnes per hectare. The fruit length and girth were measured with a flexible measuring tape in centimetres. The collective measurements determined per plot for each parameter were subjected to statistical analysis.

2.5. Soil sampling and preparations

Before planting, augered soil samples were collected per plot from five sampling points along a Z-plain at 0-20 cm depth. Soil samples from each plot were air-dried, sieved with 2 mm mesh and used for initial assessment of the soil's physico-chemical properties. After crop harvest, soil samples collected from each plot, along a Z-plain, were air-dried and divided into two portions. A portion sieved with 2 mm mesh was used for chemical analysis while the other portion sieved with 4.75 mm mesh was used for aggregate size separation. Additional core samples were also collected from each plot after the 2017 crop harvest and used for the determination of total porosity, bulk density and hydraulic conductivity. Both the soil and PM analysis was also carried out at the laboratory of the Department of Soil Science, University of Nigeria Nsukka.

2.6. Laboratory analyses

Particle size analysis was determined by the hydrometer method (Bowman et al., 2002). Hydraulic conductivity, bulk density and total porosity were determined using the core samples. The core samples were weighed after 24 h of complete saturation in water and then, placed on a tension table adjusted to 60 cm of tension for 24 h, after which they were reweighed and oven-dried until a constant weight was obtained. Saturated hydraulic conductivity (Ksat) was determined by the constant-head permeameter method (Klute and Dirksen, 1986), and calculated using Darcy's equation:

$$K_{sat} = \frac{Q}{At} \times \frac{L}{H}$$

Where Ksat = hydraulic conductivity (cm h^{-1}), Q = steady-state volume of flow (cm^3), L = length of core sample (cm), A = cross-sectional area (cm^2), t = change in time interval, and H = hydraulic head change (cm).

Bulk density measurement was obtained by the cylindrical core method as described by Blake and Hartge (1986), while total porosity was determined in undisturbed water-saturated core samples. The above parameters were calculated as follows:

Bulk density = mass of oven-dry soil (g) / volume of bulk soil (cm^3)

Total porosity = volume of H_2O in the soil at saturation (cm^3) / volume of bulk soil (cm3)

Aggregate size separation was performed on 25 g of 4.75 mm-sieved soil by wet sieving method (Cambardella and Elliot, 1994) using a series of four sieves (2 mm, 1 mm, 0.5 mm, 0.25 mm) to obtain five different water-stable aggregates (WSA) fractions as follows; > 2.00 mm, 1.00-2.00 mm, 0.50-1.00 mm, 0.25-0.50 mm, and < 0.25 mm. The aggregate fractions were carefully transferred into a container using a wash bottle and the oven-dry weight obtained after 24 h at a temperature of 105^{o}C. After that, all the WSA fractions were merged and dispersed in with 0.1N NaOH, and then washed through 0.50-mm sieve to obtain the mass of sand > 0.50 mm used for the computation of per cent aggregate stability (%AS). The mass of aggregates > 0.25 mm was calculated by subtracting the sum of the oven-dried weights of materials retained on each sieve from the air-dried weight of the original sample. The proportion of each aggregate class to the total sample weight was computed as the ratio of the weight of the oven-dry aggregates (uncorrected for sand) in the size class fractions to the total weight of the initial material (25 g). The mean weight diameter (MWD) and the %AS were determined from the equations below;

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

Where MWD = mean-weight diameter of aggregates (mm), Xi = mean diameter of each size fraction (mm), and Wi = proportion of the total sample weight occurring in the corresponding size fraction.

% AS = [(mass of WSA (≥ 0.50) - mass of sand) / (mass of sample - mass of sand)] × 100

Where % AS = percent aggregate stability, and WSA (≥ 0.50) = water stable aggregate ≥ 0.50 mm.

The soil pH was measured using pH meter in 1:2.5 soil to water, and 0.1N KCl suspensions (McLean, 1982). Organic carbon (OC) was determined by the Walkley and Black wet oxidation method (Nelson and Sommers, 1982) whereas total nitrogen was by the Kjeldahl distillation procedure (Bremmer, 1996). Available phosphorous was by Bray II bicarbonate extraction method (Olsen and Sommers, 1982). The exchangeable bases (Na^+, K^+, Ca^{2+} and Mg^{2+}) were extracted using ammonium acetate (NH4OAC). While Na^+ and K^+ were measured by the flame photometer, Ca^2+ and Mg^{2+} were determined by the complexometric EDTA titration (Thomas, 1982). The exchangeable acid (H^+ and Al^{3+}) were measured using extracts from IN KCl as described by McLean (1982). Effective cation exchange capacity (ECEC) was determined by the summation of the exchangeable acid and bases.

2.7. Data Analysis

The data collected from the various parameters were statistically subjected to analysis of variance (ANOVA) using GenStat for Windows, 9th Edition (GenStat, 2007). The significant variations in means were determined using the least significant difference at the 5 % probability level. Correlation analysis was performed amongst cucumber yield indices, and some soil chemical properties to show their relationships.

3.0. Results

3.1. Chemical properties of the poultry manure input

The chemical properties of the PM obtained across the three cropping years (Table 1) showed similar pH value that was moderately alkaline with similar high available P contents. However, the OC, N, Ca^{2+}, Mg^{2+}, Na^+ and K^+

contents of the PM varied amongst the cropping years with higher OC, N, Ca^{2+} and Mg^{2+} contents recorded in 2015 than in 2016 and 2017. The OC contents were appreciably higher when compared to the N contents. As such, the PM obtained over the years showed a rather narrow C/N that ranged from 6.47 to 12.65. Amongst the exchangeable basic cations, the PM contained higher Ca^{2+} and Mg^{2+} than Na^+ and K^+ cations.

3.2. Pre-cropping soil physicochemical properties

The pre-cropping soil textural properties of the experimental site in 2015 indicated the dominance of sand (70 %) with low silt (7 %) and clay (23 %) contents. Accordingly, the textural class of the soil was sandy clay loam. The individual treatment plots showed that the soil is strongly acid with pH-H_2O of 5.33 and 5.02 before the 2015 and 2016 cropping years, respectively (Table 2). Before 2015 cropping year, the soil available P was relatively moderate (8.08 to 9.33 mg/kg) while the OC, total N, C/N, and exchangeable cations amongst the treatment plots were low. Also, there was no significant ($P \leq 0.05$) difference amongst the treatment plots for all the soil chemical parameters except the OC and Na contents of the soil. Accordingly, while the OC content was significantly higher in the 30 t/ha PM plot than in the control plot, the 10 t/ha PM plot showed higher Na content than the 20 and 30 t/ha PM plots. Before 2016 cropping year, however, there was no significant difference in the soil pH or the OC, N, P and K^+ concentrations of the treatment plots.

3.3. Post-cropping effect of poultry manure on soil physical properties

Table 1: Chemical properties of the poultry manure across the three cropping years

	------------------ **Cropping years** ----------------		
Chemical properties	2015	2016	2017
pH (H_2O)	8.40	8.60	8.40
pH (KCl)	8.30	8.20	8.10
Organic carbon (g kg^{-1})	310.00	77.00	106.00
Total nitrogen (g kg^{-1})	24.50	11.90	9.67
C/N	12.65	6.47	10.96
Available phosphorus (mg kg^{-1})	2201.08	2200.00	2611.44
Calcium ($cmol_c$ kg^{-1})	32.00	8.40	16.00
Magnesium ($cmol_c$ kg^{-1})	22.00	7.20	8.00
Sodium ($cmol_c$ kg^{-1})	0.87	0.48	0.35
Potassium ($cmol_c$ kg^{-1})	2.33	0.54	1.02

There was no significant ($P \leq 0.05$) change in the bulk density, total porosity, and hydraulic conductivity of the treatment plots after three years' continuous cucumber cropping with PM application. The bulk density of the treatment plots ranged from 1.42 to 1.51 g cm^{-3} while total porosity and hydraulic conductivity ranged from 43.02 to 47.30 % and from 8.73 to 23.40 cm^{-3}, respectively. Nonetheless, PM application significantly influenced the stability of aggregates in all the cropping years (Fig. 1a-c). With few exceptions, increased PM rates significantly ($P \leq 0.05$) increased the >2.00 mm macro aggregates but reduced the smaller WSA (micro aggregates) of 0.50-0.25 mm in all the cropping years. The silt and clay size fraction (<0.25 mm) was only significantly influenced in 2015. In 2016 however, all the WSA fractions were significantly affected except the <0.25 mm fractions. Significant increase in MWD (Fig. 2a) and %AS (Fig. 2b) was also obtained with increased PM input rates. The % AS ranged from 51.67 to 67.00%, 48.55 to 65.95%, and from 52.47 to 81.78% in years' 2015, 2016 and 2017, respectively.

3.4. Post-cropping effect of poultry manure on soil chemical properties

The effect of PM treatment on the soil chemical properties after crop harvest (Table 3) indicated a significant ($P \leq 0.05$) increase in soil pH-KCI with increased PM rate in 2015 and 2017 cropping years. While differences in the OC and N levels amongst the treatment plots was only evident in years 2015 and 2017, respectively, the C/N ratio of the treatments differed significantly only in the year 2017. Throughout the three cropping years, the soil available P increased significantly ($P \leq 0.05$) with the PM rates. All the exchangeable cations (Ca^{2+}, Mg^{2+}, Na^+, K^+, H^+) showed significantly highest values with the 30 t/ha PM rate and lowest in the control soil, in the year 2015. In 2017 however, the significant effect of the applied ≥ 20 t/ha PM was only evident in increasing the Ca^{2+} and K^+ amongst other exchangeable cations.

3.5. Effect of poultry manure on cucumber yield

The applied PM rates had no significant effect on the fruit length and girth of cucumber obtained across the cropping years (Table 4). In contrast, the average number of harvested cucumber fruits, as well as their corresponding weights differed significantly ($P \leq 0.05$) amongst the treatments, in all the cropping years. In the years 2015 and

Table 2: Pre-cropping soil chemical properties of individual treatment plots in the year 2015

PM Treatment	pH (H_2O)	pH (KCl)	OC g kg^{-1}	N g kg^{-1}	C/N	Avail.P mg kg^{-1}	Ca^{2+} cmol$_c$ kg^{-1}	Mg^{2+}	Na^+	K^+	H^+	ECEC
0 t/ha	5.33	4.37	7.83	0.80	10.45	8.08	4.73	1.13	0.27	0.16	1.13	7.43
10 t/ha	5.27	4.20	8.67	0.70	12.50	8.71	3.60	1.07	0.33	0.20	1.27	6.47
20 t/ha	5.43	4.30	8.53	0.67	13.27	8.71	3.73	1.00	0.21	0.27	1.07	6.28
30 t/ha	5.23	4.20	9.73	0.97	10.22	9.33	3.33	0.90	0.19	0.17	1.00	5.60
$LSD_{(0.05)}$	NS	NS	1.04	NS	NS	NS	NS	NS	0.09	NS	NS	NS

PM = poultry manure; LSD = least significant difference; ECEC = effective cation exchange capacity; OC = organic carbon; OM = organic matter; NS = not significant.

2017, cucumber fruit weight showed a clear increasing trend with increased PM input rates. A similar trend was evident in the percent yield increase in both years; with over 190 % yield increase in the ≥ 20 t/ha PM plots.

3.6. Relationship between cucumber yield indices and soil chemical properties

Table 5 shows the correlation coefficients *(r)* of the cucumber yield indices and soil chemical properties. All the cucumber fruit yield indices (number, length, girth and weight of cucumber) positively correlated significantly with P, Ca^{2+} and K^+ contents of the soil. A similar relationship was obtained between the soil pH-KCl and the yield indices except with fruit girth. While soil N correlated negatively with the cucumber yield indices, a positive significant ($P \leq 0.05$) was obtained between OC and fruit length, and also between C/N and number- and weight- of cucumber. The soil pH positively correlation significantly with OC, C/N, P, K^+, and Ca^{2+} but showed a negative correlation with H^+.

Table 3: Influence of poultry manure on soil chemical properties after cucumber crop harvest across the three cropping years

PM Treatment	pH (H_2O)	pH (KCl)	OC g kg^{-1}	N g kg^{-1}	C/N	Avail. P mg kg^{-1}	Ca^{2+}	Mg^{2+}	Na^+	K^+ cmol$_c$ kg^{-1}	Al^{3+}	H^+	ECEC
Year 2015													
0 t/ha	5.23	4.30	9.03	0.90	10.29	7.46	3.73	0.67	0.19	0.21	nd	1.27	6.07
10 t/ha	6.23	5.43	9.93	1.10	9.38	22.08	6.40	1.53	0.23	0.46	nd	1.07	9.69
20 t/ha	6.33	5.77	11.10	1.17	9.72	28.29	5.00	1.67	0.25	0.44	nd	1.33	8.69
30 t/ha	6.57	5.90	11.33	1.60	7.17	40.73	7.30	2.67	0.27	0.63	nd	1.60	12.47
$LSD_{(0.05)}$	0.57	0.45	0.86	NS	NS	16.35	2.35	1.08	0.05	0.14	-	0.22	2.73
Year 2016													
0t/ha	5.73	4.73	11.19	-	-	25.80	3.07	1.00	0.12	0.09	0.27	0.80	5.23
10t/ha	5.63	4.97	12.38	-	-	38.24	4.20	0.67	0.10	0.08	0.60	0.53	6.09
20t/ha	6.03	5.47	10.93	-	-	55.96	5.33	1.73	0.17	0.14	0.40	0.33	7.96
30t/ha	5.83	5.23	11.72	-	-	46.17	4.13	1.00	0.13	0.09	0.13	0.27	5.64
$LSD_{(0.05)}$	NS	NS	NS	-	-	16.73	NS	NS	NS	NS	NS	NS	NS
Year 2017													
0 t/ha	5.47	4.57	14.76	0.11	13.53	21.76	3.13	1.40	0.13	0.18	nd	2.07	6.91
10 t/ha	5.83	5.00	16.23	0.12	13.80	47.88	3.60	1.27	0.13	0.26	nd	1.73	6.99
20 t/ha	5.97	5.53	17.02	0.07	25.68	78.65	4.27	1.13	0.14	0.45	nd	1.53	7.53
30 t/ha	6.13	5.37	17.42	0.11	16.64	81.45	4.53	1.07	0.15	0.70	nd	1.73	8.18
$LSD_{(0.05)}$	NS	0.54	NS	0.03	4.52	29.62	0.94	NS	NS	0.24	-	NS	NS

PM = poultry manure; OC = organic carbon; OM = organic matter; Avail. P = available phosphorus; OC = organic carbon; OM = organic matter; ECEC = effective cation exchange capacity, LSD = least significant difference; NS = not significant; nd = not determined.

4.0. Discussion

4.1. Chemical properties of the poultry manure

Despite being sourced from the same poultry farm, the PM input obtained across the cropping years showed considerable variation in chemical properties except for the pH and available P concentration. The variation may be due to differences in poultry management relating to breed of beds, bedding material, broilers poultry feed, feed consumption, growth metabolism, etc. The moderately alkaline pH of the PM input as recorded across the cropping

Table 4: Effect of poultry manure rates on yield components of cucumber fruits

PM Treatment	Number of fruits	Fruit length (cm)	Fruit girth (cm)	Fruits weight (t ha^{-1})	% Yield increase (%)
Year 2015					
0 t/ha	12.67	12.54	11.93	2.09	-
10 t/ha	24.67	13.45	11.54	4.97	138
20 t/ha	30.67	13.21	11.40	6.13	193
30 t/ha	32.67	14.19	13.52	7.55	261
$LSD_{(0.05)}$	1.26	NS	NS	2.48	-
Year 2016					
0t/ha	5.33	22.99	16.11	2.30	-
10t/ha	13.33	18.14	16.02	6.17	168
20t/ha	16.67	18.33	15.69	7.46	224
30t/ha	10.00	18.55	15.87	5.26	129
Year 2017					
$LSD_{0.05}$	1.04	NS	NS	3.31	-
0t/ha	10.00	13.66	17.57	3.10	-
10t/ha	13.33	16.62	15.80	5.87	89
20t/ha	22.00	17.08	15.70	10.28	232
30t/ha	22.67	20.73	16.76	10.77	247
$LSD_{0.05}$	0.89	NS	NS	2.17	-

PM = poultry manure; LSD = least significant difference; NS = not significant.

years seems desirable, given the acid nature of the study soil. So, continuous application of PM input of pH 8.50 to the experimental field of pH 5.32 would possibly increase the soil pH and thus, reduce soil acidity. Soil acidity-ameliorating effect of PM has been reported (Duruigbo et al., 2007).

The high available P content of the PM input conforms to other high P values reported in the literature (Ikeh et al., 2012; Enujeke, 2013). The high P composition of the PM could result from the type of poultry feed the birds consumed (Alabadan et al., 2009). Besides, high P concentration in PM does not guarantee P availability because P is influenced by several factors like soil temperature, soil moisture, soil pH, soil clay content and clay type. While soils with high clay content can retain high levels of P reserves, P availability is optimum between pH of 6.0 to 7.0 (NAS, 2010) but relatively insoluble at both low (< 4) and high (> 8) pH levels (Sanginga and Woomer, 2009). Since the soil pH is a little bit above 4, improvement in P availability with increased PM rates is expected concerning soil pH response to PM input.

Table 5: Correlation coefficients (r) of cucumber yield indices and soil chemical properties (n = 12)

Yield indices	pH-KCl	OC	N	P	C/N	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	H^{+}
Number of fruits	0.65*	0.47	-0.48	0.67*	0.60*	0.75**	-0.27	0.42	0.69*	-0.51
Fruit length	0.77**	0.67*	-0.27	0.84**	0.47	0.82**	-0.20	0.42	0.89**	-0.48
Fruit girth	0.52	0.43	-0.39	0.63*	0.51	0.72**	-0.38	-0.02	0.67*	-0.25
Fruit weight	0.73*	0.53	-0.48	0.76**	0.63*	0.80**	-0.32	0.16	0.77**	-0.48
pH-KCl	-	0.74**	-0.45	0.90**	0.64*	0.72**	0.08	0.48	0.70**	-0.67*

*, ** = Significant at 0.05 and 0.01 alpha level (2-tailed), respectively.

The PM input exhibited higher concentrations of OC, N, C/N, Ca^{2+}, Mg^{2+} and K^{+} in the order of the year 2015 > 2017 > 2016; suggesting better cucumber growth and yield response to PM input in the same order. Accordingly, the macronutrients (NPK) ratio portrays dissimilarity in the PM quality given that the ratio of their NPK concentration translated to 2.450:0.220:0.002, 1.190:0.220:0.001, and 0.967:0.261:0.001 in the 2015, 2016 and 2017, respectively. Notably, the higher proportions of Ca^{2+} and Mg^{2+} in 2015 PM input may have serious implication to the soil pH status.

4.2. Effect of poultry manure input on the soil physical properties

The dry bulk density, total porosity and the hydraulic conductivity of the soil did not improve with increased PM application rate. This could be attributed to the nature of the soil, which shows a high proportion of sandy minerals, having originated from weathered Sandstone parent material (Nwadialo, 1989). So, it may take a longer period of repeated PM addition before soil structural changes would become pronounced. Agbede et al. (2008) reported a significant reduction in soil bulk density, as well as a significant increase in total porosity following three years of 7.5 t/ha PM application to an Alfisol, cropped to sorghum.

The observed increase in the >2.00 mm WSA (macro-aggregates) with increased PM rates portrays the positive contribution of PM to soil structural improvement. The improvement was made possible by the vital contribution of OC in the amalgamation of the micro-aggregates (0.50-

0.25 and <0.25 mm) to macro-aggregates, hence the reduced proportion of the micro-aggregates with the application of ≥ 20 t/ha across the cropping years. The % OC, which followed a similar trend with the >2.00 mm WSA also affirms the potential of aggregation in enhancing OC stabilization in soils (Chaplot and Cooper, 2015). The link between the stability of the macro-aggregates (>2.00 mm) and the soil's OC content appears to supersede the contribution of the soil's clay content to macro-aggregate stability. Hence, it is not incongruous to attribute the enhanced stability of the >2.00 mm aggregates to the OC content of the PM input. Remarkably, the 20 and 30 t/ha PM rates individually contributed to about 91 and 99% improvement in >2.00 mm aggregate stability, in 2017. This consequently enhanced the aggregate MWD substantially and the % AS of the ≥ 20 t/ha PM amended soils. Indeed, the 74 and 82 % improvement in % AS with the 20 and 30 t/ha PM, respectively, as recorded in 2017, confers a more significant potential for the soil to withstand disaggregation when moistened. Such improvement implies enhancement in soil strength, soil resistivity to mechanical stress, soil tilth, infiltration rate, soil water retention, and in stabilization of soil structure and soil organic matter (Alabadan et al., 2009; Canasveras et al., 2010; Chaplot and Cooper, 2015). Therefore, continuous cucumber cropping with ≥ 20 t/ha PM input would improve soil resistivity against breakdown by impacts of rainfall, overland flow and water erosion.

4.3. Effect of poultry manure input on the soil chemical properties

The strongly acid pH status of the soil before the PM application could be due to the excessive precipitation that characterized the study location, and so predisposes the soil to leaching, interrill erosion and runoff processes. This consequently causes considerable loss of nutrients and thus explains the low OC, total N and exchangeable cations contents of the soil, a true reflection of most Ultisols of southeastern Nigeria that are strongly weathered and of low activity clay mineralogy (Asadu, 1990). Nonetheless, the observed differences in OC and Na^+ concentrations amongst the treatment plots before the 2015 crop establishment could be attributed to soil heterogeneity emanating from previous differences in land use and management.

The effect of ≥ 20 t/ha PM rates on the chemical properties of the soil was more pronounced in 2015 and 2017 than in 2016, an observation associated with variations in PM quality. The pH-KCl effect of the ≥ 20 t/ha PM amended plots in 2015 and 2017 was expected considering the liming effect of the PM input due to its relatively higher Ca^{2+} content. Duruigbo et al. (2009) reported a similar significant increase in soil pH-KCl with 15 t/ha PM input on loamy sand Ultisol. In the year 2016 likewise, there was also a noticeable increase (though not significant) in soil pH of the ≥ 20 t/ha PM treatment plots (5.47/5.23) which was quite higher than that of the control plot (4.73). This unpronounced pH effect may be due to the weak Ca^{2+} composition of the 2016 PM, which was not sufficient to displace much of the H^+ from the exchange site into the soil solution to effect a significant increase in pH and consequently, reduce soil acidity. The maximum improvement in OC content of the PM amended soils in the year 2015 could be due to the higher OC composition (310 g/kg) of the PM input which was about four- and three- times higher than that contained in the PM input of 2016 and 2017, respectively. While prolonged moisture stress in 2015 may have slowed down mineralization of the PM input and contributed to higher OC storage in the PM amended soils, improvement in the stabilization of the soil OC was not observed because, after the nine months' fallow that preceded the year 2016 cropping, much of the OC was lost, suggesting that mineralization and leaching were strong enough to diminish the OC effect observed after the 2015 crop harvest. Hence, there was no residual effect of the previous PM rates applied in 2015.

The higher composition of N and exchangeable cations of the 2015 PM input accounts for the observable differences between the 30 t/ha PM treatment and the control treatment. This assertion also explains the overall soil chemical response (except for available P) to PM input in the order of the year 2015 > 2017 > 2016. Even with the prolonged moisture stress in 2015 than in other years, soil fertility improvement with PM addition seems to depend not only on the quantity but also on the quality of PM input. The higher quality of 2015 PM may have contributed to its superior impact on soil fertility improvement after crop harvest. It thus becomes imperative to cultivate the land during the major cropping season to benefit from the stored/residual nutrients that were somewhat lost to leaching and mineralization within the nine months of bare fallow. The lack of improvement in the nutrient concentrations (except available P) of the treatment plots after 2016 harvest could be due to the poor quality of the applied PM. The lowest C/N of the 2016 PM input presupposes rapid mineralization and concomitant efficient utilization of the available nutrients in the PM amended plots. It seems that soil chemical response to PM input rates depends mainly on PM quality.

The available P of all the PM application rates increased continuously over the three cropping years, showing that much of the high P inputs with PM were effectively stored in the soils. The high P retention implies improvement in soil quality and cucumber fruit yield since according to Papadopoulos (1994), adequate P enhances fruiting and root growth during plant development. The PM rates showed no N effect in 2015 and 2016 cropping years because the low N composition of the PM input could not supply sufficient N to offset the N limitation of the soil. Remarkably, the low N content (0.07 g/kg) of the 20 t/ha PM soil after 2017 harvest suggests an effective N utilization that translated to a high, and comparable cucumber yield to the 30 t/ha PM soil. Nonetheless, the low N values of the treatment plots in 2017 indicate no N effect of the PM rates. Therefore, improvement in soil pH, available P, Ca^{2+} and K^+ status was evident after the three continuous application of ≥ 20 t/ha PM rates. Similar enhancement in the fertility (OM, N, P, K^+, Ca^{2+} and Mg^{2+}) of an Alfisol and an Ultisol after two years' cucumber cropping with 6 t/ha and 15 t/ha PM input, respectively, have also been reported (Moyin-Jesus, 2015; Law-Ogbomo and Osaigbovo, 2018).

4.4. Effect of poultry manure on cucumber yield

Poultry manure is known for increasing cucumber fruit length and girth (Enujeke, 2013; Moyin-Jesu, 2015; Law-Ogbomo et al., 2018), but our study lends no credence to that. The lack of improvement in cucumber length and girth could be due to insufficient N supply from both the soil and PM input which would have impeded efficient N uptake. Higher N accessibility induces protein production that promotes more meristem cells and cell division leading to higher cucumber girth and length (Salardini and Mojtahedi, 1988).

The PM input increased the number as well as the weight of cucumber fruit in all the cropping years. The maximum number of cucumber fruits obtained in the 20 and 30t/ha PM treatment plots was about 2 to 2.5 times higher than in control, after the 2015 and 2017 harvest. Accordingly, the 20 and 30 t/ha PM input which produced 6.13 and 7.55 t/ha cucumber fruits, respectively, in 2015 progressed to producing 10.28 and 10.77 t/ha cucumber fruits, respectively, in 2017. The latter cucumber weights corresponding to a three-fold increase when compared to the control was possible because the higher PM rates (≥ 20 t/ha) increased soil OC and thus, favoured accelerated mineralization and the release of more nutrients (N, P, K^+ and Ca^{2+}) for enhanced cucumber yield. Even though the fruit weight yield amongst the PM treatments was similar in 2016; possibly because of the poor quality of 2016 PM input, and other favourable environmental factors not considered in the study, our findings showed that the percent yield increase was generally highest with the 20 t/ha PM input.

The cucumber fruit yield obtained in 2017 is similar to the findings by Ikeh et al. (2012) and Agu et al. (2015) who obtained about three-fold maximum cucumber yield increase with 8 and 40 t/ha PM rates, respectively, in a two-year cropping seasons experiments. Because of that, the recommended rates of 8 t/ha and 40 t/ha PM which yielded fruit weight of 11.29 t/ha (Ashley variety) and 11.15 t/ha (Pionsett variety), respectively, are comparable to the yield of 10.53 t/ha (Ashley variety) obtained in our study. These fruit yields were, however, far below the reported 50.50 t/ha Market more variety, which still corresponds to about three-fold yield increase with 20 t/ha PM (Enujeke, 2013). Despite the above differential genotypic responses to PM application, it does appear that most of the 'agronomic' PM recommendations revolve around a three-fold increase in cucumber fruit yield when compared to the control treatment. This calls for further research on the economic analysis of PM input rates to ascertain the rate that delivers a high economic return. In our study, however, where the 20 and 30 t/ha PM produced similar cucumber yield increases by over 200 % in 2017, 20 t/ha PM would be attractive to farmers. From an agronomical point of view, 20 t/ha PM input is appropriate for continuous application to an Ultisol for improved cucumber cropping. More importantly, the over 200 % yield increase with 20 t/ha PM implies an increase in household food security, increased income, and subsequent improvement in farmer's livelihoods.

4.5. Relationship between cucumber fruit yield indices and soil chemical properties

The considerable correlation of cucumber yield indices (number-, length-, girth-, and weight- of fruit) with P, Ca^{2+} and K^+ is an indication of the relative importance of the nutrients in controlling cucumber yield. Phosphorus and K^+ are involved in almost all aspect of growth and metabolism in plants. The vital functions of P in flower and fruit setting (Papadopoulos, 1994); K in soil-plant-water relations (water uptake, retention and transportation) (Marschner, 1995); and Ca in plant structural framework and cell division/enlargement (White and Broadly, 2003) lend credence to our deduction. Calcium has been recognized as a central regulator of plant growth and development (Hepler, 2005), and as well been externally used to enhance cucumber growth and productivity (Siddique et al., 2017). Hence, sufficient amounts of these nutrients in PM input are needed to optimize and sustain cucumber yield in Ultisols. The negative correlation between N and cucumber yield indices does not underrate its function in plant vegetative growth. However, since C/N is positively associated to number- and weight- of cucumber fruit by about 60 %, the higher composition of OC (relative to N) in PM input would favour improvement in cucumber fruit length (r = 67 %) and soil nutrient retention. The highly positive correlation of soil pH with cucumber yield indices (except fruit girth) justifies the negative correlation of H^+ with pH since the reduction of H^+ in soil solution increases the soil pH. Noteworthy is the significant association of the pH of the soil to OC, C/N, P, K^+ and Ca^{2+} nutrients, thus affirming their involvement in maintaining chemical balance in the soil. Also, the correlation of Ca^{2+} with soil pH affirms the presumed liming effect of PM input.

5.0. Conclusion

Poultry manure input improved the fertility of an Ultisol for increased cucumber productivity. The application of 20 and 30 t/ha PM rates improved the number and weight of cucumber fruits that corresponds to a three-fold yield increase. Also, these rates substantially improved the soil structural stability (macro-aggregation > 2 mm) by over 90 %. However, soil chemical response to PM input rates was variable across cropping years and dependent on PM quality. Nonetheless, the three years' continuous addition of 20 and 30 t/ha PM rates improved soil quality by increasing the pH, available P, Ca^{2+} and K^+ status of the soil. From agronomical viewpoint and for convenience, 20 t/ha PM is therefore recommended for optimum cucumber yield and soil health on Ultisols.

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Reference

Agbede, T.M., Ojeniyi, S.O., Adeyemo, A.J., 2008. Effect of poultry manure on soil physical and chemical properties, growth and grain yield of sorghum in Southwest, Nigeria. American-Eurasian Journal of Sustainable Agriculture 2(1), 72-77.

Agu, R.S., Ezema, R.A., Udegbunam, O.N., Okoro, A.C., 2015. Effect of different rates of poultry manure on growth and yield of cucumber (Cucumis sativum) in Iwollo, Southeastern Nigeria. Agro-Science 14(3), 41-44.

Alabadan, B.A., Adeoye, P.A., Folorunso, E.A., 2009. Effect of different poultry wastes on physical, chemical and biological properties of soil. Caspian Journal of Environmental Sciences 7 (1), 31-35.

Asadu, C.L.A., 1990. A comparative characterization of two foot-slope soils in the Nsukka area of Eastern Nigeria. Soil Science 150(2), 527-534.

Blake, G.R., Hartge, K.H., 1986. Bulk density, in: Klute, A. (Ed.), Methods of Soil Analysis, Part 1. American Society of Agronomy, Madison, Wisc. Pp. 363-382.

Bowman, G., Hutka, J., McKenzie, N., Coughlan, K., Cresswell, H., 2002. Particle size analysis, in Soil Physical Measurement and Interpretation for Land Evaluation, pp. 224-239.

Bremner, J.M., 1996. Nitrogen-total. Methods of Soil Analysis, Part 3. Chemical Methods, (methodsofsoilan3), 1085-1121.

Cañasveras, J.C., Barrón, V., Del Campillo, M.C., Torrent, J., Gómez, J.A., 2010. Estimation of aggregate stability indices in Mediterranean soils by diffuse reflectance spectroscopy. Geoderma 158(1-2), 78-84.

Cambardella C.A., Elliott E.T., 1994. Carbon and nitrogen dynamics of soil organic matter fractions from cultivated grassland soils. Soil Science Society of America Journal 58, 123-130.

Chaplot, V., Cooper, M., 2015. Soil aggregate stability to predict organic carbon outputs from soils. Geoderma, 243, 205-213.

Duruigbo, C.I., Obiefuna, J.C., Onweremadu, E.U., 2007. Effect of poultry manure rates on soil acidity in an Ultisol. International Journal of Soil Science 2 (2), 154-158.

Eifediyi, E.K., Remison, S.U., 2009. The effects of inorganic fertilizers on yield of two varieties of cucumber (Cucumis sativus L.). Report and Opinion 1(5), 74-80.

Eifediyi, E.K., Remison, S.U., 2010. Growth and yield of cucumber (Cucumis sativus L.) as influenced by farmyard manure and inorganic fertilizer. Journal of Plant Breeding and Crop Science 2(7), 216-220.

Enujeke, E.C., 2013. Growth and yield responses of cucumber to five different rates of poultry manure in Asaba area of Delta State, Nigeria. International Research Journal of Agricultural Science and Soil Science 3(11), 369-375.

Ewulo, B.S., Ojeniyi, S.O., Akanni, D.A., 2008. Effect of poultry manure on selected soil physical and chemical properties, growth, yield and nutrient status of tomato. African Journal of Agricultural Research 3(9), 612-616.

FAOSTAT (Food and Agricultural Organization of the United Nations), 2019. Crops. http://www.fao.org/faostat/en/#data/QC (accessed 12 February 2019).

Gambo, B.A., Magaji, M.D., Yakubu, A.I., Dikko, A.U., 2008. Effects of Farmyard manure, nitrogen and weed interference on the growth and yield of onion (Allium cepa L.) at the Sokoto Rima valley. Journal of Sustainable development in Agriculture and Environment 3(2), 87-92.

GenStat, 2007. GenStat for Windows (GenStat 9th edition). Lawes Agricultural Trust, Rothamsted Experimental Station, UK.

Grubben, G.J.H., Denton, O.A., 2004. Plant resources of tropical Africa 2. Vegetables. Plant resources of tropical Africa 2. Vegetables.

Hamma, I.L., Ibrahim, U., Haruna, M., 2012. Effect of poultry manure on the growth and yield of cucumber (Cucumis sativum L.) in Samaru, Zaria. Nigerian Journal of Agriculture, Food and Environment 8(1), 94-98.

Hepler, P.K., 2005. Calcium: a central regulator of plant growth and development. Plant Cell 17, 2142-2155.

Ikeh, A.O., Udoh, E.I., Uduak, G.I., Udounang, P.I., Etokeren, U.E., 2012. Response of cucumber (Cucumis sativus L.) to different rates of goat and poultry manure on an Ultisol. Journal of Agriculture and Social Research 12(2), 132-139.

Klute, A., Dickson, C., 1986. Hydraulic conductivity and diffusivity: laboratory methods, in Klute, A. (Ed.), Methods of Soil Analysis. Part 1. Soil Science Society of America, Madison, W. I, pp. 687-732.

Law-Ogbomo, K.E., Osaigbovo, A.U., 2018. Productivity of cucumber (Cucumis Sativus L) and post-harvest soil chemical properties in response to organic fertilizer types and rates in an Ultisol. Tropical and Subtropical Agroecosystems 21(3).

Marschner, H., 1995. Mineral Nutrition of Higher plants. 2nd edition. Academic Press. San 113 Diego, C.A.

Mangalassery, S., Kalaivanan, D., Philip, P.S., 2019. Effect of inorganic fertilizers and organic amendments on soil aggregation and biochemical characteristics in a weathered tropical soil. Soil and Tillage Research 187, 144-151.

McLean, E.O., 1982. Soil pH and lime requirement, in: Page, A.L., Miller, R.H. and Keeney, D.R. (Eds.), Methods of Soil Analysis; Part 2. America Society of Agronomy, Madison, WI, pp. 199-224.

Moyin-Jesu, E.I., 2015. Efficacy of different organic fertilizers on soil fertility improvement, growth and fruit parameters of cucumber (Cucumis sativus L.). Journal of Agriculture and Food Technology 5(2), 1-7.

Nachurs Alpine Solutions (NAS), 2010. Potassium: An essential element in crop production. http://www.nachurs.com/potassium.html

Nelson, D.W., Sommers, L., 1982. Total carbon, organic carbon, and organic matter 1. Methods of soil analysis. Part 2. Chemical and microbiological properties (methodsofsoilan2), 539-579.

Nwadialo, B.E., 1989. Soil–landscape relationship in the Udi-Nsukka plateau. Catena 16, 111- 120.

Nweke, I.A., Okoli., P.S.O., Enyioko, C.O., 2014. Effect of different rates of poultry droppings and plant spacing on soil chemical properties and yield of cucumber. Elixir Agriculture 70, 23934-23940.

Okoli, P.S.O., Nweke, I. A., 2015. Effect of poultry manure and mineral fertilizer on the growth performance and quality of cucumber fruits. Journal of Experimental Biology and Agricultural Sciences 3(4), 362-367.

Olowokere, F.A., Odulate, L.O., 2019. E□ects of tithonia diversifolia, poultry manure, cow dung, and their composts on soil chemical properties under okra (Abelmoschus esculentus L. Moench) production. Journal of Organic Agriculture and Environment, 6.

Olsen, S.R., Sommers, L.E., 1982. Phosphorus, in: Page, A.L., Miller, R.H., Keeney D.R. (Eds.), Methods of soil analysis. Part 2. Chemical and microbiological properties. 2nd edition. American Society of Agronomy and Soil Science Society of America, Madison, Wisconsin USA, pp. 403-430.

Onyegbule, U.N., Asawalam, D.O., 2015. Effect of different rates of poultry manure on soil properties, growth and yield of garden egg (Solanum gilo) in Okigwe Southeastern Nigeria. Nigerian Journal of Soil Science 26, 221-236.

Papadopoulos, A.P., 1994. Growing greenhouse seedless cucumbers in soil and in soilless media. Agriculture and Agri-Food Canada.

Salardini, A., Mojtahedi, M., 1988. Principles of plant nutrition. Published by Tehran University, 2.

Sanginga, N., Woomer, P.L. (Eds.), 2009. Integrated Soil Fertility Management in Africa: Principles, Practices and Developmental Process. Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture. Nairobi, pp. 79

Siddique, S., Ayub, G., Nawaz, Z., Zeb, S., Khan, F.S., Ahmad, N., Khan, A., Rauf, K., 2017. Enhancement of growth and productivity of cucumber (Cucumis sativus) through foliar application of calcium and magnesium. Pure and Applied Biology 6(2), 402-411.

Soropa, G., Nyamangara, J., Nyakatawa, E.Z., 2019. Nutrient status of sandy soils in smallholder areas of Zimbabwe and the need to develop site-specific fertiliser recommendations for sustainable crop intensification. South African Journal of Plant and Soil 36(2), 149-151.

Thomas, G.W., 1982. Exchangeable cations. Methods of soil analysis. Part 2. Chemical and microbiological properties (methodsofsoilan2), 159-165.

White, P.J., Broadly, M.R., 2003. Calcium in plant. Annals of Botany 92, 487-511.