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Moisture characteristics and soil chemical variations of a degraded soil treated with selected animal wastes

Nweke, IA; Chime, EU

Department of Soil Science, Chukwuemeka Odumegwu Ojukwu University, Anambra state

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****Corresponding Author***
Nweke, I.A
E-mail: *nweksoniyke@gmail.com*

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ABSTRACT

The ability of animal waste to restore and reclaim the productivity of degraded soil is dependent on the nutrient content of the waste, rates applied and ability to release nutrients in available form for crop production. In this present study the comparative effectiveness of three (3) animal wastes; poultry waste, swine waste and cow waste in improving the productivity of a degraded soil was simultaneously investigated in a greenhouse study. The experiment was laid out in factorial experiment in randomized complete block design and each treatment was replicated three (3) times. A control was also included. The findings from the study showed that animal wastes and rates studied significantly increased water potentials at 0.1bar, 1.0bar and 15bar for the 2 years study. The readily available water and total available water was increased. On the average the water retention on the amended soils showed an increased order of PW > SW > CW > CO (1st year cropping) and SW > PW > CW > CO (2nd year cropping). The characterization of nutrient content showed that animal wastes significantly increased the available P, OC, TN and ECEC of the degraded soil. On the average the nutrient output of the wastes showed an order PW > SW > CW > CO. Na/K and Ca/Mg ratios were enhanced by the waste application. Animal waste and rates studied is recommended for organic farmers, potted plant growing farmers with limited land availability and green house farmer.

INTRODUCTION

Most soils in Nigeria are highly weathered, degraded and infertile due to over cultivation, erosion, high bulk density and intense weathering going on in the soil as a result of high temperature. Many of these soils like ultisols predominantly in south east of Nigeria have acid surface and subsurface horizon and their moisture stress conditions make these soils extremely difficult to manage under low-input conditions. Moisture is a very pressing constraint to food production and maximization of the degraded soils like sandy soil because when there is no moisture available in the soil, the soil organic matter (SOM) find it difficult to thrive and create an enabling environment for soil organism to live in. Thus the SOM takes a very huge position in the soil as it tends to aid water retention and therefore can only thrive in moisture enhanced conditions. Inadequate moisture content can be seen in the degraded sandy soil due to very little OM content, porous size nature of the aggregates that allow freely drainage, thus making the soil to be susceptible to soil erosion. In fact soil moisture stress in degraded sandy soil is perhaps the overriding constraint to its maximization in crop production. Though the same soil may have more than one constraints, low moisture content is not only a function of the low and erratic precipitation but also of the ability of the soil to hold and release moisture. All these scenario lead to low chemical soil nutrients for OM is the store house of soil chemical nutrients coupled with low activities of soil microbes that will liberate plant nutrients through their activities in soil. Organic matter maintains better soil quality and reduces contamination of air, water, soil and final food products. Thus a sustainable food production in a degraded sandy soil must adopt an ecological approach of using balanced nutrient inputs from organic materials such as animal wastes which are biological sources. Through this enhanced nutrient input and recycling, food security in a degraded sandy soil can be achieved for a rapidly expanding population in the tropical region like Nigeria. The use of animal wastes is essential to maintain adequate physical, chemical and biological properties of soils. Hence the essence of this present study is to evaluate the moisture characteristics and soil chemical variations of a degraded sandy soil treated with three (3) different rates of contrasting animal wastes.

MATERIALS AND METHODS

Sample collection

Using soil auger, 0-20cm top soil from University of Nigeria Nsukka, Teaching and Research Farm was collected. The soil sample was air dried at room temperature and sieved through a 2mm sieve. The animal waste (Cow waste, Swine waste and Poultry waste) materials were dried at room temperature and crushed to fine particles (< 2mm). Maize used as a test crop for the study was purchased locally. The study was carried out in the department of Soil Science green house complex of the University. 4kg of soil was weighed out and mixed thoroughly and separately with the following rates of cow waste, poultry waste and swine waste 0, 0.25, 0.50 and 1.00% an equivalent of 0, 5, 10 and 20tha^{-1}. They were transferred into clay pots with drainage holes at the base. To avoid excessively loss of water by drainage the holes were plugged with cotton wool. The soil and the amendment mixtures were incubated for one week before planting maize. Five seeds of maize NS1 variety were planted per pot and later thinned down to three stand per pot after germination. The plant height was measured and after 42 days of growth, the shoots were cut and oven dried at 60% for seven days for dry matter yield determination. The same procedure above was repeated without further addition of wastes to test the residual effect of the animal wastes on maize growth and yield. Agronomic aspect of this work were discussed in Nweke and Igwe (2021). The experiment was arranged as a factorial experiment in a randomized complete block design with each treatment replicated three times. A control was also included.

Laboratory analysis

pH determination: The pH was determined in distilled water solution using soil/liquid ratio of 1:2.5

Organic carbon: This was determined by the Walkley and Black (1934) method.

Total Nitrogen: Total nitrogen was determined by Kjeldahl method (Bremner, 1965)

Exchangeable basis: The complexiometric titration method describe by Chapman (1965) was used for the determination of calcium and magnesium. Sodium and potassium were determined from IN ammonium acetate (NH_4OAC) using the flame photometer.

Available phosphorous: Bray and Kurtz, (1945) was used for available P determination

Efective cation exchange capacity (ECEC): This was obtained by summing of the exchangeable bases and the exchangeable acidity determined from IN KCl extract.

Physical properties: Particle size distribution was determined by the method of Bouyoucos (1951).

Moisture retention: Moisture retention at -10 and -1500kPa potentials using the saturation water percentage based estimation models of Mbah (1998) and total available water capacity (TAWC) computed as difference between moisture retained at -10kPa (field capacity) and -1500kPa potentials (wilting point).

Determination of saturated water percentage

For the determination of saturated percentage ceramic crucible with perforated bottom were used. Duplicate determinations were made per sample. Portions of the air dry soil samples were transformed into the crucible a little at a time with intermittent gentle tapping on the work bench to consolidate the mixture. The process was continued until the crucible was about four-fifth full. The crucible was then transferred into a basin and water was added into the basin up to a depth of about two third of height of the crucible. It was then allowed to stand in the basin for the soil to absorb water by capillarity through the porous base of the crucible. Water absorption continued until the exposed soil surface glistened as it reflected light, indicating that saturation point had been reached. This point was reached after 24hrs of contact with water. The crucible were then removed from the basin and the outside wiped dry. After obtaining the mass of the crucible and saturated soil, it was dried in the oven for 24hours at 105^{o}C. Therefore, the mass of the crucible plus dry soil was recorded. Saturation water percentage was then calculated as follows

$$SP = \frac{K-J}{J-C} \times \frac{100}{1}$$

Where K = weight of crucible + wet sample
J = weight of crucible + dry sample
C = weight of crucible only

Data analysis

Data collected from the study were analysed according to the procedures for a factorial experiment in a randomized complete block design and least significant difference (LSD) was used to detect differences between treatment means

RESULTS

The pre-analysis result of the studied soil and animal waste presented in Table 1 indicated the soil to be acidic in reaction (4.80) and plant nutrients below their critical value for crop production. In contrast animal waste showed to be higher in the tested parameters and therefore expected to influence positively the productivity of the studied soil.

Table 1 Properties of soil and animal wastes before the beginning of the study

Parameters	Soil	CW	PW	SW
Silt%	2	-	-	-
Clay %	12	-	-	-
Fine sand%	36	-	-	-
Coarse sand%	60	-	-	-
Textural class	Sandy	-	-	-
OC %	0.56	7.86	13.50	6.84
OM %	0.96	13.55	23.29	11.79
TN %	0.067	1.85	2.86	2.00
Na cmolkg^{-1}	0.11	0.43	0.72	0.44
K cmolkg^{-1}	0.15	0.48	1.50	0.65
Ca cmolkg^{-1}	0.8	1.50	8.10	2.30
Mg cmolkg^{-1}	0.6	1.29	6.89	1.09
Avail. P ppm	3.2	0.23	2.05	0.82
CEC cmolkg^{-1}	7.0	-	-	-
pH H_2O	4.80	6.69	7.11	6.38

CW = Cow waste; PW = Poultry waste; SW = Swine waste

The result in Table 2 presented the chemical variations in each treatment composition before the commencement of the study and planting of the maize. The result showed that nutrient concentration was highest in poultry waste (PW) followed by swine waste (SW) and least in cow waste (CW). Magnesium (Mg) concentration however, was highest in swine waste and lowest in cow waste.

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Table 2 amount of nutrient in each treatment gkg^{-1}

Amendment	Mg	Ca	K	Na	N	P (PPM)
PW5	245	1013	188	90	358	256
PW10	490	2026	376	180	716	512
PW20	980	4052	752	360	1432	1024
Mean	572	2364	439	210	835	597
SW5	263	288	81	55	250	103
SW10	526	576	162	110	500	206
SW20	1052	1152	324	220	1000	412
Mean	614	672	189	128	583	240
CW5	175	189	60	54	233	29
CW10	350	378	120	108	466	58
CW20	700	756	240	216	932	116
Mean	408	441	140	126	544	68

CW = Cow waste; PW = Poultry waste; SW = Swine waste

Effect of animal waste on the moisture characteristics of degraded soil

The recorded value for moisture characteristics of the degraded soil in Table 3 indicated significant different ($P < 0.05$) among the treatments for 0.1bar, 1.0bar and 15bar for the 1st year cropping and 1.0bar and 15bar for the 2nd year cropping respectively. Every other tested parameter showed non-significant different ($P < 0.05$) among the treatment in both 1st and 2nd year cropping. An indication that organic matter (OM) content of the animal waste addition rates do not influence the parameters. There was increase in soil moisture content in the 1st year cropping compared to the 2nd year cropping with regard to the recorded value obtained for the parameters tested. There was also inconsistence in the values obtained in both 1st and 2nd year cropping relative to the rates of waste applied. As in most parameters the $10tha^{-1}$ and $20tha^{-1}$ waste recorded the same value independent of the type of waste applied. While in some parameters value increased with increment in the rate of waste applied though not constant. Moisture retained at these tested parameters in the amended soils were appreciably higher relative to control soil in both 1st and 2nd year cropping. At the rates of 5, 10, $20tha^{-1}$ of the animal wastes readily available water capacity (RAWC) of degraded soil was slightly increased over the control in both cropping seasons. On the average water retention in the amended soils showed an increased order of PW > SW > CW > CO for 1st and 2nd year cropping respectively.

Table 3 Effect of the Animal waste on moisture characteristics of the degraded sandy soil

Treatment	1st Year copping						2nd Year cropping					
	Saturation	0.1bar	1.0bar	15bar	TAWC	RAWC	Saturation	0.1bar	1.0bar	15bar	TAWC	RAWC
CW5	35.40	21.70	12.80	9.40	12.30	8.90	35.01	20.70	12.56	8.79	11.96	8.80
CW10	36.00	22.20	13.20	9.40	12.50	9.00	35.15	21.15	13.18	9.58	12.40	9.00
CW20	35.10	21.50	12.60	9.30	12.10	8.90	35.00	20.49	12.50	9.27	12.20	8.85
Mean	35.50	21.80	12.87	9.47	12.30	8.93	35.05	20.78	12.75	9.21	12.19	8.88
PW5	35.30	21.60	12.60	9.30	12.30	9.00	34.75	21.60	12.55	9.00	12.20	8.75
PW10	35.90	22.10	13.10	9.70	12.40	9.00	34.98	22.05	13.05	9.45	12.37	9.00
PW20	35.90	22.10	13.10	9.70	12.30	9.00	35.58	22.08	13.08	9.40	12.19	8.76
Mean	35.70	21.93	12.93	9.57	12.33	9.00	35.10	21.91	12.89	9.28	12.25	8.84
SW5	35.60	21.90	12.90	9.50	12.50	9.00	35.40	21.50	12.60	9.38	12.50	9.01
SW10	35.70	22.00	13.00	9.60	12.40	9.00	35.65	21.80	12.95	9.56	12.47	8.58
SW20	35.50	21.80	12.80	9.50	12.30	9.00	35.37	21.65	12.76	9.50	12.25	8.67
Mean	35.60	21.90	12.90	9.53	12.40	9.00	35.47	21.65	12.77	9.48	12.41	8.75
Control	33.70	20.40	11.6	8.50	11.9	8.8	33.60	20.21	11.47	8.49	11.65	8.65
LSD0.05	NS	0.95	0.53	0.07	NS	NS	NS	NS	0.53	0.65	NS	NS

CW = Cow waste; PW = Poultry waste; SW = Swine waste

Effect of animal waste on the chemical nutrient content of the degraded soil

The chemical nutrient content variation of the degraded soil presented in Table 4 showed significant different ($P < 0.05$) among the treatment in the parameters tested. Except for the result of OC of the 1st year cropping season. All the parameters showed increase in value with increment in the rates of animal waste applied, though not fairly constant in some parameters. On the average the nutrient concentration in the animal wastes showed an increased variation of PW > SW > CW > CO for 1st Year and 2nd year cropping. Also on the average the highest ECEC value was obtained from SW (1st year) and PW (2nd year) of the amended soil. The Na/K and Ca/Mg ratios of the waste amended soils indicated the 2nd year cropping result to be higher in value than the 1st year cropping result. Except for SW amended soil. In most cases the 2nd year result showed higher values in rates studied relative to 1st year cropping with regard to Na/K and Ca/Mg ratios.

Table 4 Effect of animal waste on the chemical properties of degraded sandy soil

Treatment	1st Year cropping						2nd Year cropping					
	OC gkg^{-1}	TN gkg^{-1}	P $mgkg^{-1}$	Na/K	Ca/Mg	ECEC $cmolkg^{-1}$	OC gkg^{-1}	TN gkg^{-1}	P $mgkg^{-1}$	Na/K	Ca/Mg	ECEC $cmolkg^{-1}$
CW5	600	58	12.8	0.93	1.0	6.7	500	14	11.79	1.0	1.19	6.32
CW10	640	60	16.8	0.87	1.07	6.6	590	18	14.68	0.85	1.14	6.51
CW20	680	61	21.0	0.93	0.67	7.0	600	20	19.09	1.07	1.0	7.47
Mean	640	60	16.87	0.87	0.91	6.8	560	17	15.19	1.0	1.11	6.77
PW5	650	62	25.2	0.88	0.87	6.6	600	15	25.01	0.86	0.91	6.53
PW10	720	59	31.5	0.94	1.19	7.1	890	17	30.16	0.87	1.33	7.15
PW20	780	69	58.8	0.94	1.19	7.5	1010	30	54.35	0.81	1.24	7.27
Mean	720	63	38.5	0.94	1.08	7.1	830	21	36.51	0.87	1.17	7.99
SW5	640	61	18.9	0.92	0.88	6.2	500	13	17.19	0.81	0.90	6.09
SW10	640	63	31.5	1.0	0.88	7.2	610	20	31.05	1.0	0.86	7.22
SW20	760	70	48.3	0.93	0.72	8.2	820	16	47.23	0.93	0.59	8.23
Mean	680	65	32.9	0.93	0.82	7.2	640	16	31.82	0.73	0.77	7.18
Control	600	58	16.8	0.83	1.0	6.8	490	11	14.82	0.92	1.10	6.90
LSD0.05	NS	3.0	2.05			0.4	40	3	2.35			0.25

CW = Cow waste; PW = Poultry waste; SW = Swine waste

DISCUSSION

The appreciable increase in moisture retained in the waste amended soil relative to the control soil could be attributed to the OM content of the waste. Thus indicating that OM from the waste contributed to the improvement in the soil moisture characteristics of the degraded soil. Organic matter through its effect on the physical condition of a soil increase the amount of water a soil can hold and proportion of this water available for plant establishment, growth, and performance. Mineralization of plant nutrient is greatest when soil moisture is near field capacity and declines with soil drying. Manure characteristics significantly influence nutrient mineralization. The application of poultry manure ranging from 10-50tha^{-1} by Ewulo et al. (2008) was observed to improve moisture availability in soil and reduced soil bulk density leading to nutrient availability and increased tomato yield. They found out that moisture content increased as the level of manure increased, thus concurring to the findings of this study. Also with yearly application of OM, moisture content increased giving cumulative positive effect on water retention on soils (Agbede et al., 2008). In another study Mubarak et al. (2009) found a decrease in water movement in sandy soil amended with organic residues of which provides better environment for crop to absorb water and nutrients instead of the nutrients being leached down rapidly. The addition of animal wastes at the rates studied was found to significantly increased moisture retained at all potentials. Also waste addition rates was found to have much influence on the total available water capacity (TAWC) by the virtue of higher value recorded in the amended soils relative to control. Edward et al. (2000) found that soil application of different organic residues increased soil moisture over the untreated soil. All the animal waste addition fairly increased the readily available water (RAWC) over the control. This probably may be due to high OM added by these wastes. The more the readily available water in a soil the less the likelihood of moisture stress in crops.

All the amended soils when compared with the control showed increases in chemical parameters of the studied soil. On the average the soil/poultry (PW) recorded the highest value in these parameters. Relative improvement in P, ECEC, OC and TN observed over the control may be due to higher content of these nutrients in the rates of wastes applied. Increases in these nutrients appeared to be associated with their high contents and values as shown in Table 2. Manure from different animals have different qualities and require different application rates, they contribute to the fertility of the soil by adding OM and nutrients such as N that is trapped by bacteria in the soil. The P, OC and TN levels of the studied soils may be associated with improved biological and mineralization process due to high quality resulting from chemical decomposition. The obtained Na/K and Ca/Mg ratios were due to degradation and mineralization of applied animal waste with consequent release of nutrients. Though the recorded values indicated to be non-optimal to most crops probably because it is potted experiment or due to the rates of animal wastes used. In all the amended soils increases in the Na/K and Ca/Mg were not all that reflected in the increasing rate of application. The highest increment in the ratios however were obtained from PW amended soil. Increases in exchange properties of soils following organic wastes application were well documented in Nweke, (2018 and 2019ab). The chemical composition of animal waste varies with the animal size and species, housing and rearing management, feed ration, method of manure storage, climate etc all these might have contributed to the nature of result obtained from this study.

CONCLUSION

Based on the results obtained from the present study animal wastes (Poultry, Swine and Cow wastes) have a high fertilizing value with good potential for restoration of productivity of degraded soil. The moisture and chemical characteristics of the soil improved with the application of the animal waste. Following the characteristics of the nutrients of the animal wastes, poultry waste had the highest concentration of nutrients compared with swine waste and cow waste of which the order of increase showed PW > SW > CW > CO. Thus animal wastes and rates studied are good soil amendments, they improved water retention ability of the degraded soil and essential element contained in then were mineralized of which is capable to support any growing crop in the medium.

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