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Characterization of a Commercial Grade Humic Acid (HA) and Its Impact on Soil Properties and the Yield of Maize

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ABSTRACT: The study was conducted at the Prince Audu Abubakar University Research and Demonstration Farm, Anyigba, during the 2020 farming season. The broad objective of this research was to determine the effect of humic acid (HA) on soil properties, growth and yield of maize in southern guinea savannah. The parameters measured includes, plant height (cm), number of leaves, stem girth (cm), fresh cob weight (g), dry cob weight (g), fresh biomass (g), dry biomass (g), cob length (cm) cob diameter(cm), 100 grains weight (g) and total yield (kg). The experiment had eight (8) treatments (T1 = Control, T2 = HA10, T3= HA20, T4= HA30, T5= RNPK, T6= 1/3RNPK+HA30, T7= 1/2RNPK+HA30 and 2/3RNPK+HA30) which were replicated three (3) times and the experimental design was randomized complete block design (RCBD). From the result obtained, the HA concentrate has high pH (10.07), high in carbon (36.48) and high HA percentage (92.00). Pre-cropping soil analyses confirm the soil to be acidic (4.85), low in nutrient and the textural class is sand. Post-cropping soil analyses showed HA10 helped reduce soil pH the most (5.22) and application of HA generally help increase the concentration of micronutrients. The application of HA on maize had no significant ($p<0.05$) influence on the plant height, number of leaves, stem girth and most of the yield parameters tested with the exception of 100grain weight and total yield. Treatment 2/3RNPK+HA30 had a seed weight (21.50) which is statistically same with treatment RNPK (21.67).The total yield of maize gotten in this study showed that treatment HA10 had the highest yield (2.93) after treatment RNPK (3.53).Therefore, long term studies are required in the study location to know if positive responses will be observed on soil properties and growth of crops with the application of HA.

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KEYWORDS: Humic acid, maize, yield

INTRODUCTION

Soil is a finite resource that is crucial to human wellbeing (Lal, 2015). However, agricultural lands are currently under threats of soil degradation. Soil degradation is characterised by declining soil organic matter, nutrient depletion and loss of soil fertility (Lal, 2015). Soil degradation has been identified as a major cause of low agricultural productivity in many developing countries (Hüttil and Frielinghaus, 1994). Loss of soil organic matter specifically affects soil biological, chemical and physical properties. Changes in soil properties due to loss of organic matter have negative impact on soil biodiversity, soil buffering capacity, cation exchange capacity, nutrient availability and water infiltration, and can also lead to increased soil compaction and erosion (Karami *et al.,* 2012). Annually, gigatonnes (Gt) of grain crops residues are produced globally. However, these residues are often removed from the farms for alternate uses such as fuel, hay and other uses (Lal, 2004). In sub-Saharan Africa, nutrient depletion caused by low-input and extractive farming was estimated to be 40 kg of NPK ha^{-1} on cultivated land (Lal, 2004). Low crop production due to increasingly degraded agricultural soils is a threat to achieving global food security. Therefore, to satisfy the food demand of the current world population (7.3 billion and rising) and cope with the future food demand, there is need to adopt techniques that maximize food production from our agricultural soils whilst improving soil quality, using available organic amendments. Periodic application of fresh organic matter either as litter or crop residue is an effective way of rehabilitating degraded soils (Abiven *et al.,* 2009).

Soil organic matter is an important regulator of many environmental processes that affect crop productivity (Tejada *et al.,* 2006) through its beneficial effects at improving soil physical properties, increasing plant growth and crop yields (Karami *et al.,* 2012).

The use of leonardite in agriculture is expanding due to its high content of humic acid. Humic acid (HA) is an organic substance in the soil and is essential for soil fertility. Humic substances (HS) are remains of decomposed plant and animal materials such as lignin, tannins, cellulose, and cutins (Tan *et al*., 2000; Billingham, 2012; Hayes and Swift, 2020). It is a high-quality plant stimulant and soil conditioner and can be applied in all plants. Humic acid is known to be among the most bio-chemically active materials found in soil and are considered to be the most abundant naturally occurring organic molecules on earth and also described as being the "most important component of a healthy fertile soil (Calvo *et al*, 2014). Humic acid term is used for the brown-black, polymeric, alkali-soluble acids found in soils, plants, sea-grasses, fungi, sediments, and terrestrial and marine waters (Susic, 2016). HA can also be found in natural coal deposits. This soft brown coal layer is internationally called Leonardite. Leonardite differs from soft brown coal by a higher oxidation degree and its higher content of humic acid. Humic acids affect soil properties, both physical and chemical, and they also improve its fertility. Since the detection of high humic acid contents in leonardite, their commercial production for the agricultural purposes increased drastically. HA fraction contains about 60% organic carbon (C), which plays an important role in the growth of soil microorganisms (Sible *et al.,* 2021). Humic acid is an important soil component that can improve nutrient availability and impact on other important chemical, biological, and physical properties of soils (Meganind *et al*., 2015). Humic acid is an effective agent to use as a complement to synthetic or organic fertilizers and regular humic acid use will reduce the need for fertilization due to the soil's and plant's ability to make better use of it. Inorganic fertilization can be eliminated entirely if sufficient organic material is present and the soil can become self-sustaining through microbial processes and humus production (Khaled and Fawy, 2011). Humic substances are classified as humic acids (HA), fulvic acids (FA), and humins based on their solubility in water, acidic or alkaline solutions (De Melo *et al.,* 2016). Usage of organic based materials has gained importance within the last few years for sustainable agriculture and preventing soil degradation (Alagöz and Erdem, 2009). The external sources of HS are mostly commercially produced from soils, coal, lignite, and organic materials (Gollenbeek and Van Der Weide, 2020; Yang *et al*., 2021).

Maize occupies an important position in the cereal crops (Rahmati, 2012) and is considered as the mainstay of our livelihood because it provides staple food to a large portion of the human population (Farhad *et al*., 2009). Maize production in the Guinea Savannah of Nigeria is been faced with a lot of problems, ranging from natural to anthropogenic causes. These factors degrade soil in the long run. Farmers and agricultural scientists now resort to the use of soil organic amendment to bolster soil fertility and health. (Rahmati, 2012). Therefore, incorporation of humic acid as an organically charged biostimulant deserves more consideration for accelerating yield of various crops without impairing soil quality as 1 kg of humic acid can substitute for 1000 kg of farm yard manure (Hammad *et al.,* 2011; Tahir *et al.,* 2011; Humintech, 2012). However, information related to its structure, elemental and mineral composition is quite limited. Quality and property of leonardite might vary widely from deposit to deposit. Physical and chemical characterization of humic acid from leonardite would be useful and might lead to appropriate use as soil conditioner. Few research works on humic substances (HS) used as soil amendment had been conducted in the study area. There is information gap on the use of HA to boost soil fertility and improve crop yield in the study area. The objectives of the study were to characterize the commercial grade HA used, assess its effect on the soil properties and yield of maize.

MATERIAL AND METHODS

Experimental land area and design

This research work was carried out between June and September 2020 at Student Demonstration Farm, Prince Audu Abubakar University, Anyigba Kogi State. Anyigba is in the southern guinea savannah region (Nigeria). It lies on latitude 7º15' 29"N and longitude 7º11'E with an altitude of 420m above sea level. The general climate is humid, having a distinct raining and dry season. The mean annual temperature and rainfall are 27ºC and 160mm respectively (Amhakian *et al.,* 2006). The total land area for the experiment was 357.75m² (27m x 13.25m). The experiment was laid out in a randomized complete block design (RCBD) with eight treatments and three replications. The treatments consisted of T1 = control, T2 = 10kg of humic acid per hectare, T3 = 20kg of humic acid per hectare, T4 = 30kg of humic acid per hectare, T5 = the recommended rate of NPK (120kg: 60kg: 60kg) per hectare, T6 = 1/3 of NPK + 30kg of humic acid, T7 = ½ of NPK + 30kg of humic acid and T8 = 2/3 of NPK + 30kg of humic acid. HA was applied two weeks before planting by broadcasting to allow for mineralization while mineral fertilizer was applied two weeks after planting through side placement method. Humic acid (trade name - grand humus plus) was imported and procured from company's rep in Nigeria.

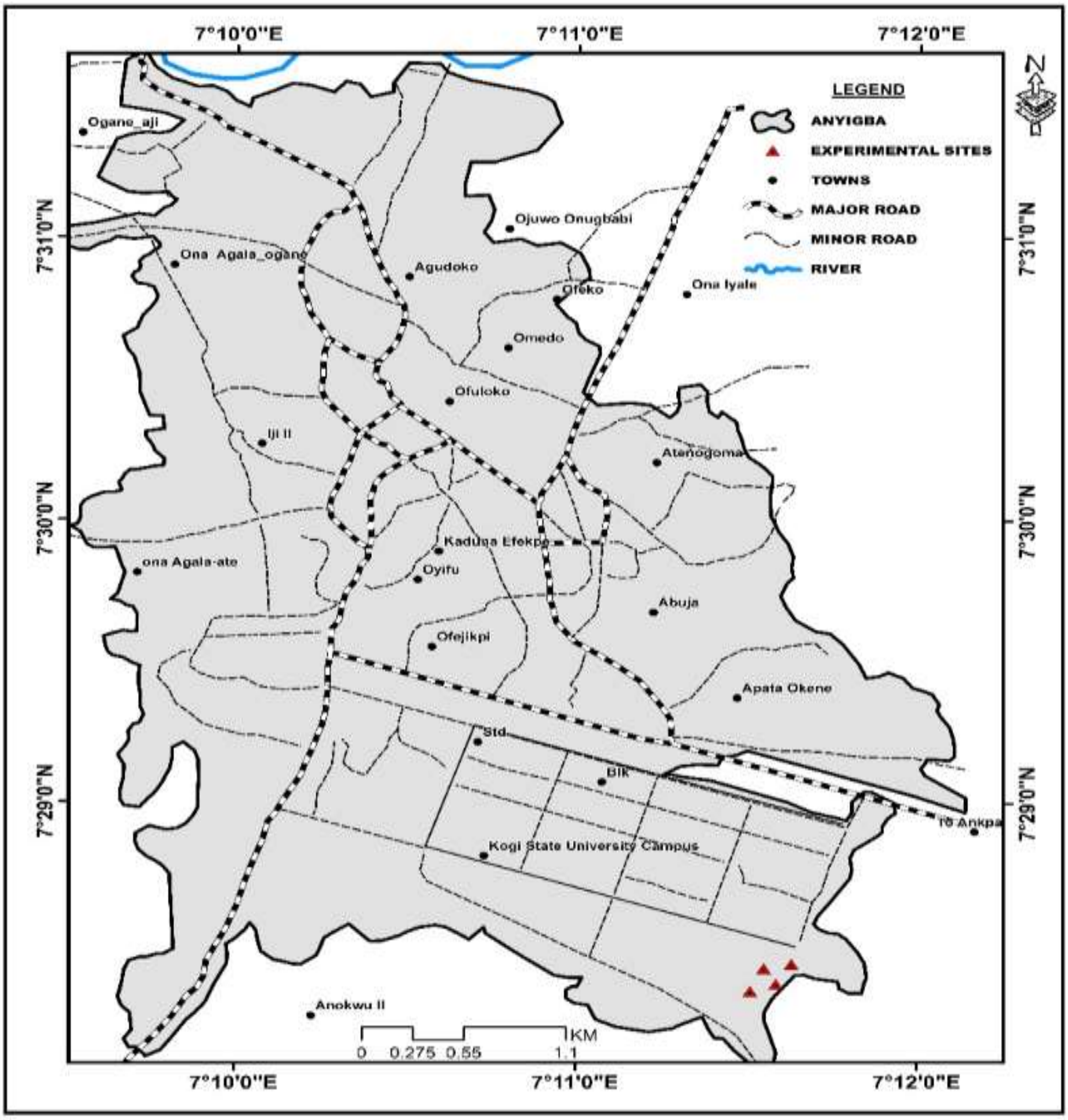

Figure 1: Map of Anyigba indicating the experimental site.

Humic acid characterization

The crystal morphology of HA was determined by scanning electron microscope (SEM). The determination was performed using JOEL (model JSM-7600F) SEM machine. The method used for the preparation of HA and FA was adapted according to the guidelines of the International Humic Substance Society (IHSS) involving alkaline extraction followed by acidification to separate from fulvic fraction (Lamar *et al*., 2014). The heavy metal and micronutrients concentrations were measured by atomic absorption spectrophotometer (AAS, Perkin Elmer Model 560 Perkin Elmercorp Norwalk CT) method by Sheldrick and McKeague (1960).

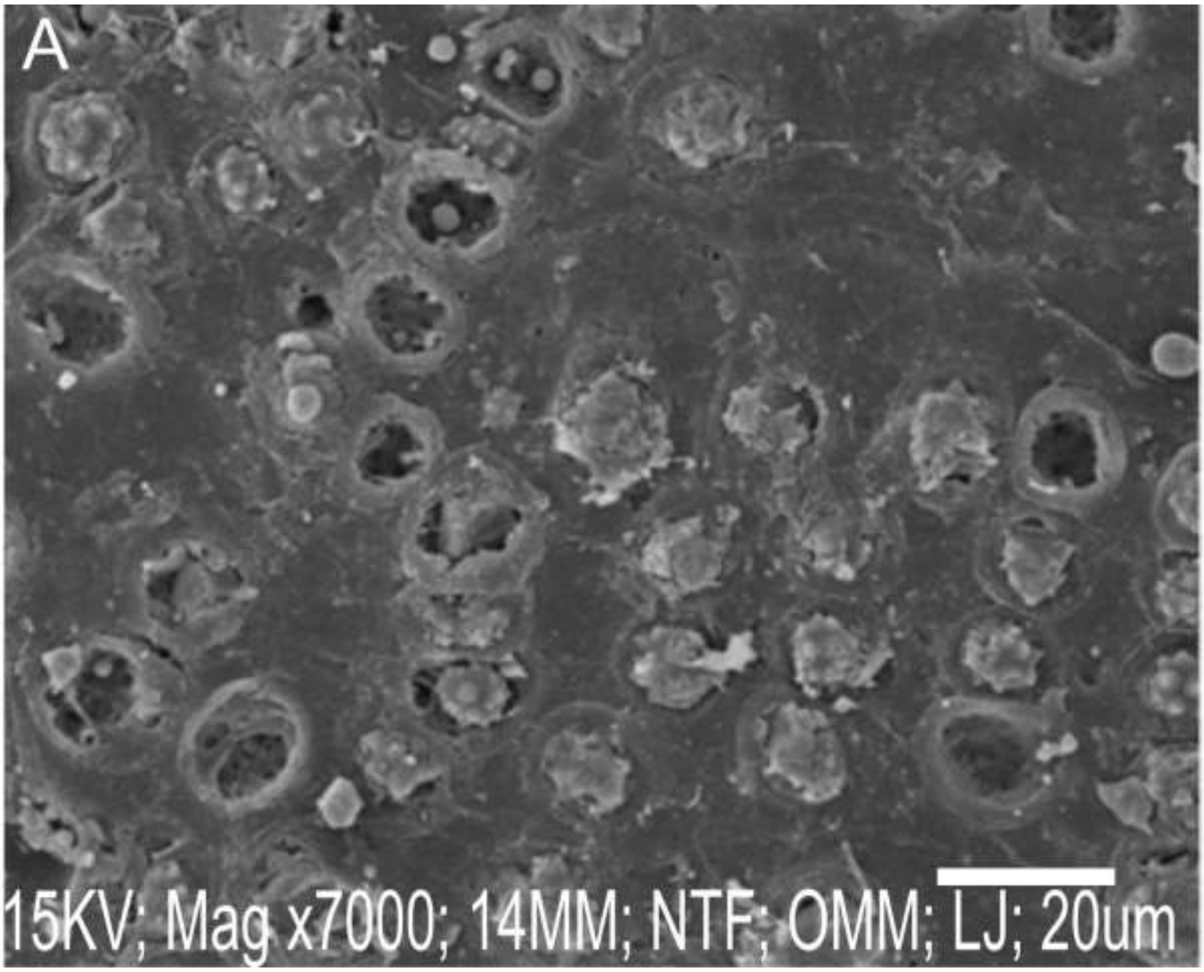

Plate 1: Image of HA from scanning electron microscope at 700X magnification and 20µm

Soil analyses

Soil samples were collected from 0 – 20cm depth prior to planting and after planting. Representative samples (20) were collected from the experimental field and bulked together as composite sample which was used as pre-cropping sample while samples were taken from each of the sub-plots at the termination of the experiment to represent post-cropping samples. Samples were collected inside labeled polythene bags with the use of a soil auger which was air dried, crushed and sieved with 2mm mesh in order to assess the physical and chemical properties of the soil. Bulk density (BD) was obtained by core method (Obi, 2000). Total porosity (TP) was obtained from bulk density value and assumed particle density of 2.65 Mg m-3 as (TP) = [1- (Bulk density/ particle density)] ×100 (Obi, 2000). The particle size distribution was determined by hydrometer method (Gee and Or, 2002). The textural class of the soil was determined using the textural triangle. Particle density of a soil sample is measured by first determining its mass after drying to 105˚C and then dividing that mass by the volume of the particles, excluding spaces among them. Soil pH was determined using glass electrode in 1:1 soil water (Soil and Plant Analysis Council, 2000). Exchangeable bases (Ca, Mg, K and Na) were extracted using NH_4OAC buffered at pH 7.0 (Thomas, 1982).The Ca and Mg were determined using atomic absorption Spectrophotometer and K and Na were estimated using flame photometer. Exchangeable acidity in soil (Al^{3+} and H^+) was extracted with Kcl (Thomas, 1982) and determined by titration with 0.05m NaOH using phenolphthalein as indicator. The total nitrogen in the soil samples was determined by macro-Kjeldahl method. Available phosphorus was determined by Bray-2 extractant method. (Olsen and Sommer, 1982; Bray and Kurtz, 2015). Organic carbon content was determined using Walkley-Black (1947) wet digestion method.

Data collection and analysis

Data on the effect of humic acid on the growth and yield of maize were obtained on four (4) randomly selected plants at 2, 4, 6 and 8 weeks after planting for plant height, stem girth and number of leaves. The plant height was taken by measuring the maize plants from the ground level to the tip of the apical meristem of the main axis using meter rule. The number of leaves/plant was counted at 2, 4, 6 and 8 weeks after planting (WAP) and averaged. Stem girth was measured with a vernier caliper. The stem girth was obtained from the tagged plants per plot. Number of Cobs per plant was obtained by counting the number of cob per each tagged plants produced and was recorded for every plot. An average of the entire plants on each plot was taken to obtain an estimate per plant. Other yield parameters (cob length, cob diameter, cob weight, 100 grain weight, above ground biomass, yield (kg/ha) were also taken. All data collected were subjected to analysis of variance (ANOVA) using Statistical Tool for Agriculture Research (STAR, 2013 Edition) and treatments' means were separated using Duncan Multiple Range Test (DMRT).

RESULTS

The result in Table 1 shows the analysis of the HA used in this study. Result shows the HA concentrate has a high pH (10.07) which indicate the alkalinic nature of the HA. The concentrate also has a high concentration of humic acid (92 %) and organic carbon which is essential for soil fertility. It is important to note that micronutrient is essential for the growth and development of crops. The analysis shows that HA has a reasonable concentration of micronutrients required by crops according to soil survey manual, United States Department of Agriculture (1993). Materials to be considered as soil organic amendment should not contain heavy metals; from the result gotten, HA concentrate contains 0% of the selected heavy metals assayed. Results in Table 1 shows the suitability of the HA concentrate to be considered as soil organic amendment.

Table 1: Some selected physical and chemical properties of HA

Properties	Values
P^H (H_20)	10.07
% Organic carbon	4.79
% Total Nitrogen	0.235
% Carbon	36.48
% Oxygen	43.77
% Hydrogen	3.12
% Total Phosphorus	0.036
% Na	2.00
% K	3.65
% Ca	0.236
% Mg	0.068
% Sulpur	0.160
% Humic Acid	92.00
Mn (mg/kg)	14.4
Fe (mg/kg)	2,925.00
Cu (mg/kg)	5.60
Zn (mg/kg)	19.80
Chloride (mg/kg)	36.78
Hg (mg/kg)	0.00
As (mg/kg)	0.00
Cr (mg/kg)	0.00
Pb (mg/kg)	0.00
Cd (mg/kg)	0.00
Surface area (g/cm^2)	1.567
Packed bulk density (g/m^3)	0.8635
Loose bulk density (g/m^3)	0.6752
C/N Ratio	1:0.1

The pre-cropping soil analyses result (Table 2) shows some chemical and physical soil test result of the experimental site before planting. The soil textural class was indicated to be sand and the soil is also acidic. Results also show that the concentrations of nitrogen, soil organic carbon and available phosphorus are quite low which makes the soil appropriate to assay the effect of treatments applied on the growth and yield of maize.

Table 2: Chemical and Physical properties of the experimental site before planting

Properties	Values
P^H (H_20)	5.75
P^H ($Cacl_2$)	4.85

E.C	60.00
% Organic Carbon	0.29
% Total Nitrogen	0.032
Available P (mg/kg)	6.84
Exch. Acidity (cmol/kg)	0.25
Exch. H^+ (cmol/kg)	0.25
Exch. Al^{+++} (cmol/kg)	0.00
Ca (cmol/kg)	31.76
Mg (cmol/kg)	1.14
K (cmol/kg)	0.06
Na (cmol/kg)	0.31
CEC (cmol/kg)	33.52
Mn (mg/kg)	36.00
Fe (mg/kg)	54.00
Cu (mg/kg)	0.52
Zn (mg/kg)	0.61
Sand (%)	94.40
Silt (%)	2.60
Clay (%)	3.00
Textural class	Sand
Particle density (g/cm^3)	2.65
Bulk density (g/cm^3)	1.73
Porosity (%)	35.00

The result of HA on some selected soil chemical properties (post-cropping analyses) is presented in Table 3. Significant effects were observed in pH in H_20, pH in $Cacl_2$, %organic carbon, available P and Ca. The result indicates a significant influence ($p<0.05$) of humic acid on soil pH (H20). The pH values ranged from 5.30 to 5.63 with the control treatment having the highest pH but has no significant difference ($p<0.05$) from HA20 treatment (5.59). In pH (Cacl2) the values ranged from 4.50 to 5.22. There was a significant difference ($p<0.05$) among the treatments with treatment HA10 having the highest pH value. Although HA10 is not significantly different from treatments – control, HA20, HA30, RNPK and 1/3RNPK+HA30. But they are significantly different from treatments- 1/2RNPK+HA30 and 2/3RNPK+HA30. Organic carbon values ranged from 0.02 to 0.82, and there was a significant difference ($p<0.05$) across the treatments. The treatment ½RNPK+HA30 had the highest value. HA10 and ⅓RNPK+HA30 had the lowest values with an insignificant difference between. Total nitrogen concentration shows no significant effect ($p<0.05$) of HA application. The values ranged from 0.01 to 0.24. Treatment ⅔RNPK+HA30 had the highest value while HA10 had the lowest value. Available phosphorus values ranged from 6.52-9.04mg/kg. Interestingly, control had the highest and it is quite different significantly ($p<0.05$) from other treatments. Calcium concentrations increased significantly across the treatments. Values ranged between 31.91 – 40.41 cmol/kg with ⅔RNPK+HA30 having the highest while control had the lowest.

The values recorded for % total nitrogen, magnesium, sodium and cation exchange capacity shows increase across the treatments although these increases were not significant ($p<0.05$) when compared to control.

Table 3: Effect of HA on some soil chemical properties of soil

Treatments	pH (H_20)	pH ($Cacl_2$)	% OC	% TN	AV. P mg/kg	Ca	Mg	K	Na	CEC
							cmol/kg			
Control	5.63^{a}	5.03^{ab}	0.20^{e}	0.02	9.04^{a}	31.91^{b}	1.17	0.04	0.64	34.33
HA_{10}	5.45^{c}	5.22^{a}	0.12^{f}	0.01	7.04^{d}	33.05^{b}	1.15	0.05	0.27	34.97
HA_{20}	5.59^{a}	4.89^{ab}	0.02^{g}	0.11	6.76^{f}	33.71b	1.23	0.05	0.40	35.66
HA_{30}	5.53^{b}	4.93^{ab}	0.69^{b}	0.07	6.96^{e}	32.40^{b}	1.15	0.05	0.36	34.24
RNPK	5.51^{b}	4.71^{ab}	0.28^{d}	0.03	7.44^{b}	32.74^{b}	1.14	0.05	0.29	34.53
1/3RNPK+HA_{30}	5.52^{b}	4.71^{ab}	0.12^{f}	0.01	7.36^{c}	33.18^{b}	1.19	0.08	0.35	35.07

1/2RNPK+HA30	5.30d	4.50b	0.82a	0.09	6.52g	33.53b	1.19	0.05	0.39	35.46
2/3RNPK+HA30	5.31d	4.51b	0.53c	0.24	7.00de	40.41a	0.86	0.06	0.31	41.71
LSD	*	*	*	NS	*	*	NS	NS	NS	NS

Means with the same letter(s) are not significantly different at 5% level of probability.HA_{10} = 10kgHA/ha, HA_{20} = 20kgHA/ha, HA_{30} = 30kgHA/ha, RNPK = 120kgNPK/ha, 1/3RNPK + HA_{30} =HA_{30}1/2RNPK, 1/2RNPK + HA_{30} = HA_{30}1/2RNPK, 2/3RNPK + HA_{30} = HA_{30} +1/2RNPK; OC=organic carbon; TN= toal nitrogen; Ca= calcium; Mg= magnesium; K= potassium; Na= Sodium; Cation exchange capacity

Results gotten for other selected soil chemical properties is presented in Table 4. The effect of HA levels on exchangeable acidity, exchangeable Al^{+++} , exchangeable H^+ and copper (Cu) concentration showed no significant increase ($p<0.05$) when compared with the control treatment. Significant increases were observed in some of the micronutrients assayed. Manganese concentration ranges from 40.00 to 51.00 mg/kg. HA10 had the lowest value while HA30 had the highest which is significantly higher than the value gotten for the recommended rate of mineral fertilizer (post-cropping). Iron (Fe) concentration ranged from 52.00 to 71.00, RNPK with the lowest and 1/3RNPK+HA30 had the highest value. All treatments are significantly different ($p<0.05$) except HA20 and 1/2RNPK+HA30. In terms of Zinc (Zn) concentration as influenced by HA application, concentrations ranged from 0.65 to 0.89mg/kg with RNPK the lowest and 1/2RNPK+HA30 the highest. 1/2RNPK+HA30 had a higher significant effect in terms of zinc concentration when compared to the recommended rate of mineral fertilizer.

Table 4. Influence of HA application on exchangeable acidity and soil micro nutrients

Treatments	EA	Exch. H^+	Exch. AL^{+++}	E.C (us/cm)	Mn	Fe	Cu	Zn
					←	mg/kg		→
Control	0.30	0.28	0.02	60bc	47.50bc	61.00ad	0.67	0.86ab
HA_{10}	0.33	0.30	0.03	56c	40.00e	58.00d	0.50	0.79cd
HA_{20}	0.27	0.27	0.00	61b	43.00de	63.00c	0.59	0.72e
HA_{30}	0.28	0.28	0.00	51d	51.00a	66.67b	0.70	0.83bc
RNPK	0.31	0.30	0.00	70a	46.70bc	52.00e	0.60	0.65f
1/3RNPK+HA_{30}	0.30	0.30	0.00	62b	45.20cd	71.00a	0.64	0.78d
1/2RNPK+HA_{30}	0.30	0.30	0.00	71a	48.00abc	63.00c	0.71	0.89a
2/3RNPK+HA_{30}	0.28	0.28	0.00	63b	49.00ab	58.00d	0.66	0.80cd
LSD (0.05%)	NS	NS	NS	*	*	*	NS	*

Means with the same letter(s) are not significantly different at 5% level of probability.HA_{10} = 10kgHA/ha, HA_{20} = 20kgHA/ha, HA_{30} = 30kgHA/ha, RNPK = 120kgNPK/ha, 1/3RNPK + HA_{30} =HA_{30}1/2RNPK, 1/2RNPK + HA_{30} = HA_{30}1/2RNPK, 2/3RNPK + HA_{30} = HA_{30} +1/2RNPK; EA= exchangeable acidity; EC=electrical conductivity; Mn=manganese; Cu= copper; Zn=zinc, Fe=iron

Table 5 shows the result gotten for the analyses of some physical properties of soil (post-harvest soil sample) as influenced by HA application. Sand (%) shows there was a significant difference ($p<0.05$) among the treatments. The values ranged significantly from 92.40 to 95.30, the lowest value was observed in the control treatment and highest value was observed in HA_{10} and RNPK. HA20, HA30 and 1/3RNPK +HA_{30} are not significantly different ($p<0.05$) from one another. The effect of HA levels on percentage silt indicates that, there was significant difference ($p<0.05$) among the treatments and the highest value was observed in control treatment and lowest value was observed in RNPK. From the table, the values ranged from 0.70 to 4.00 which implies that, there was a significant difference ($p<0.05$) across the treatments. Percentage clay, bulk density, particle density and porosity are the other physical properties analyzed in this study. Results from the test showed no significant effect ($p<0.05$) in percentage clay, bulk density, particle density and porosity across the treatments. This means that the application of different HA rates does not have any positive impact on these soil physical properties.

Table 5: Effect of HA on physical properties of soil

Treatments	% Sand	% Silt	% Clay	Particle Density g/cm^3	Bulk density	Porosity %	Textural Class
Control	92.40^{c}	4.00^{a}	3.60	2.65	1.73	35.00	Sand
HA_{10}	95.30^{a}	1.70^{bc}	3.60	2.65	1.73	35.00	Sand
HA_{20}	93.30^{bc}	2.07^{b}	5.00	2.65	1.73	35.00	Sand
HA_{30}	93.30^{bc}	2.70^{ab}	4.00	2.65	1.73	35.00	Sand
RNPK	95.30^{a}	0.70^{c}	4.00	2.65	1.73	35.00	Sand
1/3RNPK+HA_{30}	93.30^{bc}	2.70^{ab}	4.00	2.65	1.73	35.00	Sand
1/2RNPK+HA_{30}	94.40^{ab}	2.60^{b}	3.00	2.65	1.73	35.00	Sand
2/3RNPK+HA_{30}	94.40^{ab}	2.60^{b}	3.00	2.65	1.73	35.00	Sand
LOS	*	*	NS	NS	NS	NS	

Means with the same letter(s) are not significantly different at 5% level of probability.HA_{10} = 10kgHA/ha, HA_{20} = 20kgHA/ha, HA_{30} = 30kgHA/ha, RNPK = 120kgNPK/ha, 1/3RNPK + HA_{30} =HA_{30}1/2RNPK, 1/2RNPK + HA_{30} = HA_{30}1/2RNPK, 2/3RNPK + HA_{30} = HA_{30} +1/2RNPK

From the result of effect of HA on plant height of maize as represented in the Table 6 below, the application of HA had no significant ($p<0.05$) effect on the plant height at 2, 4 6 and 8 WAS. RNPK had the highest plant height at 2WAS, 4WAS and 6WAS while control had the lowest. A different trend was observed at 8 WAS with HA20 having the highest plant height and control having the lowest. Although increase was observed across the treatments, this increase is statistically not significant.

Table 6: Plant Height (cm) as influenced by HA application

	Sampling Periods (Weeks After Sowing)			
Treatments	2WAS	4WAS	6WAS	8WAS
Control	7.14	31.30	60.65	97.26
HA10	7.35	30.38	63.49	96.94
HA20	7.96	32.50	67.69	108.94
HA30	7.40	28.85	58.69	92.86
RNPK	9.14	38.70	72.15	106.86
1/3RNPK+HA30	8.55	32.85	65.08	104.88
1/2RNPK+HA30	7.47	31.44	62.07	97.99
2/3RNPK+HA30	6.90	31.40	64.12	99.51
LSD (0.05%)	NS	NS	NS	NS

Means having the same letters are not significantly different according to Duncan's Multiple Range Test (DMRT) at 5% level of probability**.** WAS- Weeks after Sowing**,** LSD- Least Significant Difference**,** N.S- Not Significant. *-significant CV: Coefficient of Variations

Table 7 shows result for maize number of leaves as influenced by HA application. A different trend was observed in this table. At 2 WAS, Control and HA30 had the highest number of leaves while HA30 had the lowest. At 4WAS, 2/3RNPK+HA30 had the highest with HA30 having the lowest while control and 1/2RNPK+HA30 had the same number of leaves. Result obtained at 6WAS showed RNPK had higher number of leaves as when compared to other treatments with HA10 having the lowest. At 8WAS the result was different as well, RNPK had the highest mean value for number of leaves and the lowest number of leaves was recorded in control.

Table 7: Effect of HA application on maize number of leaves

	Sampling Periods (Weeks After Sowing)			
Treatments	2WAS	4WAS	6WAS	8WAS
Control	4.50	6.92	9.17	11.75
HA10	4.25	7.25	8.58	12.33
HA20	4.08	7.08	9.42	12.33
HA30	4.50	6.83	9.06	12.25
RNPK	4.33	7.17	9.75	13.17
1/3RNPK+HA30	4.25	7.08	9.50	12.75
1/2RNPK+HA30	4.33	6.92	9.42	12.25
2/3RNPK+HA30	4.17	7.42	9.25	12.17
LSD (0.05%)	NS	NS	NS	NS

Means having the same letters are not significantly different according to Duncan's Multiple Range Test (DMRT) at 5% level of probability**.** WAS- Weeks after Sowing**,** LSD- Least Significant Difference**,** N.S- Not Significant. *-significant

From the result of application of HA on Stem Girth of Maize as represented in the Table 4, the application of HA had no significant ($p<0.05$) effect on the Stem Girth at 2, 4 6 and 8 WAS. Plots treated with the equivalent of RNPK gave the widest girth with mean value of 0.76cm, 1.16cm, 1.60cm and 1.71cm at 2, 4, 6, and 8 WAS respectively. The lowest mean value was obtained from control with mean value of 0.57cm and 1.35cm at 2 and 6 WAS, while, HA20 had 0.95cm and 1.52cm at 4 and 8WAS respectively.

Table 8: Effect of HA application on maize stem girth (cm)

	Sampling Periods (Weeks After Sowing)			
Treatments	2WAS	4WAS	6WAS	8WAS
Control	0.57	1.01	1.35	1.63
HA10	0.70	1.14	1.44	1.71
HA20	0.60	0.95	1.48	1.52
HA30	0.57	0.96	1.36	1.55
RNPK	0.76	1.16	1.60	1.71
1/3RNPK+HA30	0.58	0.99	1.44	1.69
1/2RNPK+HA30	0.66	1.13	1.48	1.69
2/3RNPK+HA30	0.63	1.07	1.43	1.61
LSD (0.05%)	NS	NS	NS	NS

Means having the same letters are not significantly different according to Duncan's Multiple Range Test (DMRT) at 5% level of probability**.** WAS- Weeks after Sowing**,** LSD- Least Significant Difference**,** N.S- Not Significant. *-significant CV: Coefficient of Variations

HA application effect was also tested on certain yield parameters. Results presented in Table 9 shows maize yield response to different loading rates of HA. Application of HA had no significant ($p<0.05$) influence on the fresh cob weight (g), dry cob weight (g), fresh biomass (g) and dry biomass (g). Plots treated with RNPK had the highest fresh cob weight (215.00g) while the least was control with mean value of 155.83g. In terms of dry cob weight (g), Plots treated with RNPK again had the highest mean value of 113.33g, while the least was 2/3RNPK +HA_{30} with a value of 82.50g. For fresh biomass (g) parameter, plots treated with HA20 had the highest with mean value of 863.33g, while the least was Control with mean value of 556.67g. The dry biomass weights (g) were also tested; plots treated with RNPK had the highest with a weight of 233.33g while the least was control with a weight of 183.33g. Although increases were observed which were higher than control in most cases (both cob and biomass weight), these higher values were not statistically different from the control. What this means is that although the different loading rates of HA gave heavier cobs and biomass; these values in the real sense are not quite different from the maize weights recorded in control.

Table 9: Influence of HA application on the yield parameters of maize

Treatments	FreshCob Weight (g)	Dry Cob Weight (g)	Fresh Biomass (g)	Dry Biomass (g)
Control	155.83	85.83	556.67	183.33
HA10	175.00	95.83	620.00	200.00
HA20	183.33	85.00	863.33	200.00
HA30	170.00	85.00	653.33	200.00
RNPK	215.00	113.33	770.00	233.33
1/3RNPK+HA30	189.33	90.83	800.00	223.33
1/2RNPK+HA30	193.33	89.17	806.67	216.67
2/3RNPK+HA30	173.40	82.50	750.00	210.00
LSD (0.05%)	NS	NS	NS	NS

*Means having the same letters are not significantly different according to Duncan's Multiple Range Test (DMRT) at 5% level of probability. LSD- Least Significant Difference, N.S.: Not Significant. *-significant, CV: Coefficient of Variations*

Result gotten for the effect of HA on cob length (cm), cob diameter (cm), 100 grains weight (g) and total yield (kg/ha) of maize is represented in Table 10. The application of HA had no significant ($p<0.05$) influence on the cob length (cm) and cob diameter (cm). However, significant effect ($p<0.05$) for 100 grains weight (g) and total yield (kg/ha) were observed. Result for maize cob length shows that plots treated with RNPK had the longest with mean value of 14.72cm, while the least was 1/3RNPK+HA30 with mean value of 13.01cm. The cob diameter (cm) parameter also shows no significant effect, plots treated with HA10 had the highest with mean value of 4.08cm, while the least was 2/3RNPK+HA30 with mean value of 3.71cm. 100 grains weight (g) Plots treated with the equivalent of RNPK had the highest with mean value of 21.67g which is not significantly different from 2/3RNPK+HA30 with a weight of 21.50g, while the least was control with mean value of 17.33g. This means that the application of 2/3 recommended rate of mineral fertilizer in combination with HA can give the expected result as with the use of mineral fertilizer alone in the study area. Treatment RNPK had the highest total yield per hectare (3.53) while control gave the lowest yield (1.72). All treatments are statistically different from one another.

Table 10: Effect of HA on other yield component of maize

Treatments	Cob length (cm)	Cob diameter (cm)	100grains weight (g)	Total yield (kg/ha)
Control	13.36	3.72	17.33^{c}	1.72^{c}
HA10	13.66	4.08	19.33^{b}	2.93^{ab}
HA20	13.03	3.86	21.00^{ab}	2.14^{bc}
HA30	14.26	3.93	20.67^{ab}	2.64^{abc}
RNPK	14.72	4.02	21.67^{a}	3.53^{a}
1/3RNPK+HA30	13.01	3.93	20.60^{ab}	2.67^{abc}
1/2RNPK+HA30	14.17	3.81	20.83^{ab}	2.74^{ab}
2/3RNPK+HA30	13.21	3.71	21.50^{a}	2.54^{abc}
LSD (0.05%)	NS	NS	*	*

Means having the same letters are not significantly different according to Duncan's Multiple Range Test (DMRT) at 5% level of probability. LSD- Least Significant Difference, N.S- Not Significant. *-significant, CV: Coefficient of Variations

DISCUSSION

The results of this study indicated that humic acid application especially at 10kg/ha help reduce soil acidity and this is in agreement with the study carried out by Sharif *et al*. (2002).The study showed that, the application of HA to the soil also increased electrical conductivity and organic carbon also increased. The E.C was higher among combined treatment than the control but the highest E.C content was observed in ½RNPK+HA30 treatment. This is in agreement with the study carried out by (Yılmaz, 2010). There was decreased in Al^{3+} and increased in H^{+} and application of humic acid improved physical properties of soil such as sand (%) and silt(%); as for clay(%) differences were not significant enough.

Soil available phosphorus was the most dramatically affected by the HA application. Control had the highest available P value, while treatments HA10, HA30, RNPK, 1/3RNPK+HA30 and 2/3RNPK+HA30 had values higher than that recorded in the pre-cropping soil sample. This shows that application of sole HA and its combination with mineral fertilizer can help increase the availability of phosphorus. Generally, total nitrogen content of soil increased with increasing amendment rates of HA. As also reported by Yılmaz (2011), addition of HA increased N accumulation over control with no significant differences within the treatments of different levels of HA applied. Humic acid increased Mg, K, Na, and C.E.C over the control. This is in agreement with the study carried out by Atiyeh *et al.* (2002). But there was no significant difference among the treatments.The Calcium was higher among combined treatment than the control but the highest value of Ca was observed on ⅔RNPK+HA30 treatments. With the application of humic acid, significant changes were observed in soil Fe, and Mn content when compared to the control treatment. From the study, there was drastic increase of Mn, Fe and Zn. Sole application of HA (HA30) had the highest concentration of Mn, combination of HA and mineral fertilizer (1/3RNPK+HA30) had the highest concentration of Fe while for Zn, combination of HA and mineral fertilizer (1/2RNPK+HA30) had the highest. Cu recorded increase across the treatment with 1/2RNPK+HA30 having the highest value but the values are not statistically different. From Table 5, study indicates there was no significant increased on particle density, bulk density and porosity across all the treatments. Humic substance plays a major part in sustaining soil fertility and productivity. It enhances the soil's physical, chemical and biological properties and impacts plant growth. Utilization of these as a source of organic amendment reduces the dependence on chemical fertilizers and also provides substantial quantity of nutrient elements and helps in the exchange of nutrients from the soil to the plant. However, from the result of effect of HA on growth and yield of maize all the parameter measured- plant height, number of leaves, stem girth, fresh cob weight, dry cob weight, fresh biomass, dry biomass, cob length and cob diameter, studied had no significant ($p<0.05$) influence. However 100 Grains weight and total yield studied had significant ($p<0.05$) influence. According to Sun *et al.*, (2020), HA is a kind of macromolecular organic matter produced by aerobic fermentation of plant residues. It has many aromatic structures, phenolic hydroxyl structures and carboxyl structures, which make humic acid faintly acid and show solubility, electrification, adsorbability, ion exchange and complexation chelating properties. It is released from humic acid up to 20 kg HA ha^{-1} and requires almost 60 days to complete the process (Sathiyabhama *et al.,* 2003) because it is a slow release fertilizer of N (Dev and Bhardwaj, 1995). Similarly, Schlten *et al.* (1993) stated that slow-release fertilizers involve a slower release rate of nutrients than conventional water-soluble fertilizers, but the rate, pattern, and duration of release are not controlled (Trenkel, 2010) because they depend on microbial organisms whose effectiveness is dependent on soil temperature and moisture conditions. Slow-release fertilizer releases nutrients gradually with time, and it can be an inorganic or organic form. Also, Suntari *et al.* (2013) reported that urea-humate more stable and suggest a slow release of its nitrogen.Majority of the growth and yield parameters tested showed insignificant difference across the different loading rate of HA, reasons could be adduced to the fact that many soil organic amendments have long duration time before mineralization occur. Also, HA is a new soil organic amendment newly introduced to the study area, it might take some time before it adjust itself to soil and climate. It was also observed that no significant effect was recorded for most of the growth parameters but that was not the case for some yield parameters assayed. The maize seed planted (premier seed-oba super 2) was an improved variety, this variety uses assimilates to develop fruits and seeds than they do their vegetative parts.

CONCLUSION

The study was carried out to study the effects of humic acid on soil properties, growth and yield of maize. It can be stated that the results obtained suggested a better state of most soil properties when HA is applied. The results of this study indicated that humic acid application helps to improved soil chemical and physical properties and some yield component of maize. The study showed that, the application of humic acid to the soil increased/ improved some of the major elements such as Ca, Mg, k, N, Na, P and micro nutrients. In some cases, sole application best influences soil property while in some cases humic acid in combination with mineral fertilizer gave best result. Therefore, HA, NPK+HA are essential tools that could maintain high soil quality and also serve as soil conditioner. The different loading rates of HA did not significantly affect the growth and some yield parameters of maize assayed. However, 100 Grain Weight and Total Yield were highly influenced and was significantly ($p<0.05$) influenced.

RECOMMENDATION

The use of HA may contribute to enhancing the level of organic carbon and nitrogen in soil. From the results shown, HA (grand Humus plus) has potential to be used as an effective conservation and management tool for sustainability of the soil environment. It is therefore recommended that further studies be carried out in many cropping seasons on the effect of humic acid application on growth of crops in the study area. Better positive responses could be observed if HA application to soil is study over several years.

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