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Effect of Organic Waste Amendments on the pH of Soil Supporting the Oil Palm

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ABSTRACT
The effect of fresh cow dung and cow dung biochar on soil pH and nutrient availability were determined. The organic treatments were applied at varying rate of 10-40g/kg soil in polybag, with a reference treatment arranged in a completely randomized design and replicated four times. The results showed that the effect was immediate and persisted during the twelve – week study period. Cow dung biochar amended soil had significantly higher pH than the fresh cow dung, and unamended soil. The highest rate (40k/ha^{-1}), (amendment) increased the pH from 4.8 to 7.8 for the biochar and from 5.1 to 6.6 for the fresh cow dung. Mineral N, available P, K, Ca and Mg increased immediately after application of the fresh cow dung amendment and available P and K remained significantly higher in fresh cow dung amended than the biochar amended, and unamended soil at the end of the study.

Keywords: Cow Dung, NIFOR Oil Palm, pH, Soil

INTRODUCTION
The 1996 World Food Summit highlighted sub-Saharan Africa as the remaining region in the world with decreasing food production per capita. The worst levels of poverty and malnutrition in the world exist in this region [1].

Interest in organic farming has long been expressed by individuals who view the advent of high-input technology (especially agricultural chemicals) in farming systems as a potential threat to the environment and human health. However, attempts to grow food crops by organic farming methods have proven to be uneconomical because of low yields, increased labor requirements, high incidence of weed and insect infestations and inadequate amounts of good quality organic amendments to sustain the crop's nutrient requirements. As a result, research on alternative agriculture was conducted that included organic farming, nature farming, rain shelter, and integrated pest management.

Because of increasing concern about the adverse effects of agrochemicals on the environment and human health and questions on the sustainability of these intensive agricultural systems, research on alternative farming emerged with special emphasis on the use of agricultural wastes. Through these concerted efforts, Nigerian agriculture is beginning to utilize available agricultural and processing wastes, which has greatly improved soil quality and the environment.

It is well established that crop production on acid soils can be improved greatly when soil pH is adjusted to near neutrality. Soil pH affects nutrient solubility, and influences the sorption or precipitation of nutrients with Al and Fe [2].

For some time, the research community has recognized low soil fertility, particularly nitrogen and phosphorus deficiencies, as one of the major biophysical constraints affecting the oil palm plantations due to continuous soil-fertility depletion. The urgency to address these threats creates
an ever increasing demand for solutions that can be implemented now or at least in the near future. These solutions need to be widely implemented both locally by individuals and through large programmes in order to produce effects on a global scale. One such approach is the use of cow dung, an animal waste.

The present communication describes the investigation of the effect of organic waste amendment on NIFOR soil pH. This research was intensified to bring about a more efficient agricultural amendment material that is productive, highly profitable, sustainable and environmentally-friendly.

EXPERIMENTAL
Material
The Cow Dung was obtained from the environs of the Nigerian Institute for Oil Palm Research, Benin City, Nigeria.
The Cow Dung was obtained fresh and used as received. The sample was divided into two portions; for one portion, four samples of weight: 10.0, 20.0, 30.0, and 40.0g each were weighed and used for further analysis. The other portion was dried and 4.0kg was pyrolyzed at 300°C for three hours. The Biochar obtained were then milled to fine powder, and sieved through a mesh size of 150µm. The Biochar particles that passed through the screen were collected, characterized and used for further analysis.

Soil samples (0-30cm) collected using auger, used for the study were obtained from the institute plantation site and prepared for further analysis. All the reagents used for analysis were of analytical grade and were used without further purification.

Characterization of the cow dung and the Soil samples

The fresh cow dung and the cow dung biochar were characterized as follows; % moisture content, Ash content was determined according to the method described by ASTM D1762-84 [3], the bulk density was determined according to the method described Ahmedna et al [4], the pH was determined using ASTM D 1512 method [5], conductivity was determined using the pH-conductivity meter. The proximate and mineral composition determined according to AOAC (1990). The calcium and magnesium contents were determined by complexometric titration, while the sodium and potassium content were determined by flame photometry and the nutrients value (Carbonates, Carbon, Nitrogen, and total Phosphorus) were determined using standard methods, heavy metal present were determined using the Atomic Absorption Spectrophotometer(AAS).

The soil samples were characterized as follows: Bulk density was measured by core method [6], Soil pH was measured in 1:1 soil-water ratio [7], Soil organic carbon was estimated by combustion at 840°C [8], while total nitrogen was obtained by microkjeldahl method. Cation exchange capacity was measured using ammonium acetate leaching at pH 7.0 [9]. Available phosphorus was determined by Olsen method [10] and soil heavy metal content was determined using the AAS.

Cow dung-Soil mixture preparation; Experimental Details

Measured quantities of each of the fresh cow dung and cow dung biochar samples (0, 10.0, 20.0, 30.0 and 40.0kg/ha) were thoroughly mixed with soil respectively and were placed in five-liter polyethylene containers. One sprouted seedlings of the oil palm was planted in the center of each pot. The soil was irrigated with water to field capacity.

Determination of the physical chemical properties of the cultivated cow dung- Soil mix

In all, 9 treatments (4 fresh Cow dung, 4 cow dung biochar, concentrations levels; 1 control) per set were arranged in a green house in a complete randomized design with three replications. Observations on height, and physical condition of experimental plant were recorded at periodic intervals.

Soil samples were collected at weekly interval and analyzed for pH and important chemical and physical parameters using recommended procedures.

Statistical analysis

The average data obtained for soil pH and percentage of soil N, P, K, Ca, Mg, soil pH, and Organic matter of oil palm seedlings are analyzed using an ANOVA F-test.

RESULTS AND DISCUSSION

Table 1 shows the characteristics of fresh cow dung (FCD) and cow dung biochar (CDB)

These properties have fundamental importance for a range of effects of amendments on soil properties. From the table, the iodine number of 72.56 mg/g for CDB compared to 25.15mg/g for FCD elicits the amount of surface area for surface reactions with nutrient elements such as adsorptive reactions with ions [11] or element transformations. The greater, the surface area, the more effective the amendments will be in relation to affecting soil properties (although the nature of the surfaces plays an equally important role). Macropores, in the surface area are also relevant to the movement of roots through soil and as habitats for a vast variety of soil microbes.

From the table, the electrical conductivity of CDB is higher than that of FCD showing a tendency for high amount of electrolytes added to soil which could affects its flocculation [12].However, It can be expected that this has an effect on soil only at very high application rates, but may be a factor to consider with some crops that are sensitive to increased salt concentrations or soils with unstable soil structure.

More important is the pH of amendments, which from the table range from 6.1 for FCD to 10.1 for CDB. It has been reported that pH can be high or low depending upon feedstock and production conditions. A high pH can be a key feature of amendments in improving acid soils [13] which is a characteristic feature of the soil supporting the oil palm.

Bulk density of CDB is higher than that of FCD from the table which means higher transport properties of CDB, therefore, the resulting bulk density of soils after amendments additions, would show improve penetrability, drainage and aeration of soils that are essential for good plant growth [12].

Total carbon content of CDB is higher than that of FCD from the table. The total carbon provides a measure of the total amount of organic carbon that is added to the soil and is therefore relevant to the carbon balance and sequestration aspect of biochar management. It also provides a good indicator (along with knowing the ash composition) of the composition of the parent biomass and the process conditions under which the amendment is produced [14]. It supplies a baseline to determine the rate of removal of carbon from the amendment as a function of time in the environment. Since biochar is manufactured from biomass, it is expected that they are high in carbon and contain a range of plant macro- and micro-nutrients.

From the table the nutritive value of the FCD is higher compared to that of the CDB, due to high values of the Magnesium, Calcium, Potassium and Nitrogen content, which influences the cation exchange capacity (CEC) of soil when amendments are added. CEC is a measure of the surface charge in soil or biochar. CEC increases as the biochar ages [15] and this has been attributed to an increase in some of the oxygenated functional groups on the surface of the biochar, unlike the FCD and the unamended [16]. Interactions between surfaces of the biochar and soil particles [17], dissolved organic matter (DOM) [18], gases and water are also a function of the total surface charge and total concentration of functional groups. At the surfaces of the biochar, a range of functional groups exist that include pyranone, phenolic, carboxylic, lactone and amine groups [19].

Cow dung amendments show same ash content, obviously due to the same source of feedstock. However, two factors, feedstock and process conditions, control the amount and distribution of mineral matter in amendments. The mineral ash content of feedstocks varies significantly; woody feedstocks generally have low (<1 per cent by weight) ash contents, whereas grass, straw and grain husks, which have high silica contents, may have as much as 24 per cent by weight ash [20]. Much of the mineral content in the feedstock is carried over into the biochar where it is concentrated due to loss of C, H and O during pyrolysis. Biochar from manures and rendering wastes typically have very high ash contents. Chicken-litter biochars, for example, can have 45 per cent mineral matter [21], and bone biochars may have as much as 84 per cent mineral matter [22]

Table 2 shows the physico-chemical properties of the Soil. The result shows that the soil is acidic and the nutritive value is low, hence the need for improvement in the quality of the soil for increase yield and productivity.

The application of cow dung amendments to soil had an immediate effect on soil pH. The pHs of CBD-amended and FCD-amended soils were significantly higher than unamended soil and the effect persisted during the twelve week period of the study. The application of 40kg/ha CDB and FCD per kilogram soil provided the highest buffering capacity of the manure rates examined and increased the pH from 4.8 to 7.8.
There was an immediate increase in the pH of the soil after application of the cow dung amendments and the effect persisted during a 12-wk treatment period of soil-amendments mixture. Other studies have reported a similar effect on soil pH after application of fresh or composted animal manure [23]. However, soil pH has been shown to decline in some organic waste amended soils. The effect of organic waste on soil pH will depend on the manure source and soil characteristics.

Immediately after application mineral nitrogen concentrations were greater in FCD-amended than unamended soil, significantly higher in the 40kg/ha manure amended soil. Mineral nitrogen concentrations tended to be greater in FCD-amended than unamended soils immediately after application of fresh manure. Ammonium levels in FCD and CDB-amended and unamended soils declined significantly in the

first 2wks of treatment, followed by an increase from week 2 to 12. The net decline in the mineral nitrogen concentration of FCD amended soils may have been due to immobilization or stabilization of nitrogen in non-extractable chemically or physically protected pools, and possibly gaseous losses. It seems possible that organic waste applications stimulated microbial activity, either by increasing soil pH or providing readily available carbon substrates for microbial growth, which may have resulted in net nitrogen immobilization after 12week treatment. Conversely, CDB-amended and unamended soil produce net increase in the mineral nitrogen pool, which suggest conditions were more favorable for microbial growth and activity.

Available P, K, Ca and Mg were higher in FCD- amended soil, followed by CDB-amended soil than unamended soil, immediately after the application. Subsequently, available P,Ca, and Mg concentrations were significantly higher in soils receiving 20,30,40kg/ha CDB per kilogram soil, while available K levels were significantly higher in soil with FCD-amended with 30 or 40kgha FCD per kilogram than unamended soil. After 12-wk, available P levels remained significantly higher in soil amended with 20,30 or 40kg/ha FCD per kilogram. Available Ca and Mg concentrations after 12-wk were significantly higher in soil amended with 40kg/ha CDB than FCD and unamended soil.

The bicarbonate concentrations was higher in FCD-amended than unamended soil immediately after application, however, the difference in bicarbonate levels between FCD-amended and unamended soil after 12-wk period decreased. The bicarbonate concentration in soil amended with 40g FCD per kilogram was higher than unamended soil after application and after 12-wk period.

It has been proposed that changes in the pH of soils amended with cow dung are due to buffering from $CaCO_3$. Since much of the $CaCO_3$, added to cow diets may be excreted in waste [24]. We did not detect carbonate in either the waste or soil examined in this study, although, large quantities of bicarbonate were present in fresh cow dung, and FCD-amended soils. The higher soil pH in FCD AND CDB- amended than unamended may have been partially, although not totally, due to buffering from bicarbonates. However, compounds other than $CaCO_3$ and bicarbonates such as organic acids with carboxyl and phenolic hydroxyl groups, have an important role in buffering soil acidity and increasing the pH of soils amended with organic waste.

Available P and K concentrations were greater in amended than unamended soils throughout the study, which suggests that much of the P and K added through amendment remains in a pool that is readily available for plant uptake. Despite the addition of Ca and Mg from cow dung to soil-amended mixtures, quantities of plant available Ca and Mg were greater only in soils amended with the highest amendment rate than unamended with the highest amendment rate than unamended soil after 12wk treatment.

Tables 5 summaries the effect of cow dung amendments on the growth rate of the oil palm sprouted seedlings over a period of twelve weeks.

The table shows a significant growth rate expressed in terms of the height of the oil palm sprouted seedlings for both FCD and CDB amendments, however, the CDB showed a significant effect on growth compared to that of the FCD during the period, relative to the growth in the control, which is quite lower when compared to soils containing the amendments.

The probable reason for this is due to high nutritive value of the CDB of the amendments, which has a significant effect on the soil supporting the oil palm.

CONCLUSION

The study reveals that organic waste amendments can increase soil pH and supply considerable quantities of plant –available nutrients.

The results show that amendments prepared from cow dung influenced the physico-chemical properties of soil supporting the oil palm and that the growth rate of the sprouted seedlings compared to the control is remarkable, in terms of obvious results of the biometric data.

The results indicate that there is an improvement in the ability of the soil to improve growth of the oil palm by reason of the introduction of the amendment.

Table 1: Characteristics of cow dung samples.

Parameters/ Samples	**Fresh cow dung**	**CowDung Biochar**
pH of slurry at 28^{o}C	6.1±0.1	10.1±0.1
Conductivity (µs)	7150±701	14110±2612
Bulk Density(g/ml)	0.411±0.125	0.625±0.111
Surface area (Iodine Ads)mg/g	25.15±0.15	72.56±0.10
Ash Content (%)	9.8±0.1	9.8±0.1
Potassium content (mg/kg)	655±15	610±18
Magnesium content (mg/kg)	12,250±122	11,700±205
Calcium content (mg/kg)	12700±181	11,050±119
Sodium content (mg/kg)	6005±21	6840±45
Carbon (g/kg)	385±11	711±9.8
Nitrogen(g/kg)	68±3.1	34±3.4
Total Phosphorus(mg/kg))	1135±11	755±32

Table 2: Physio-chemical properties of the soil sample

Properties		**Value**
Depth, cm		30
pH		4.8±0.1
Conductivity,µs ©		2720±602
Bulk Density(g/ml) (BD)		1.58±0.05
Moisture content(MC)		6.4±0.1
Particle size(PS)	%clay	6.38
	%silt	1.40
	% sand	92.22
Total Acidity(TA)		5.7±0.1
Total Organic Carbon (g/kg)(TOC)		1.568±0.05
Total Nitrogen,(g/kg)(TN)		0.104±.02
Phosphorus,(mg/kg)(P)		33.706±5.14
Sodium content, (mg/kg)(SC)		718±11
Potassium content, (mg/kg)(PC)		987±24
Magnesium content(mg/kg)(MC)		499.2±9.8
Calcium content,(mg/kg)(CC)		608±6.1
CEC(mg/kg)		2792.2

Table 3: Effect of cow dung on extractable nutrients and cation-exchange capacity (CEC) of the oil palm soil immediately after application.

Sample	Rate(g)	pH	N	P	K	Ca	P	Mg	HCO_3^- (mg/kg)
Soil-CDB	0	4.8	10.41	33.7	98.70	60.8	3.8	0.2	228.1
	10	5.8	12.77	36.8	99.05	65.4	6.8	9.8	384.2
	20	6.2	13.50	35.6	100.50	68.5	11.5	10.5	361.0
	30	6.8	14.42	37.8	110.05	69.9	28.6	14.8	561.5
	40	6.8	20.18	39.7	124.51	72.5	35.6	18.2	605.5
	C.V(%)	13.7	29.5	6.2	10.4	6.7	81.4	63.4	36.1
	LSD(5%)	0.37	0.76	0.41	2.00	0.81	2.54	1.23	27.85
Soil-FCD	0	4.8	10.41	33.7	98.70	60.8	3.8	0.2	228.1
	10	5.3	8.72	38.1	125.08	61.5	9.8	11.3	221.1
	20	6.0	11.85	45.8	145.03	64.7	13.0	15.4	327.1
	30	6.1	23.25	51.5	180.91	66.9	33.1	17.4	412.5
	40	6.4	25.46	65.7	205.05	68.5	56.2	19.7	556.5
	C.V(%)	11.4	49.0	26.7	28.2	5.2	90.8	27.4	43.9
	LSD(5%)	0.12	1.41	2.26	7.70	0.60	3.78	0.73	27.04

CDB = Cow dung Biochar, FCD = Fresh cow dung, LSD (5%): Least square difference at 5% probability, C.V: Coefficient of variation

Table 4: Effect of cow dung on extractable nutrients and cation-exchange capacity (CEC) of the oil palm soil after 12-wk treatment

Sample	Rate (g)	pH	N	P	K	Ca	P	Mg	HCO_3 (mg/kg)
Soil-CDB	0	4.8	11.41	38.7	108.29	64.4	33.7	0.1	292.0
	1	6.5	18.94	42.4	110.89	67.5	7.3	15.8	315.2
	2	6.8	19.95	58.3	132.16	69.5	38.6	18.8	486.9
	3	7.3	25.53	65.3	187.90	71.1	49.8	22.6	501.3
	4	7.8	30.88	74.5	197.71	75.5	69.7	28.9	641.5
	C.V(%)	17.2	29.1	27.7	29.5	5.4	82.3	61.8	39.2
	LSD(5%)	0.71	1.15	2.79	7.82	0.69	5.05	1.93	30.52
Soil-FCD	0	4.8	11.41	38.7	108.29	64.4	33.7	0.1	292.0
	1	5.8	19.81	48.9	125.51	65.7	10.1	0.6	352.1
	2	6.6	25.80	57.2	160.66	68.1	14.5	0.6	411.1
	3	6.4	27.81	66.7	193.25	69.6	36.2	0.7	485.5
	4	6.6	29.84	68.9	224.77	70.5	49.4	0.9	591.5
	C.V(%)	12.4	32.3	22.4	29.4	3.8	56.5	5.1	27.4
	LSD(5%)	0.14	1.34	2.27	8.63	0.47	2.94	0.05	21.15

CDB = Cow dung Biochar, FCD = Fresh cow dung, LSD (5%): Least square difference at 5% probability level

Table 5: Biometric observations of the oil palm sprouted seedlings showing the height and leaf number

Control (FCD)	Ht (cm)	LN	**W1**	Ht (cm)	LN	**W2**	Ht (cm)	LN	**W3**	Ht (cm)	LN	**W4**	Ht (cm)	LN
4	6.5	2		9.1	3		10.0	2		11.5	3		11.5	2
8	7.5	2		9.5	3		10.5	2		12.2	2		12.5	2
10	8.1	3		10.1	2		10.8	2		12.5	2		13.1	2
12	9.5	3		10.8	3		11.5	3		13.8	3		14.5	3
Control (CDB)	**Ht** (cm)	**LN**	**W1**	**Ht** (cm)	**LN**	**W2**	**Ht** (cm)	**LN**	**W3**	**Ht** (cm)	**LN**	**W4**	**Ht** (cm)	**LN**
4	9.0	1		11	2		11.5	2		12.5	2		16.5	2
8	10.0	3		11.5	2		12.0	3		13.0	2		18.5	3
10	10.5	2		11.5	2		12.0	2		15.5	3		19.0	2
12	11.5	2		12.0	3		13.5	3		15.5	3		20.0	3

Ht=Height, LN = Leaf Number

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