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Research article

Comparative study of the influence of water hyacinth – based liquid organic fertilizer, poultry droppings and inorganic fertilizer on the cultivation of *Zea mays* on loamy and white sandy soils

Ikuesan, M.O[1], Ikuesan, F.A[2]*, and V. O. Oyetayo[1]

[1]Department of Microbiology, The Federal University of Technology, Akure, Nigeria
[2]Department of Biological Sciences, Olusegun Agagu University of Science and Technology, Okitipupa, Nigeria

fa.ikuesan@oaustech.edu.ng

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Abstract
The influence of water hyacinth-based liquid fertilizer and two soil amendment materials on the growth and yield of *Zea mays* were comparatively investigated. White sandy and loamy soils and Water hyacinth were collected respectively from Igbokoda and Obaile and Alape River in Ondo State, Nigeria. The liquid organic fertilizer developed by wet fermentation method, poultry droppings and NPK fertilizer were then applied as soil amendment materials to *Zea mays* planted in 20 litre soil- filled perforated buckets and then monitored monthly for three months. Sample analyses by standard physical and chemical analytical techniques revealed a pH of 6.78 and 7.27 and heavy metal concentration in the range of 0.00 -187.56 (mg/kg) and 0.06 – 293.16 (mg/kg) for the loamy and white sandy soil respectively. The Water hyacinth plant parts also differ in their proximate composition with the leaf having highest value of moisture (65.45%), protein (12.18%) and carbohydrate (5.30%). The study also revealed highest values of ash (18.48%), fat (3.84%) and crude fibre (12.50%) in the plant root relative to leaf and stem. The present study revealed that the application of water hyacinth- based liquid fertilizer, poultry droppings and the inorganic fertilizer had significant influence on the growth parameters and yield of maize on both soil types relative to the unamended control, but the growth responses and the number of ear maize produced vary with treatments, growth period and soil types. The number of ear maize at the end of the planting season were 2, 2, 4 and 2 for white sandy soil and 1, 3, 8 and 7 for loamy soil respectively for the un-milled biofertilizer, milled biofertilizer, poultry dropping and NPK treated soils. This study revealed that water hyacinth – based biofertilizer has the potential to improve the quality and integrity of soil for improved *Zea mays* production.

Keywords: Fertilizer, Loamy soil, Maize, Poultry dropping, Water hyacinth, White sandy soil.

Introduction

Profitable agriculture partly determined by the quality and integrity of agricultural soil is the ultimate desire of every farmer. Soil is a medium for the anchorage of plants, supply of nutrients for plant growth and habitat for micro flora and micro fauna but varies in types and functions (Ikuesan *et al*., 2019). Whatever be the type and variety of crops, good soil health is required for the cultivation and yield of crops and therefore considered to be the foundation of productive agriculture. Soil types and functions can however be adjusted. A pH value of 6.5-7.5 is considered optimum for growth of many plants (Oyem and Oyem, 2013). Extreme pH values decrease microbial activity in soils, thereby affecting many soil processes such as organic matter decomposition, nitrification and the biological nitrogen fixation. An acidic soil of pH 4.5 could be adjusted by liming to pH 7.4 (Odeyemi, 2014). Other soil characteristics affecting soil quality include soil moisture, organic matter and organic carbon contents. Soil organic matter is principal soil property affecting biological activity in soil. Clay soils may need to be amended with bulking agents in order to improve oxygen transport. Sandy soils may need to be amended with organic matter to improve the soil water holding capacity (Ikuesan *et al*., 2016).

While loamy soils are recognized for their relatively balanced texture and fertility (Ahlgren *et al.,* 2013), white sandy soils tend to possess low nutrient content, inadequate water retention, and a scarcity of organic matter (Bashir *et al.,* 2021). Implementing effective soil amendment techniques is vital for maximizing crop yields and promoting sustainable farming practices in these varied soil conditions (Selim, 2020).

The quest for profitable agriculture has led to increased usage of chemical fertilizers for greater crop yields (Gamage *et al.,* 2023) but its imbalance and continuous usage have a detrimental effect on soil quality with concomitant decline in crop yields (Pahalvi *et al.,* 2021; Vejan *et al.,* 2021). Makawita *et al*. (2021) and Hoang *et al.* (2018) reported that the excessive use of synthetic fertilizers, growth stimulants, and pesticides resulted in unfavorable outcomes in agricultural production. Shukla and Saxena (2020) and Laditi *et al*. (2012) also stated that the continued use and overuse of petrochemical- based fertilizers and toxic pesticides have caused detrimental effects to the soils, water supplies (surface and groundwater pollution particularly through nitrate leaching), foods as well as human and animal health. These negative consequences due to the protracted use of chemical fertilizers prompted the introduction of organic fertilizer as viable alternative (Khoshru *et al*., 2020) to improve soil quality and integrity thereby promoting plant growth and improved crop yield for biosafety food (Bhardwaj *et al*., 2014; Buragohain *et al*., 2017). Therefore, to sustain soil quality and crop production for prolonged periods, it is imperative to adapt the advanced crop management practices which avoid the use of agrochemicals and rely on ecosystem management (Srivastav *et al.,* 2021). These innovative techniques to improve soil fertility while reducing environmental degradation is attractive and sustainable through the use of organic amendments, especially plant-based fertilizers due to its potential to boost crop yields while preserving ecological equilibrium (Rastogi *et al*., 2023). Liquid fertilizer is any type of fertilizer that is applied to the soil in liquid form. This form of fertilizer is rapidly absorbed by the soil and boost the supply of nutrients for plant growth especially those growing in poor soil conditions.

Aquatic weeds are those persistent plants which grow and complete their life cycle in water and cause severe economic and ecological harm to aquatic environment. Water hyacinth (*Eichhornia crassipes*), is a free -floating perennial freshwater plant, which proliferates rapidly in large areas of water across continents especially where nutrient levels are often high due to agricultural runoff, deforestation and insufficient wastewater treatment causing a significant economic and ecological burden and considered as the world's worst aquatic weed (Andika *et al*., 2013; Jafari, 2010). The weed represents a significant environmental challenge due to its rapid proliferation and detrimental impact on aquatic ecosystems (Harun *et al.,* 2021). The environmental nuisance of *Eichhornia crassipes* include blockage of rivers, lakes and waterways and obstruction of irrigation, navigation and fishing as well as reducing light and oxygen, change water chemistry, affect flora and fauna and causing significant increase in water loss due to evapotranspiration and threat to biodiversity (Sahana and Sowmyalatha, 2022; Andika *et al*., 2013, Jagadish *et al*., 2012). Water hyacinth (*Eichhornia crassipes)* has resisted biological, physical and mechanical control measures with huge cost implications (Rajan *et al*., 2023; Andika *et al*., 2013). However, it has been found useful both as fertilizer and raw material for handicrafts production (Andika *et al*., 2013) and feed for fish and animals; cattle, goats, pigs and poultry (Rajan *et al*., 2023). The high biomass and nutrient content offer potential as raw material for producing organic fertilizers, particularly through fermentation processes (Gaurav *et al.,* 2020). Water hyacinth-derived fermented leaf fertilizers provide vital minerals like potassium (K), phosphorus (P), and nitrogen (N), all of which are necessary for plant growth and development (Sierra-Carmona *et al.,* 2022; Nega *et al.,* 2022). Microbial decomposition of water hyacinth results in the breakdown of fats, lipids, proteins, sugars and starch contents (Sahana, and Sowmyalatha, 2022; Andika *et al*., 2013) while according to (Simbarashe *et al*., 2012) water hyacinth liquid manure has appreciably high nitrogen (3.72%) and phosphorous (2.86%) contents suggesting its suitability as a macronutrient fertilizer. In addition to providing crops with essential nutrients, the use of water hyacinth-based fertilizers in agricultural soils enhances microbial activity and improves soil structure, contributing to overall soil health.

Ikuesan and Fajolu (2022) reported that water hyacinth is an inoculum carrier for biofertilizer, harbouring diverse groups of bacteria and fungi such as *Azospirillum*, *Azotobacter, Rhizobium*, *Bacillus* spp. *Aspergillus* spp., *Trichoderma* spp. which are classified as microbial biofertilizers while Ikuesan *et al*. (2023) additionally stated that water hyacinth exhibited the occurrence of micro and macro nutrients suggesting its potential as raw material for biofertilizer and can be used to promote plant growth. These benefits make such fertilizers a viable alternative or supplement to conventional organic and inorganic options without negative consequences.

Food crops which include fruits, vegetables, grains and tubers like potatoes are subsistence crops for human consumption and are diverse and vary in types, nature, yield, nutrient composition as well as method of cultivation and growth requirements. Maize (*Zea mays*) is one of the most versatile and the third widely cultivated crops among the cereals following wheat and rice (Adiaha, 2017), having several uses for human development and survival providing nutrition and key ingredient for medical, pharmaceutical, herbal, economic, industrial and research values (Adiaha, 2017).

With the increasing demand for maize and its critical roles in global agriculture as a key food source, livestock feed, and raw material for various industrial applications (Tanumihardjo *et al.*, 2020; Murdia *et al*., 2016), it is imperative to enhance cultivation methods, especially in soils of differing fertility levels. Considering the abundance and significant economic and ecological burden of water hyacinth and the white sandy nature of the communities in the coastal environment which does not support productive agriculture, integrating water hyacinth-based fertilizers could support sustainable maize cultivation while addressing soil health challenges. The study investigates the use of water hyacinth – based liquid fertilizer to improve agricultural practices as alternative source of nutrient for maize production which is a cheap source of food energy to meet family food needs and convert the environmental and economic nuisance of water hyacinth to agricultural and economic values.

Material and Methods

Collection of Samples

Water hyacinth (*Eichhornia crassipes*)

Samples of Water hyacinth was collected manually into sterile polythene bag from Alape River in Ilaje Local Government Area of Ondo State and transported within twenty - four (24) hours of collection in ice chest to the laboratory for analysis. The fresh plants were authenticated at the Herbarium of the Federal University of Technology, Akure, Nigeria.

Soil Samples:

White sandy and loamy soils were collected at a depth of 15-20 cm respectively from Igbokoda, Ilaje Local Government area and a farm in Obaile, Akure North LGA of Ondo State with a sandhog into a sterile polythene bag and then transported to the laboratory within twenty -four (24) hr from the point of collection.

Maize seed and NPK (20: 20:20)

Maize seed and NPK (20: 20:20) fertilizer were respectively purchased from an Agroshop at Ijapo and Hospital Road both in Akure, Ondo State.

Poultry Dropping (Organic Fertilizer)

Poultry dropping was collected from a poultry farm in Obaile, Akure North Local Government, Ondo State, Nigeria.

Preparation of Water Hyacinth Plant for the Study

The unwanted foreign materials in the fresh water hyacinth weed were removed by sorting, drained and washed three or four times with clean water to eliminate all sand particles. The fresh water hyacinth was air- dried for 3 days and then cut into pieces of approximately 5-10 cm in length using a cutter to obtain four samples and labeled WP, PR, PS and PL for whole plant, plant root, plant stalk and plant leaf respectively.

Wet State Fermentation

Exactly 5 kg of the well - prepared water hyacinth (*Eichhornia crassipes*) was placed into a sterile 120 litre black plastic local fermenter as fermentation tank and was covered with water and left undisturbed for 21 days to ferment according to the modified method of Dev and Sumathy (2018). The fermented water hyacinth liquid fertilizer was divided into two portions and then one portion was milled while the other portion remained un-milled. The milled and un-milled foliar extracts from the decomposed water hyacinth were then filtered (Andika *et al*., 2013) to remove the residues and only the solution was taken and preserved it in airtight container until use.

Analysis of Physicochemical Properties, Minerals and Heavy Metal Concentration

The physicochemical properties of the white sandy and loamy soils, water hyacinth plant, water hyacinth – based liquid fertilizer and poultry dropping samples were determined using standard physical and chemical analytical techniques (Black, 1965; Ademoroti, 1996, Chopra and Kanwar, 1998, APHA, 2005, Osuji and Nwoye, 2007, Obayori *et al*., 2008; Ekpo and Ebeagwu, 2009).

Proximate Analyses of Water Hyacinth and Maize (*Zea may*) Plants and Grain

Moisture content was determined by the weight loss method after drying two grams (2.0 g) of each sample in an oven maintained at 100 - 103°C for 16 hours until a constant weight was obtained. Ash content, crude protein, lipid and fiber contents were measured by the procedures described by AOAC (2009). The carbohydrate content of the samples was determined as the difference obtained after subtracting the values of protein, lipid, ash and fibre from the total dry matter (AOAC, 2009**)**.

Mineral and Heavy Metal Analyses of Water Hyacinth Plants

Mineral elements and heavy metals were analyzed using the ash of each sample digested by adding 5 ml of 2 MHCl to the ash in the crucible and heated to dryness on a heating mantle. 5 ml of 2 MHCl was added again, heated to boil and filtered through Whatman No. 1 filter paper into a 100 ml volumetric flask. The filtrate was made up to mark with distilled water, stoppered and made ready for reading of concentration of calcium, potassium and sodium on the Jenway Digital Flame Photometer (PFP7 Model) using the filter corresponding to each mineral element. The concentration of phosphorus was obtained by the colorimetric method. The digest of the ash of each sample was washed into 100 ml volumetric flask with deionized or distilled water and made up to mark. These diluents were aspirated into the Buck 211 Atomic Absorption Spectrophotometer (AAS) through the suction tube. The concentration of each metal was then read at their respective wavelengths with their respective hollow cathode lamps using appropriate fuel and oxidant combination.

Influence of Water Hyacinth Liquid Fertilizer, Poultry Dropping and NPK on the Growth of Maize (*Zea may* L)

The study was conducted as greenhouse experiments at the FUTA farm to determine the influence of water hyacinth – based liquid organic fertilizer, poultry dropping and NPK on the growth of maize (*Zea may* L). The experiment was arranged in a completely randomized design and four seeds of maize were planted in each plastic bucket containing 20 kg of soil (Iwuagwu *et al*., 2013). Treatment of seeded white sandy and loamy soils were carried out 10 days after planting (Iwuagwu *et al*., 2013) in triplicate replicates. Five sets of pots were formulated and replicated three times giving a total of fifteen experimental units for each soil type. The treatments included: control (no application), un-milled biofertilizer (UBF), milled biofertilizer (MBF), poultry dropping (PD) and NPK fertilizer. The prepared fermented leaf fertilizer (FLF) was diluted to 7% v/v with water before it is applied (Fern´andez and Eichert, 2009) in order to reduce the risk of low nutrient absorption, injury to the leaf surface, or general phytotoxicity (Ito, 2006).

The plant growth parameters including plant height, stem base diameter, root length, shoot length were determined monthly for three months using calibrated meter rule and chemical analytical method for chlorophyll content and the growth responses to water hyacinth fertilizer (un-milled and milled) were compared to the poultry dropping and chemical fertilizer (NPK).

Statistical Analysis

Means of triplicate readings were determined and subjected to analysis of variance (ANOVA). Means were separated using Duncan's Multiple Range Test (DMRT) with the aid of statistical package for social scientist (SPSS) version 21.0. Differences were considered significant at $P < 0.05$.

Results

Physicochemical Properties, Heavy Metal and Nutrient Contents of Loamy and White Sandy Soil Samples

The results shown in tables 1 and 2 revealed that the two soils samples (LS and WSS) differ in their physicochemical properties, heavy metal and nutrient contents. The white sandy soil (WSS) showed a higher pH value of 7.27 over the 6.78 of the loamy soil (LS).

The loamy soil had higher moisture content (16.97%), total organic matter (2.74%), total organic carbon (1.63%) and bulk density (2.24g/cm^3) than the white sandy soil with 13.97%, 2.17%, 1.30% and 2.19g/cm respectively for moisture content, total organic matter, total organic carbon and bulk density. The textural class determined by the percentage of silt, sand and clay revealed that experimental soil (WSS) was sandy with silt, sand and clay contents as 7.70%, 85.20% and 7.10% respectively while soil LS had 18.30%, 66.90% and 14.80% respectively of silt, sand and clay and classified as loamy. Other soil parameters such as nutrients (nitrate, sulphate, nitrogen, phosphate), mineral elements and heavy metals vary in amount with the white sandy soil having higher values of nitrate (10.70 mg/kg), phosphorous (18.30 mg/kg) and sulphate (0.18%) than the loamy soil with 4.67mg/kg, 13.49mg/kg and 0.09% of nitrate, phosphorous and sulphate respectively. The results indicated in table 2 that among the heavy metals, the concentration of iron in both soil types was higher than any of the other metals (Zn, Pb, Cu, Cd, Ni, Si, Cr, As and Co).

Proximate and Mineral Content of Water Hyacinth (*Eichhornia crassipes*) and Maize Grain

Tables 3 and 4 showed the proximate, nutrient and heavy metal constituents of water hyacinth (*Eichhornia crassipes*) whole plant and parts. These parameters vary among the constituent parts (leaf, stem and root). The proximate values for moisture (65.45%), protein (12.18%) and carbohydrate (5.30%) were highest in the leaf part compared to the stem and roots. Similarly, table 3 shows that highest values of ash (18.48%), fat (3.84%) and crude fibre (12.50%) were obtained in the plant root relative to leaf and stem. Apart from magnesium and phosphorous, mineral elements such as sodium, calcium and potassium were more abundant in the leaf. Table 4 revealed that among the heavy metals, Lead (Pb), Cadmium (Cd), Nickel (Ni), Chromium (Cr), Arsenic (As) and Cobalt (Co) had negligible or undetectable values for the plant and constituent parts (leaf, stem and root).

Table 1: Physicochemical and Nutrient Composition of Soil Samples

Parameters	LS	WSS
Ph	6.78±0.02	7.27±0.02
Moisture content (%)	16.97±0.17	13.97±0.34
Bulk density (g/cm$^{3)}$	2.24±0.10	2.19±0.00
Total Organic Matter (%)	2.74±0.06	2.17±0.02
Total Organic Carbon (%)	1.63±0.01	1.30±0.01
Soil texture: Silt (%)	18.30	7.70
Sand (%)	66.90	85.20
Clay (%)	14.80	7.10
Textural Class	Loamy	Sandy
Nitrate (mg/kg)	4.67±0.24	10.70 ± 0.08
Sulphate (%)	0.09±0.0	0.18±0.02
Nitrogen (%)	0.26±0.01	0.19±0.0
Phosphate (mg/kg)	25.37±0.26	18.43±0.21
Cation Exchange Capacity (Cmol$_c$/kg)	15.17±0.05	10.59±0.04
Na (mg/kg)	1 .57±0.05	2.2±0.14
Ca (mg/kg)	4.6±0.16	5.4±0.14
K (mg/kg)	1.3±0.08	0.8±0.08
Mg (mg/kg)	1.65±0.01	2.51±0.01
P (mg/kg)	18.30±0.02	13.49±0.04

Legend: LS; Loamy Soil, WSS; White Sandy Soil

Table 2: Concentration of Heavy metals in soil samples

Parameters (mg/kg)	**LS**	**WSS**
Zn	12.47±0.04	22.87±0.04
Pb	0.26±0.01	0.54±0.0
Cu	1.40±0.0	2.95±0.01
Fe	187.56±0.06	293.16±0.04
Cd	0.02±0.00	0.06±0.0
Ni	0.01±0.00	0.10±0.0
Si	38.3±0.01	81.56±0.05
Cr	0.8±0.01	1.25±0.01
As	0.01±0.0	0.01±0.0
Co	0.00±0.00	0.01±0.0

Legend: LS; Loamy sandy soil, WSS; White sandy soil

Table 3: Proximate Composition of Whole Plant, Leaf, Stem and Root of *Eichhornia crassipes* (Water hyacinth)

Parameters (%)	WP	PL	PS	PR
Moisture	60.19±0.01[a]	65.45±0.04[a]	58.44±0.01[a]	52.65±0.04[a]
Ash	10.31±0.05[b]	6.81±0.01[a]	12.26±0.01[c]	18.49±0.01[d]
Fat	3.11±0.01[c]	1.98±0.03[a]	2.56±0.21[b]	3.84±0.01[d]
Crude Fibre	12.73±0.02[d]	8.28±0.01[a]	11.32±0.00[b]	12.50 ± 0.01[c]
Protein	9.65±0.00[b]	12.18±0.01[d]	10.18±0.02[c]	7.45±0.03[a]
Carbohydrate	4.01±0.07[a]	5.30±0.01[c]	5.12±0.04[b]	5.06±0.04[b]

Legend: WP; Whole Plant, PL; Leaf, PS; Plant Stem, PR; Plant Root.; a, b, c, d: Significant difference ($P \leq 0.05$)

Table 4: Nutrient and Heavy Metal Composition of *Eichhornia crassipes* (Water hyacinth)

Parameters (mg/kg)	WP	PL	PS	PR
Na	28.43±0.17[c]	33.40±0.14[d]	21.13±0.12[a]	22.47±0.05[b]
Ca	43.90±0.16[d]	40.77±0.55c	38.37±0.02[b]	35.47±0.34[a]
K	72.67±0.17[d]	65.60 ± 0.09[c]	58.70±0.08[b]	54.73±0.12[a]
Mg	12.52±0.02[a]	8.44±0.00[a]	8.19±0.02[a]	10.51±0.01[a]
Zn	0.82 ±0.01[a]	3.08 ±0.02d	1.39 ±0.01[b]	2.23 ±0.01[d]
P	56.17±0.01[c]	48.29±0.02[a]	54.27±0.30[b]	60.87±0.01[d]
Pb	ND	ND	ND	ND
Cu	0.23±0.0[d]	0.08±0.00[a]	0.15±0.01[b]	0.17±0.0c
Fe	3.62±0.01[d]	2.86±0.01[b]	2.96±0.01[c]	2.79±0.02[a]
Cd	ND	ND	ND	ND
Ni	ND	ND	ND	ND
Si	2.10±0.03[c]	1.85±0.0[b]	1.34±0.02[a]	3.33±0.08[d]
Cr	0.02±0.0[b]	0.01±0.00[a]	0.01±0.0[a]	0.02±0.00[b]
As	0.00±0.00			0.00±0.00
Co	ND	ND	ND	0.00±0.00

Legend: WP; Whole Plant, PL; Plant Leaf, PS; Plant Stem, PR; Plant Root

Physicochemical and Mineral content of Water Hyacinth Liquid Organic Biofertilizer and Poultry Dropping used as Soil Amendment.

Table 5 shows the physicochemical, nutrients and heavy metals constituents of un-milled (UBF) and milled (MBF) water hyacinth – based liquid fertilizer and poultry dropping used as soil amendment materials. Results revealed that the un- milled and milled liquid fertilizers had lesser amounts of all the parameters assayed including nitrate, ammonia, mineral elements and heavy metals compared with the poultry dropping. The un-milled biofertilizer (UBF) had lower amount of nitrate, total nitrogen and total organic matter than the milled biofertilizer (MBF).

Influence of Soil Treatment on Plant Growth Parameters of Maize (*Zea may* L)

The effects of soil amendment with water hyacinth-based liquid fertilizer (un-milled and milled), poultry dropping and NPK on growth performance parameters such as plant height, stem base diameter, root length, shoot length and chlorophyll content as well as number of ear maize of maize planted on white sandy and loamy soils are indicated in Tables 6, 7 and 8 for the three (3) months of study.

The stem diameter measured in millimetre vary for each of the months and it ranged 5.45 ± 0.05 -7.63 ± 0.31 and 4.43 ± 0.04 – 13.12 ± 0.96 for the control (WSC) and treated white sandy soil (UBFW, MBFW, PDW and NPKW) respectively for the three months with the poultry dropping treated soil (PDW) showing the value of 13.12 ± 0.96 against other treatments. The root length, shoot length and total plant length measured in centimetre showed remarkable increase for each of the months. The total chlorophyll contents also vary and ranged 0. 0041 – 0.0048 (mg/g) and 0.0043-0.0096 (mg/g) for the white sandy and loamy control soil samples respectively. The results indicated that number of ear maize produced (maize yield) on the white sandy and loamy soils at the end of the planting season of three months were 2, 2, 4 and 2 and 3, 2, 8 and 7 respectively for the un-milled biofertilizer, milled biofertilizer, poultry dropping treated and NPK against the control samples which had 0 and 1ear maize respectively for the WSC and LSC.

Table 5: Physicochemical Properties, Mineral Content and Heavy Metals of Water Hyacinth Liquid Organic Biofertilizer and Poultry Dropping used as Soil Amendment.

Parameters	UBF	MBF	PDF
Nitrate (mg/kg)	15.23±0.17	18.57±0.29	22.57±0.09
Ammonia (mg/kg)	5.27±0.12	5.50±0.22	12.77±0.21
Total Nitrogen (%)	1.55±0.00	1.52±0.01	2.29±0.02
Total Organic Matter (%)	4.77±0.12	5.33± 0.12	28.43±0.21
Turbidity (NTU)	30.00±0.00	25.00±0.00	ND
Na (mg/kg)	30.87±0.25	27.17±0.09	142.53±0.05
Ca (mg/kg)	55.17±0.4	62.27±0.21	1258±6.53
K (mg/kg)	418.67±2.49	505.67±2.87	983.67±2.62
Mg (mg/kg)	38.36±0.05	33.02±18	162.12±0.12
Mn (mg/kg)	13.67±0.04	10.87±0.01	74.32±0.07
Zn (mg/kg)	5.59±0.01	6.43±0.01	52.19±0.04
P (mg/kg)	18.58±0.02	21.82±0.01	26.45±0.04
Fe (mg/kg)	18.58±0.02	7.55±0.01	26.45±0.04
S (%)	0.13±0.00	0.17±0.00	0.35±0.0
Ni (mg/kg)	0.13±0.00	0.12±0.00	0.35±0.0
Se (mg/kg)	0.37±0.01	0.34±0.01	0.73±0.01

Legend: UBF; Un- milled Biofertilizer MBF; Milled Biofertilizer, , PDF; Poultry Dropping fertilizer, ND; Not Determined

Tabe 6: Growth Performance of *Zea may* Planted on Loamy Soil White Sandy Soil and for Month 1

	Loamy Soil					White Sandy Soil				
Parameter	LSC	UBFL	MBFL	PDL	NPKL	WSC	UBFW	MBFW	PDW	NPKW
Stem diameter (mm)	7.31± 0.02	7.4 ± 0.14	8.53± 850	10.22± 0.05	11.21± 0.03	5.45± 0.05	5.26± 0.27	5.45 ±0.05	4.43 ±0.04	5.12 ±0.23
Root length (cm)	19.03± 0.13	19.15± 0.6	22.65± 0.36	20.08± 0.71	20.5± 1.27	14.46 ±0.36	21.17 ±0.09	14.90 ±0.33	14.62 ±0.20	19.45 ±0.04
Shoot length (cm)	14.83± 0.12	13.33± 1.06	17.30± 0.7	23.99± 0.71	27.03± 1.19	9.90 ±0.08	5.35 ±1.03	9.90 ±0.08	8.70 ±0.16	6.87 ±009
Total plant length (cm)	33.92± 0.06	32.49± 1.66	39.95± 0.88	44.79± 1.27	47.87± 2.05	24.3 ±0.41	26.72 ±1.08	24.8 ±0.41	23.32 ±0.27	26.40 ±0.14
Chlorophyll mg/g)	0.0096 ±0.004	0.0063± 0.000	0.0063± 0.000	0.0031± 0.000	0.0029± 0.000	0.0041± 0.004	0.0018± 0.000	0.0036± 0.000	0.0035± 0.0	0.0009± 0.000

Legend: LSC; Loamy Soil Control, UBFL; Loamy Soil with Un-milled Biofertilizer, MBFL; Loamy Soil with Milled Biofertilizer, PDL; Loamy Soil with Poultry Dropping, NPKL; Loamy Soil with NPK, WSC; White sandy Soil Control, UBFW; White sandy Soil with Un-milled Biofertilizer, MBFW; White sandy Soil with Milled Biofertilizer, PDW; White sandy Soil with poultry dropping, NPKW; White sandy soil with NPK.

Table 7: Growth Performance of *Zea may* Planted on Loamy Soil and White Sandy Soil for Month 2

Par	Loamy soil					White sandy soil				
	LSC	UBFL	MBFL	PDL	NPKL	WSC	UBFW	MBFW	PDW	NPKW
Stem Diam (mm)	7.67 ±0.27	8.31 ±1.5	9.48 ±0.46	12.46 ±2.12	7.67 ±0.27	7.63 ±0.31	5.5 ±0.29	5.43 ±0.29	10.17 ±0.06	8.57 ±0.27
Root length (cm)	22.30 ±0.96	28.0 ±0.82	26.82 ±0.74	23.12 ±1.51	22.30 ±0.96	20.32 ±1.61	24.48 ±0.74	20.27 ±1.14	23.50 ±2.82	25.98 ±0.33
Shoot length (cm)	23.44 ±1.33	28.67 ±0.94	38.67 ±5.31	96.0 ±24.54	23.44 ±1.33	21.2 ±0.79	20.92 ±1.44	27.33 ±2.49	46.0 ±9.93	30.1 ±0.08
Total plant length (cm)	45.37 ±1.72	57.07 ±1.47	65.58 ±5.55	115.78 ±25.79	45.37 ±1.72	41.5 ±1.59	45.4 ±1.72	47.6 ±3.10	69.5 ±12.29	56.08 ±0.26
Chlo (mg/g)	0.0043 ±0.003	0.0054 ±0.001	0.0074 ±0.000	0.0067 ±0.000	0.0043 ±0.003	0.0048 ±0.003	0.0057 ±0.001	0.0072 ±0.000	0.0097 ±0.000	0.0106 ±0.00

Legend: LSC; Loamy Soil Control, UBFL; Loamy Soil with Un-milled Biofertilizer, MBFL; Loamy Soil with Milled Biofertilizer, PDL; Loamy Soil with Poultry Dropping, NPKL; Loamy Soil with NPK, WSC; White sandy Soil Control, UBFW; White sandy Soil with Un-milled Biofertilizer, MBFW; White sandy Soil with Milled Biofertilizer, PDW; White sandy Soil with poultry dropping, NPKW; White sandy soil with NPK; Par = Parameter; Chloro = Chlorophyll, Diam = Diameter

Table 8: Growth Performance of *Zea may* Planted on Loamy Soil and White Sandy Soil for Month 3

Soil			Loamy			White Sandy Soil				
Parameter	LSC	UBFL	MBFL	PDL	NPKL	WSC	UBFW	MBFW	PDW	NPKW
Stem diameter (mm)	11.36 ±0.78	9.82 ±1.71	10.80 ±3.02	9.65 ±0.5	14.52 ±0.36	7.5 ±1.73	6.4 ±0.35	7.15 ±0.25	13.1 ±0.96	9.98 ±0.79
Root length (cm)	23.3 ±1.26	25.27 ±0.52	28.33 ±3.3	28.33 ±1.25	28.0 ±2.94	22.98 ±0.84	26.4 ±0.37	25.4 ±0.57	25.85 ±1.06	25.7 ±1.55
Shoot length (cm)	72.0 ±9.42	71.67 ±13.12	93.0 ±9.63	100.67 ±1.7	133.0 ±4.32	79.77 ±8.6	79.47 ±0.41	78.02 ±.1.88	82.9 ±5.32	83.73 ±4.95
Total plant length (cm)	95.3 ±8.37	96.0 ±13.62	121.33 ±12.81	129.0 ±1.41	161.0 ±6.16	102.6± 7.86	105.87 ±0.69	102.42 ±1.42	108.7 ±6.21	109.43 ±5.33
Chlorophyll (mg/g)	0.0069± 0.0001	0.0117± 0.0053	0.0070± 0.0032	0.0074± 0.0038	0.0038± 0.0017	0.0044 ±0.005	0.0012±0 .0032	0.0038± 0.0032	0.0035± 0.0014	0.011± 0.0012

Legend: LSC; Loamy Soil Control, UBFL; Loamy Soil with Un-milled Biofertilizer, MBFL; Loamy Soil with Milled Biofertilizer, PDL; Loamy Soil with Poultry Dropping, NPKL; Loamy Soil with NPK, WSC; White sandy Soil Control, UBFW; White sandy Soil with Un-milled Biofertilizer, MBFW; White sandy Soil with Milled Biofertilizer, PDW; White sandy Soil with poultry dropping, NPKW; White sandy soil with NPK.

Biomass of Maize (*Zea may*) Planted on White Sandy and Loamy Soil

Plant biomass of maize planted on the white sandy and loamy soils is shown in figures 1and 2. The leaf/ stem, root and whole plant biomass vary according to treatment and soil types. For both soil types, the leaf/stem biomass was highest with milled bio-fertilizer supplementation with a value of 62.17 ± 1.84% and 52. 5± 6.77 respectively for white sandy soil and loamy soil. Similarly, the total plant biomass was highest in both soils treated with un-milled biofertilizer (94.88% on loamy soil, 95.5% on white sandy soil) and milled biofertilizer (94.5% on loamy soil, 89.6% on white sandy soil). This study revealed that for both soil types, the un-milled biofertilizer (UBFW and UBFL) yielded maize plant of higher biomass than the milled biofertilizer (MBFW and MBFL).

Proximate Composition of Maize Grain The proximate composition of the maize grain produced from the various treatments on the soil samples was analysed. Table 9 shows that the percentage moisture content, ash, fat, crude fiber, protein and carbohydrate for the white sandy soil ranged 8.36 ± 0.11 -10. 63 ± 0.03, 1.08 ± 0.02 – 1.83 ± 0.01, 8.3 ± 0.01 -12.29 ± 0.01, 1.29 ± 0.01- 2.16 ± 0.01, 9.19 ± 0.02 - 13.11 ± 0.11 and 61.11± 0.05 – 69.32 ± 0.09 respectively while the proximate ranged 8.25 ± 0.1 – 10.16 ± 0.05,1.18 ± 0.02 -2.13 ± 0.01, 8.65 ± 0.02 – 12.83 ± 0.05, 1.52 ± 0.01 – 2.98 ± 0.0, 9.89 ± 0.03 – 11.81 ± 0.03 and 64.33 ± 0.09 – 69.45 ± 0.06 respectively for percentage moisture content, ash, fat, crude fiber, protein and carbohydrate for the loamy soil for all treatments including the control. The percentage moisture (10.16 ± 0.05 and ash (2.13 ± 0.01) were higher in the control of the loamy soil than the treated loamy samples.

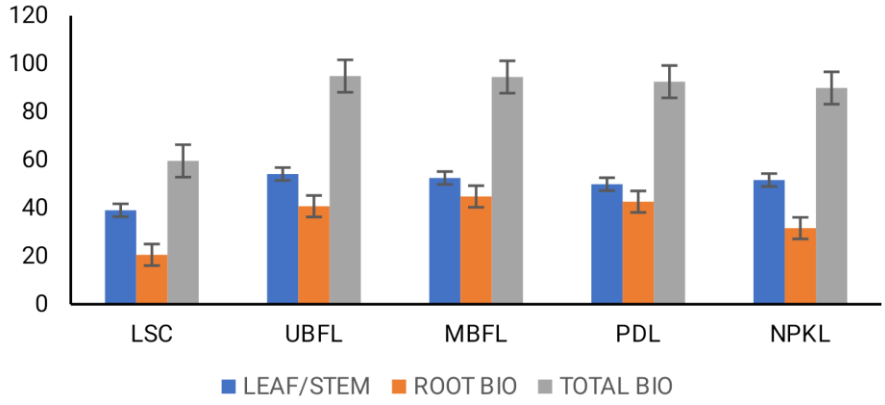

Figure 1: Biomass of Maize (*Zea may*) Planted on Loamy soil
Legend: LSC; Loamy Soil Control, UBFL; Loamy Soil with Un-milled Biofertilizer, MBFL; Loamy Soil with Milled Biofertilizer PDL; Loamy Soil with Poultry Dropping, NPKL; Loamy Soil with Poultry NPK.

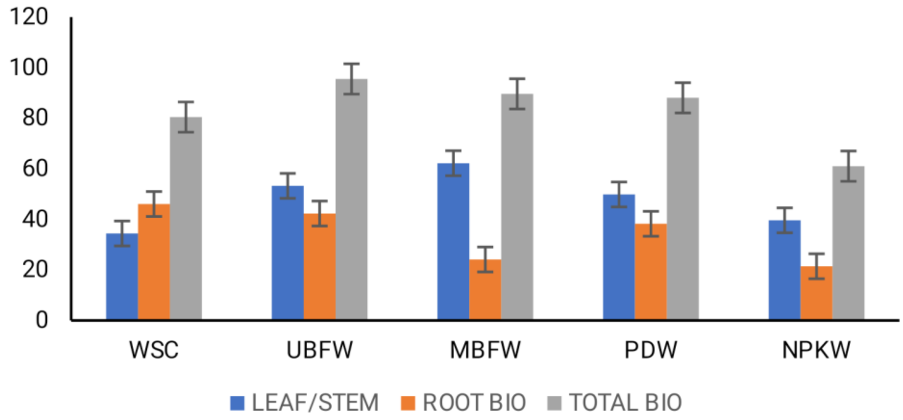

Figure 2: Biomass of Maize (*Zea may*) Planted on white soil
Legend: WSC; White sandy Soil Control, UBFW; White sandy Soil with Un-milled Biofertilizer, MBFW; White sandy Soil with Milled Biofertilizer, PDW; White sandy Soil with poultry dropping, NPKW; White sandy soil with NPK.

Table 9: Proximate Analysis of Maize Grain

Sample	Moisture (%)	Ash (%)	Fat (%)	C. fibre (%)	Protein (%)	CHO (%)
LSC	10.16±0.05[a]	2.13±0.01[g]	9.74±0.01[c]	1.85±0.02[c]	10.77±0.01[a]	65.35±0.04[d]
UBFL	10.13±0.03[a]	1.28±0.0[c]	12.83±0.05[h]	1.53±0.01[ab]	9.89±0.03[a]	64.33±0.09[c]
MBFL	8.94±0.02[a]	1.2±0.01[b]	10.81±0.01[d]	1.67±0.27[bc]	11.81±0.03[a]	65.38±0.04[d]
PDL	8.68±0.21[a]	1.18±0.02[b]	8.65±0.02[b]	1.52±0.01[ab]	10.38±0.03[a]	69.45±0.06[f]
NPKL	8.25±0.1[a]	1.21±0.01[b]	10.87±0.0[e]	2.98±0.0[e]	10.8±0.01[a]	65.88±0.1[e]
UBFW	9.69±0.03[a]	1.6±0.01[e]	12.2±0.01[f]	2.16±0.01[d]	10.93±0.04[a]	63.42±0.07[b]
MBFW	8.36±0.11[a]	1.4±0.01[d]	12.29±0.01[g]	1.29±0.01[a]	12.34±0.05[a]	64.26±0.06[c]
PDW	9.24±0.07[a]	1.83±0.01[f]	8.3±0.01[a]	2.12±0.0[d]	9.19±0.02[a]	69.32±0.09[f]
NPKW	10.63±0.03[b]	1.08±0.02[a]	12.21±0.01[f]	1.87±0.0[c]	13.11±0.01[a]	61.11±0.05[a]

Legend: LSC; Loamy Soil Control, UBFL; Loamy Soil with Un-milled Biofertilizer, MBFL; Loamy Soil with Milled Biofertilizer PDL; Loamy Soil with Poultry Dropping, NPKL; Loamy Soil with Poultry NPK, WSC; White sandy Soil Control, UBFW; White sandy Soil with Un-milled Biofertilizer, MBFW; White sandy Soil with Milled Biofertilizer, PDW; White sandy Soil with poultry dropping, NPKW; White sandy soil with NPK, a, b, c, d, e, f, g, h: Significant difference ($P \leq 0.05$).

Mineral Constituent of Maize Grain
Figure 3 shows the mineral element constituents of the maize grain produced under various treatment conditions. The concentrations of the mineral elements in part per million (ppm) obtained in this study vary with treatments and soil types.

Among the macro mineral elements, the concentration of Na (64.17 ± 0.29), K (150. 3 ± 0.14) were highest in the maize grain harvested from the (NPKW) white sandy soil amended with NPK while Ca (44.77± 0.21), Mg (28.18 ± 0.01) and P (192.26 ± 0.04) were respectively highest in loamy soil amended with poultry dropping (PDL), NPKL and un-milled biofertilizer (UBFL). The Zn (1.76 ± 0.0) and Mn (1.41 ± 0.0) which are micro mineral elements were respectively highest in loamy soil incorporated with NPKL and the unamended loamy soil (LSC) while the Fe concentration of 0.88 ± 0.03 was highest in the grain of white sandy soil amended with NPK.

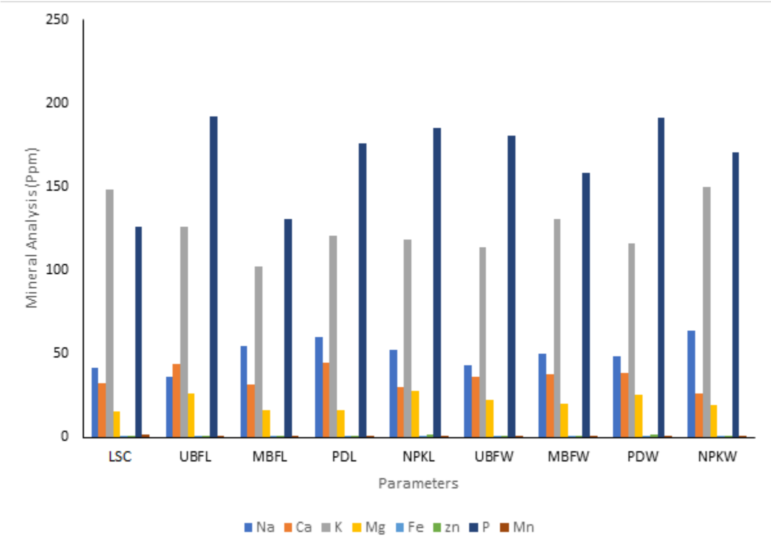

Figure 3: Mineral Analysis of Maize Grain

Legend: LSC; Loamy Soil Control, UBFL; Loamy Soil with Un-milled Biofertilizer, MBFL; Loamy Soil with Milled Biofertilizer PDL; Loamy Soil with Poultry Dropping, NPKL; Loamy Soil with Poultry NPK, WSC; White sandy Soil Control, UBFW; White sandy Soil with Un-milled Biofertilizer, MBFW; White sandy Soil with Milled Biofertilizer, PDW; White sandy Soil with poultry dropping, NPKW; White sandy soil with NPK,

Discussion

Soil fertility is the ability of soil to supply the nutrients needed by plants to grow and therefore, soil health is the foundation of productive agriculture. Fertile soil provides nutrients such as N, P, and K which are essential for the growth of plants (Rajan *et al*., 2023). Soil that has been depleted in nutrient cannot support productive agriculture which is the ultimate desire of every farmer. Soil fertility indicators such as total organic content (TOC), total organic matter (TOM), nitrate, phosphate, phosphorous, potassium, and percentage nitrogen were higher in the loamy soil compare to the white sandy soil. This suggests the potential of the loamy soil for better crop yield than the white sandy soil. The heavy metals except As and Co were in remarkable higher concentration in the white sandy soil. These metals may bioaccumulate in plant and affect plant health and survival with overall consequence on human and animal health.

The result shows that Water hyacinth *Eichhornia crassipes* contain fairly large amount of moisture content of 52.65%, 58.44%, 60.19% and 65.45% in the root, stem, whole plant and leaf respectively. These values were below the 95.5% for fresh water hyacinth plant reported by Matai and Bagchi (1990) and 89.20% (Suleiman *et al*., 2020). This implies that *Eichhornia crassipes* with high MC may deteriorate faster, having a short shelf-life since moisture content is an index of water activity and is used as a measure of stability and the susceptibility to microbial attack. The ash content (6.81- 18.49%) and moisture content (52.65- 65.45%) observed for the water hyacinth plants were in the range reported by Oluchukwu *et al*. (2018) who reported ash content 4.8%, 6.56%, 9.8% and 17.90% and moisture content of 65%, 56%, 57% and 45% respectively for water melon, cow dung, food waste and saw dust respectively in their study of the characteristics of raw materials for preparation of biofertilizer. The results also suggests that the plant is rich in minerals.

The differences in proximate composition may have been influenced by seasonal variation in temperature in agreement with the report of Andika *et al.* (2013) which stated that water hyacinth has the ability to absorb nutrients from the water and this ability increases with increase in temperature. The result of the proximate composition of water hyacinth (whole plant, leaf, root and stem) suggests that water hyacinth compares favourably with any organic resource for the production of biofertilizer. Water hyacinth also showed varying amounts of heavy metals. This corroborates the report of Ogulande (2012) that water hyacinth contained high levels of heavy metals, ranging from 12.04% in the leaf blade to 19.03% in the roots and 16.10% for petiole. The aquatic weed (*Eichhornia crassipes*) may have absorbed these metals from the water harboring it. Saha and Paul (2016) and Rango *et al*. (2013) reported that water bodies receive and absorb trace elements caused by anthropogenic activities such as rapid urbanization and industrialization. Oluchukwu *et al*. (2018) stated that the presence of high amounts of heavy metals in most agro-wastes is one of the most significant reasons that restricted their application in agricultural lands. This assertion implies that water hyacinth provides a better source of organic material for biofertilizer production since the heavy metal contents are in relatively smaller amounts.

Farnia and Hasanpoor (2015) stated that the continuous application of chemical fertilizer leads to loss of soil quality and might lead to accumulation of heavy metals in plant tissues thereby affecting fruit nutritional value and quality. The serious menace to the environment and humans due to the protracted use of chemical fertilizer leads to the introduction of biofertilizers as replacement (Khoshru *et al*., 2020). The present study revealed that the application of water hyacinth- based liquid fertilizer (UBF and MBF), poultry dropping (PD) and the inorganic fertilizer (NPK) had significant influence relative to the unamended control samples (WSC and LSC) on the growth parameters in terms of stem base diameter, root length, shoot length, total plant height and yield for maize seedling planted on both white sandy and loamy soils. Tables 6, 7, 8 show that the growth responses and the number of ear maize produced vary with treatments, growth period and soil types. Whereas the untreated white sandy soil yielded no ear maize, the milled, un-milled water hyacinth liquid organic fertilizer and NPK treated samples produced two ear maize each while the sample enhanced with poultry manure yielded four. Similarly, the un-milled and milled biofertilizers, poultry dropping and NPK treated samples yielded 3, 2, 8 and 7 ear maize respectively against the control which produced 1 on loamy soil at the end of the planting period (3 months).

The results obtained in this study by the application of water hyacinth - fertilizer against the control could be ascribed to the presence of microbial biofertilizers on the raw material (*Eichhornia crassipes*) which Thomas and Singh (2019) recently reported that these microbial fertilizers to promote plant growth by increasing efficient uptake of or availability of nutrients for plants through nitrogen fixation, phosphorous solubilization and synthesis of plant growth promoting substances, maintain the nutrient economy of soil with effects on plant growth and crop yield. The organic matter contents of the liquid fertilizer may also contribute to the results obtained since these parameters also affect soil fertility. Also, for both soil types, samples amended with poultry fecal material followed by NPK produced highest number of ear maize. This is particularly so because fecal matter serves as organic manure or fertilizer, enhances soil biological activity, favouring nutrient cycling and availability for crops, rich in nutrients such as nitrogen, phosphorous and other macro and micronutrients necessary for plant growth while also carrying microorganisms important for healthy soil.

Grain samples collected from different treatments were tested for moisture, crude ash, fat, crude fiber, and protein and carbohydrate. The proximate composition results showed highest moisture (10.63%) and protein (13.11%) for sample treated with NPK on white sandy soil. There is no significant difference in the results of the moisture and protein contents for all the other treatments and control (LSC) on the two soil types. Results of most proximate composition of the grain indicated that the values obtained for white sandy soil samples treated with milled and un-milled biofertilizers were ≥ those for the same treatment on loamy soil. Similar results were also obtained for grains derived from both soils treated with poultry dropping and NPK fertilizer.

The moisture content (8.36-9.69), crude fiber (1.29 – 2.16) and protein (10.93- 12.34) were in agreement the report of Qamar *et al*. (2016) who reported 2.98- 10.40%, 0.79 – 2.78% and 11.05 – 12.79% respectively for moisture content, crude fiber and protein.

However, for both soil types, maize grain from poultry treated soil had highest percentage of carbohydrate. It was evident from the results that treatment of the white sandy soil with biofertilizer (milled and un-milled) did have some remarkable effects on the quality and integrity of the white sandy soil for maize production. This assertion was because the untreated white sandy soil yielded no single ear maize. Also, the nutritional composition of the maize grains from the soil samples treated with the biofertilizers compares favourably with the grains from other treatments. This, implies that the application of water hyacinth derived liquid organic fertilizer can be used to enhance maize production with appropriate nutritional quality.

Conclusion

Agriculture is the second mainstay of the Nigeria economy where the people are highly dependent on the outputs of the agricultural sector especially farming for livelihood. It is therefore important to focus on the mass production of healthy food to meet the food demands of the growing populace, contributes in fighting poverty and ensuring economic growth. The application of liquid organic fertilizers to improve maize crop yield is a preferred approach as a cheap, ecofriendly and non-invasive agricultural practice without causing injury to the environment, plant, animal and human health. This study confirms that Water hyacinth- based liquid organic fertilizer can improve the quality of white sandy soil for *Zea mays* production than the chemical fertilizer since it improved the crop yield better than the chemical fertilizers. The study recommends that in order to maximize the advantages of the availability of water hyacinth in the riverine areas and Circumvent the need for synthetic or chemical fertilizers, government should encourage the production of water hyacinth – based liquid fertilizer through the establishment of liquid organic fertilizer manufacturing plants in the coastal areas where water hyacinth is dominant. The industry should engage communities in its functions especially in harvesting of the weed from Alape and other rivers in the locality as a conscious approach to rid our waterways the menace of water hyacinth, thereby creating employment for the locals, enhance food security and alleviate poverty and hunger thereby fulfilling the millennium development goal 1(MDG 1).

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