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IMPACT OF ORGANIC AMENDMENTS ON THE GROWTH OF MAIZE (*Zea mays* L.) AND CHEMICAL PROPERTIES OF ACID SULPHATE AND COASTAL PLAIN SOILS

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ABSTRACT

In a pot experiment, this study examined the impact of selected organic amendments on coastal plain and acid sulphate soils. Maize was used as a test crop. The treatments were as follows: cattle manure (cm), sheep manure (sm), mushroom production waste (mpw), water hyacinth (*Eichhornia crassipes*) biomass (whb) and urea. A completely randomized design with four replicates was used. Routine laboratory procedures were used to determine soil pH, total nitrogen, organic carbon, available phosphorus and exchangeable cations (Na, K, Ca and Mg). The organic amendments were also analyzed for pH, nitrogen and organic carbon, Mg, Ca, Na, K and P. Planting of test crop was done twice, each lasting for 30 days with a fallow period of 10 days. The following results were obtained: (i) At the end of the experiment, soil pH ranged between 6.2 and 8.2 in coastal plain sands and between 2.5 to 6.5 in acid sulphate soil. Soil pH was highest in coastal plain sands (8.2) and in acid sulphate soil (6.5) amended with water hyacinth biomass at the end of experiment, (ii) Organic carbon content was significantly higher in acid sulphate (3.7%) than in coastal plain (1.7%) soils. This trend was sustained till the end of the experiment, (iii)Yield of maize shoot was highest in coastal plain sands amended with cattle manure and sheep manure during the first and second planting. This scenario was nearly repeated in acid sulphate soil, where the highest shoot yield was harvested from pots amended with cattle manure and water hyacinth biomass. These findings seem to attest to the chemical composition of the organic amendments used in this study, and therefore warrants validation in an agronomic experiment.

Keywords: pot experiment, organic amendments, maize, soil pH.

INTRODUCTION

Continuous cropping, soil erosion, bush burning and crude oil spillage are factors that can deplete the fertility of the fragile Ultisols of South-Eastern Nigeria. In most parts of the tropics, demands on soil resources are on the increase due to rise in population, growing urbanization and increasing subsistent needs per capita. Most of the available agricultural land in the humid tropics is marginal, fragile and largely infertile especially under the prevalent Oxisols and acid Ultisols.

Attempts at ameliorating these soils by the application of chemical fertilizers and liming materials are procured by high cost, which render them unaffordable by resources – poor farmers who are responsible for the bulk of food produced in the region. The depletion of soil nutrients due to continuous cropping reduces the soil organic matter (SOM) and leads to significant acidification and reduction of yield (Sanchez and Salinas, 1981).

Numerous studies have demonstrated that organic amendments including livestock manure, sewage sludge and green plant biomass, after proper composting, can be used with desirable results (Zhang *et al.*, 2006). The application of organic amendments to soil has been shown to improve soil physical and chemical properties (Ikpe *et al.*, 2003). During decomposition of organic matter, nutrients are released to growing plants and the concentrations of plant available nutrients are increased in soil (Ikpe *et al.*, 2003).

Animal (cattle, sheep and goats, poultry and pig) manures have been shown to contain large amounts of organic matter, nitrogen (N) and significant concentrations of basic cations such as magnesium (Mg), calcium (Ca) and potassium (K) which are essential nutrients for plant growth and development (Johnson *et al*, 2006; Ojeniyi, 2000; Ojeniyi *et al*, 2009).

The main objective of this experiment, was to examine the impact of organic amendments including urea on the growth of maize and chemical properties of coastal plain sands and acid sulphate soils that are prevalent in South-Eastern, Nigeria.

MATERIALS AND METHODS

A pot experiment was conducted in the screen house of the Department of Crop/Soil Science, Faculty of Agriculture, Rivers State University of Science and Technology, Port Harcourt (latitude 04.51^{O}N and longitude 07.01^{0}E). The mean annual rainfall in Port Harcourt is 2400 mm in monomodal distribution, lasting from March to November. Temperatures are moderate. Relative humidity in the area remains high throughout the year, with mean values ranging from 78% in February to 89 in July and September. Monthly mean temperatures of the coolest (July and August) and hottest months (February to April) are 25 and 27^{0}C, respectively.

Table 1: Initial Chemical Properties of Soil used for the Experiment

	pH	TN	OC	Available P mg/kg^{-1}	Exchangeable Mg	Ca	Na	K	Sand	Silt	Clay	Textural Class
		%				cmolkg^{-1}				%		
CPS	6.60	0.08	1.20	11.93	0.66	1.52	3.81	0.25	85.2	4.0	10.8	Loamy Sand
ASS	3.50	0.15	3.70	0.07	1.69	1.10	2.13	1.14	60.21	28.28	10.91	Sandy Clay Loam

CPS – Constal plain sand ASS – Acid sulphate Soil

Table 2: Chemical Composition of Organic Amendments

		pH	TN	OC	CN	Mg	Ca	Na	K	P
1	CM	7.70	1.4	29.0	20.7	0.41	0.87	0.04	0.58	0.48
2	MPW	7.40	2.1	14.0	6.6	0.28	0.34	0.67	0.88	0.35
3	WH	6.90	0.7	39.0	55.7	0.63	0.68	0.16	1.10	0.90
4	SM	7.70	2.8	28.0	10.0	0.58	0.32	0.15	0.73	0.52
	$LSD_{(p<0.05)}$	2.91	1.35	7.14	-	0.75	0.75	0.35	1.30	1.10

CM: Cattle Manure
SM: Sheep Manure
MPW: Mushroom Production Waste
WH: Water Hyacinth Biomass

Soil preparation and analytical methods

Coastal plain surface soil (0-15cm) sample was collected from the Teaching and Research Farm of the University, while acid sulphate soil sample was obtained from mangrove ecology on the Eagle Island, Port Harcourt.

The soil samples were air-dried and sieved to pass through 2mm diameter screen. Thereafter 3kg of soil was placed in half the number of the plastic pots with either acid sulphate soil or coastal plain sands. Prior to the addition of organic amendments, the soils were sampled and analyzed for particle size as determined by Juo, 1978 using the Bouyoucos hydrometer method, pH (1.2:5) soil: water, total organic carbon (wet oxidation method), total Kjedahl-N was determined by the Kjedahl digestion and distill ation procedure as described by Eno *et al.* (2009), Bray-1 extractable –P, and extractable cations (Eno *et al*, 2009). Organic matter content was obtained by multiplying organic carbon values by a factor of 1.724 (Eno *et al*, 2009) (Table 1).

Chemical analysis of plant and manure dry matter (DM)

The chemical composition of water hyacinth biomass (WHB); cattle manure (CM) sheep manure (SM) and mushroom production waste (MPW) are shown in Table 2. Subsamples of biomass (shoots), manure and waste emanating from mushroom production were oven-dried (60^0c) for 48h for dry matter determination.

Dry matter (DM) of subsamples were milled to pass through a 1-mm screen before being subjected to acid digestion and analyzed for total – N and – P using a spectrophotometer. Digests of organic amendments obtained by nitric acid and hydrogen peroxide digestion were analyzed for pH and exchangeable cations (Eno *et al*., 2009).

Treatments

The experiment was laid out in a completely randomized design with two soil types factorially randomized with five organic amendments and assigned to plastic pots. The total number of treatments, including the control pots were twelve. This study was replicated four times.

To each pot containing (3) three kilogrammes of soil equal amount of N was added with application for organic amendments. Equivalent of 120kg total-N ha^{-1} (iso-N) was added to each pot as organic amendments before mixing thoroughly with the soil except the control pots which received no amendments.

Tap water was thereafter added to each pot to bring them to field capacity. The pots were left in the screen house for a period of ten days to stabilize and mineralization of organic amendments to begin.

Maize Cropping and Harvesting

After the fallow period of ten days, maize (*Zea mays L*.) seeds of var. Oba super II were sown in each pot at the rate of four seeds per pot. The maize seedlings were later thinned to two plants per pot. There were two plantings, each planting lasted for 30 days with a fallow period of 10 days in between plantings.

Data for maize growth (plant height and leaf area) were collected at 10, 20 and 30 days after planting (DAP). At 30 days after planting, plants were harvested by cutting the shoot a little above soil level. The roots were also carefully and gently pulled from the soil and rinsed of any soil that may adhere to them. Thereafter, they were placed in the oven at 60^0C for 48h for dry matter determination.

Statistical analysis

Statistic analysis of soil and plant data was performed using the analysis of variance (ANOVA). Where the soil type and organic amendment effects are significantly different, least significant difference (LSD) was used to compare the means.

RESULTS

Soil Physico-chemical Properties

The texture of soils used for the study was loamy sand for coastal plain sands and sandy clay loamy for acid sulphate soil (Table 1). The pH of coastal plain sands was 6.6 while that of acid sulphate soil was 3.5. The low pH of acid sulphate soil was expected due to its content of pyrites which on exposure to oxidation results in sulphuric acid. Other chemical properties that were significantly different among the two soil types were organic carbon, available phosphorus (P) and basic cations (Table 1). Also expected was the low concentration of available P in acid sulphate soil. This was due to the extremely acid reaction which results in the fixation of P with iron and aluninium which predominate in acid soils.

There were significant variations in soil chemical properties at the end of the experiment compared with those before the application of organic amendments (Table 3). For instance, the pH in both soil types increased significantly at the end of the experiment. The highest pH in both soils was observed in pots amended with water hyacinth biomass.

Table 3: Chemical Properties of Soil at the end of Experiment

Treatment	pH	TN	OC	P(mg/kg^{-1})	CA	Mg	Na	K
		%				(cmol/kg^{-1})		
Coastal plain sands								
CM	7.0	0.11	1.7	18.43	2.6	0.78	4.56	0.45
SM	7.0	1.13	1.62	15.91	2.5	0.72	4.20	0.31
MPW	6.8	0.06	0.80	13.02	1.8	0.67	4.87	0.29
WH	8.2	0.09	1.80	18.60	2.86	0.68	3.90	0.35
UP	6.2	0.16	1.03	12.13	1.72	0.63	3.20	0.15
CPS	6.3	0.07	1.02	12.40	1.48	0.65	3.00	0.18
Acid sulphat soil								
CM	3.9	0.18	3.88	0.11	1.85	1.87	2.50	1.19
SM	3.3	0.19	3.84	0.09	1.76	1.72	2.40	1.16
MPW	2.5	0.12	3.07	0.08	1.09	1.04	2.90	1.17
WH	6.5	0.11	3.63	0.09	1.94	1.01	2.26	2.02
UP	2.7	0.17	3.68	0.06	1.55	1.01	2.30	1.13
ASS	2.8	0.10	3.66	0.07	1.67	1.01	2.19	1.12
LSD (P<0.05)	1.7	0.25	1.0	1.6	0.6	1.5	1.4	0.3

CM: Cattle Manure
SM: Sheep Manure
MPW: Mushroom Production Waste
WH: Water Hyacinth biomass
CPS: Coastal Plain Sands
ASS: Acid Sulphate Soil

The pH in pots amended with urea did not differ at the end of the experiment in coastal plain sands instead it decreased in acid sulphate soil amended with urea.

Most of the chemical properties including available P, organic carbon and calcium increased by the end of the experiment in acid sulphate soil amended with water hyacinth biomass (Table 3).

Plant Growth

In the first planting, tallest plants were observed in pots amended with cow manure while the shortest plants were in pots assigned to water hyacinth biomass in coastal plain sands (Fig 1). In the second planting of 30 days, pots amended with cattle manure, sheep manure and water hyacinth biomass did not differ ($p<0.05$) differ significantly in height (Fig. 2).

Leaf area measured in the first and second planting in coastal plain sands followed a similar trend with that of plant height (Figs. 3 and 4). For acid sulphate soil, the scenario was significantly different. Pots amended with cattle manure consistently produced the tallest plants and those with largest leaf area in the first planting. The second planting failed to produce plants (Figs. 5 and 6).

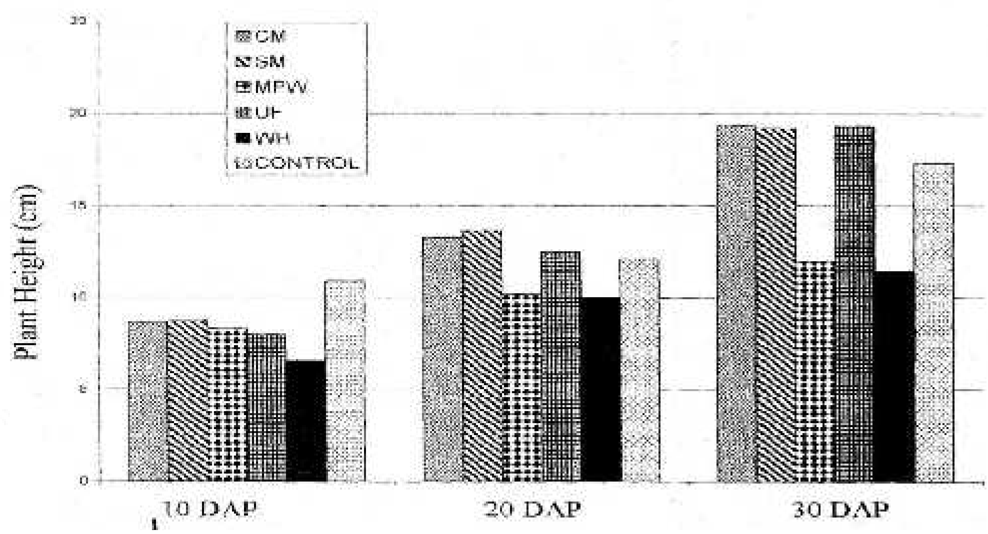

Fig. 1: Maize height at various stages of growth in response to amendment at first planting on coastal plain sands

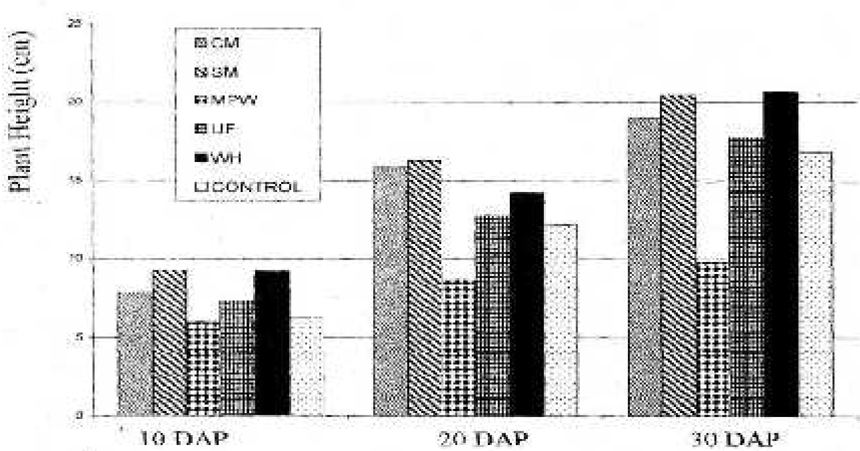

Fig. 2: Maize height at various stages of growth in response to amendment at second planting on coastal plain sands.

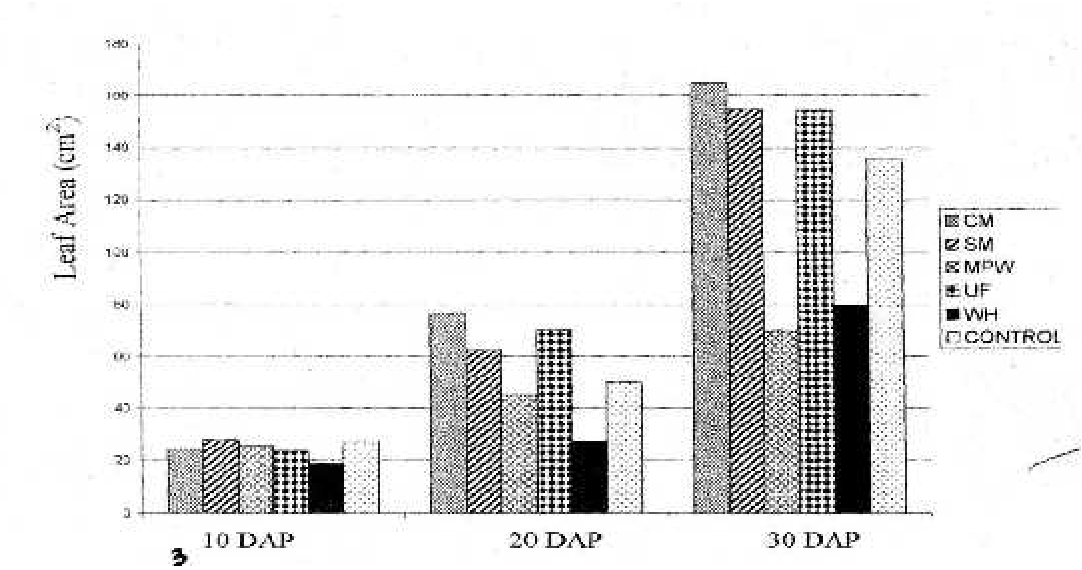

Fig. 3: Maize leaf area at various stages of growth in response to amendment at first planting on coastal plain sands.

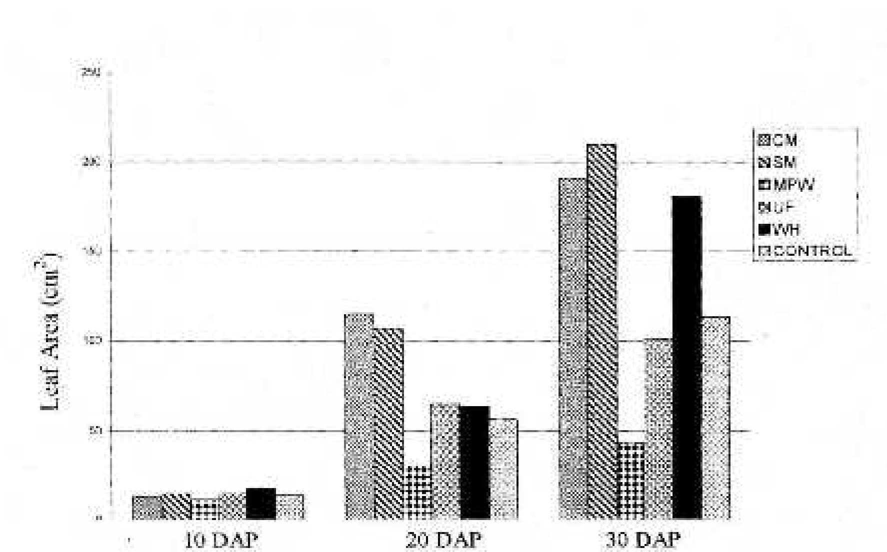

Fig. 4: Maize leaf area at various stages of growth in response to amendment at second planting on coastal plain sands.

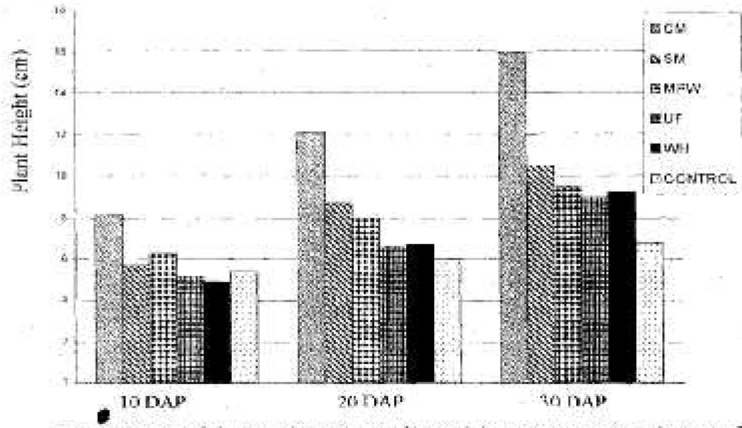

Fig 5 Maize height at various stages of growth in response to amendment at first planting on acid sulphate soil

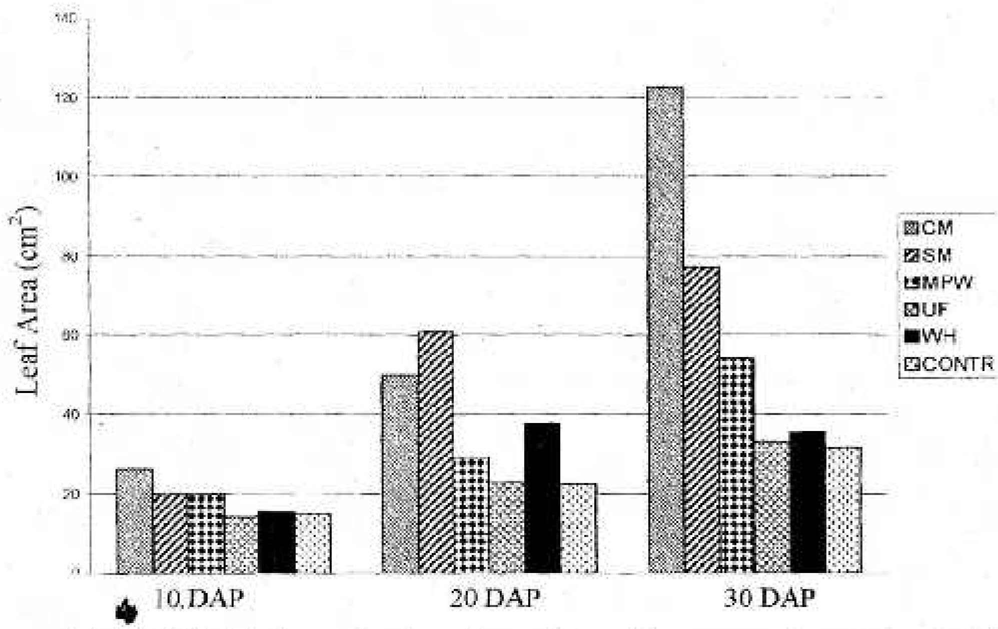

Fig 6: Maize leaf area at various stages of growth in response to amendment at first planting on acid sulphate soil

Maize Biomass Yield

Maize yield (shoot and root DM) were measured at the end of each planting (Table 4). In the first planting, using coastal plain-sands, pot amended with urea gave the greatest DM yield followed by cattle and sheep manure.

Dry matter yield obtained from acid sulphate soil was significantly lower compared with what was obtained in the coastal plain sands (Table 4). The highest DM yield was obtained from pots amended with cattle manure followed by those of water hyacinth biomass and sheep manure.

In the second planting, DM yield was generally higher in coastal plain sands than that obtained in the first planting (Table 5). The lowest DM in coastal plain sands in the second planting was observed in pots amended with mushroom waste. In acid sulphate soil, only two treatments survived till harvest. The treatments were those of cattle manure and water hyacinth biomass (Table 5).

Table 4: Maize dry matter yield at first planting

Treatment	**Root**	**Shoot**	**Total biomass**
	g		
Coastal plan sands			
CM	0.83	3.03	2.86
SM	0.88	3.03	3.79
MPW	0.67	1.19	1.86
UF	1.10	3.50	4.6
WH	0.40	0.76	1.16
CPS	0.66	2.34	1.42
Acid sulphate soil			3.54
CM	0.64	2.90	1.83
SM	0.21	1.62	1.22
MPW	0.37	0.85	0.41
UF	0.14	0.27	1.97
WH	0.47	1.50	0.40
ASS	0.11	0.29	1.0
LSD (P<0.05)	0.25	0.5	

CM: Cattle Manure
SM: Sheep Manure
MPW: Mushroom Production Waste
WH: Water Hyacinth biomass
CPS: Coastal Plain Sands
ASS: Acid Sulphate Soil

Table 5: Maize dry matter yield at second planting

Treatment	Root	Shoot	Total biomass
Coastal plain sands			
CM	0.75	6.13	6.88
SM	1.34	6.85	8.15
MPW	0.63	0.40	1.03
UF	0.96	1.91	2.87
WH	1.16	3.70	4.86
CPS	0.90	2.15	3.11
Acid sulphate soil			
CM	0.60	3.40	4.00
SM	-	-	-
MPW	-	-	-
UF	-	-	-
WH	0.95	1.95	2.90
ASS	-	-	-
LSD ($P<0.05$)	0.58	3.3	1.0

CM: Cattle Manure
SM: Sheep Manure
MPW: Mushroom Production Waste
WH: Water Hyacinth biomass
CPS: Coastal Plain Sands
ASS: Acid Sulphate Soil

DISCUSSION

The two soil types used in the study are known to be low in inherent fertility. They are highly weathered and acid and their mineralogy, dominated by low activity clays. Consequently, these soils have low cation exchange capacity (CEC), which is normally less than 8cmol kg^{-1} of soil and low base saturation. The soils have a low organic matter (0.5-3%) particularly, coastal plain sands and consequently low nutrient reserve.

The extremely high acidity of the acid sulphate soil was probably responsible for the death of most of the maize plants in the second planting (Table 6) and the extremely low available P concentrations (Table 1 and 3). Only in pots amended with cow manure and water hyacinth biomass did plants survive.

The C:N ratio of the organic amendments seems to have had a significant effect on the decomposition and consequently on the release of nutrients in this study (Table 2). Organic amendments with C:N ratio of 25 and below decompose and release nutrients faster than those above 25 (Ikpe and Powell, 2002). Thus nearly all the nutrients in mushroom production waste (C:N ratio of 6.6) may have been released in the first planting. The poor performance of maize plants in the second planting in pots amended with mushroom production waste for both soil types probably confirms this thinking. (Figs.1-6). On the contrary, cattle manure and water hyacinth biomass with C:N ratios of 20.7 and 55.7, respectively decomposed slowly and consequently released nutrients slowly during the first and second planting. This may explain why plants survived in pots amended with cattle manure and water hyacinth biomass only in acid sulphate soil.

The above scenario, seems to suggest that organic amendments with high C:N ratio of 25 and above are perhaps more suitable for cropping on acid sulphate soils. Secondly, water hyacinth biomass had organic carbon content of 39% while cattle and sheep manure had 29 and 28%, respectively.

Further studies including the fractionation of carbohydrates (carbon) in the organic amendments used in this study into structural (lignin, hemicellulose, cellulose) and total non-structural carbohydrate is warranted. Also, a decomposition study to determine the decay rate constants (k) of mushroom production waste and water hyacinth biomass, which are relatively unknown as organic amendments in South eastern Nigeria is advocated.

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