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Research Article

Assessment of Soil Applied Humic Acid on The Yield of Maize in The Guinea Savanna Agro-Ecology

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Abstract

The study was conducted at the Prince Audu Abubakar University Research and Demonstration Farm, Anyigba, during the 2021 and 2022 farming season. The broad objective of this research was to determine the effect of humic acid (HA) on the growth and yield of maize in Guinea Savanna Agro-Ecology. The parameters measured includes, plant height (cm), number of leaves, stem girth (cm), fresh biomass (g), dry biomass (g), fresh cob (g), dry cob (g), cob length (cm), Cob diameter (cm), 100-seeds weight (g) and yield (t/ha). The experiment had eight (8) treatments (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 RNPK + 30kg of humic acid, T7 = ½ of RNPK + 30kg of humic acid and T8 = 2/3 of RNPK + 30kg of humic acid) which were replicated three (3) times and the experimental design was Randomized Complete Block Design (RCBD). From the result obtained, the application of Humic Acid on maize had no significant ($p>0.05$) influence on the plant height, number of leaves and stem girth for most of the sampling periods in both cropping seasons. However there were significant difference ($p>0.05$) for all the yield parameter tested except the cob diameter. The total yield of maize gotten in this study showed that treatment 120kgNPK/ha and HA_{30}+2/3RNPK had the highest yield were statistically at par in the first (4.12 and 3.78 t/ha) and Second (4.00 and 3.77 t/ha) cropping season respectively. Therefore, application of 2/3 fraction of the recommended mineral fertilizer rate in combination with HA (2/3 RNPK + HA30) can be considered for optimum maize yield in the Study location for agriculture to be sustainable.

Introduction

Maize *(Zea mays L.)* is one of the three major cereals that feed the world (1) and, together with rice and wheat, dominates the human diet, providing at least 30% of the dietary calories of more than 4.5 billion people in 94 developing countries (2). Maize alone contributes more than 20% of total calories in the human diet in 21 low-income countries and more than 30% in 12 countries that are home to a total of more than 310 million people. The centrality of maize as a staple food in Africa and Central America is comparable to that of rice or wheat in Asia, with consumption rates highest in East and Southern Africa (ESA). Maize is the third most important cereal crop after sorghum (Sorghum bicolor) and millet (*Pennisetum glaucum*) in Nigeria and it is a major staple food that is used as fodder and industrial material with its production at both subsistence and commercial levels in the country (3). Humic acid is an organically charged biostimulant (4) produced by bacterial and chemical processes in soil. It is an essential component of organic matter that improves the physical, biological and chemical properties of the soil, e.g. water holding capacity, nutrient availability, soil permeability and soil structure (5). It increases the retention of organic matter, organic carbon and water, which ultimately increases the retention of fertilizers in the soil (6). It has the potential to improve various physiological and biochemical processes in the plant; for example, chlorophyll, net assimilation rate, carbohydrates, leaf area and root development. It can reduce nitrogen losses by stimulating soil exchangeable ammonium ($NH4^+$) and available nitrate ($NO3^-$), leading to higher soil nitrogen retention and plant uptake. Appropriate application of humic substances in the soil has the ability to increase the availability of macro (N, P, K and Ca) and micronutrients (Fe, Zn and Mn) and their uptake by plants.

Therefore, adequate application of humic substances in the soil has capability to increase the availability of macro (N, P, K and Ca) and micro nutrients (Fe, Zn and Mn) as well as their uptake in the plants. It is important to identify maize varieties which have the ability to produce higher grain yield under the cropping systems practiced by the small land holder farmers, as very little effort has been made in this regard. Sustainable crop production depends on the continuous renewal of soil fertility through a balance between N demand and supply in cropping systems. There seems to be a synergistic relationship between humic acid and N as it has a crucial role on the fate of organic nitrogen in the soil, N cycling, distribution and its availability to the plants (6) Soil of arid and semi-arid region having low precipitation and high evapotranspiration resulted in lower organic matter, nutrient deficiencies and high pH. The beneficial effect of humic acid and nitrogen in various plant species has been well described; however, the specific effect of different levels of Humic Acid with and without nitrogen in maize has yet to be investigated. In addition, we will determine the potential of humic acids to trigger total nitrogen uptake and corn grain yield under field conditions.

Material and Methods

Experimental land area and design

This research work was carried out 2021 and 2022 at Student Demonstration Farm, Prince Audu Abubakar University, Anyigba Kogi State. Anyigba is in the southern guinea savannah region (Nigeria). It lies on latitude $7^0$15' 29"N and longitude $7^0$11'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 27^0C and 160mm respectively (7). The total land area for the experiment was 357.75m^2 (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 RNPK + 30kg of humic acid, T7 = ½ of RNPK + 30kg of humic acid and T8 = 2/3 of RNPK + 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.

Soil analyses

Soil samples were collected from 0 – 20cm depth prior to planting and after planting. Representative samples (25) 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 (8). 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 (8). The particle size distribution was determined by hydrometer method. 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. Exchangeable bases (Ca, Mg, K and Na) were extracted using NH4OAC buffered at pH 7.0 (9).The Ca and Mg were determined using atomic absorption Spectrophotometer and K and Na were estimated using flame photometer. Exchangeable acidity in soil (Al3+ and H+) was extracted with Kcl (9) 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. (10 & 11). Organic carbon content was determined using (12) wet digestion method.

Data Collection and Statistical 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. 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 Weight of biomass taken were fresh biomass (g), dry biomass (g), fresh cob (g) and dry cob (g) while other yield parameters (cob length (cm), cob diameter (cm) and 100-seeds weight (g) 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 and Discussion

Humic Acid Concentrates

The result in Table 1 shows the analysis of the Humic Acid Concentrates 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 (4.78) and total Nitrogen (0.24) 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. 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.

Chemical and Physical properties of the experimental site before planting

The result in Table 2 shows the pre-cropping soil analyses result 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 1: Properties of the Humic Acid Concentrates

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
% K	3.65
% Ca	0.236
% Mg	0.068
% Sulpur	0.16
% Fulvic Acid	6.56
% Humic Acid	92
Mn (mg/kg)	14.4
Fe (mg/kg)	2,925.00
Cu (mg/kg)	5.6
Zn (mg/kg)	19.8
Chloride (mg/kg)	3678
Hg (mg/kg)	0
As (mg/kg)	0
Cr (mg/kg)	0
Pb (mg/kg)	0
Cd (mg/kg)	0
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	01:00.1

From the result of effect of HA on plant height of maize as represented in the Table 3 below, the application of HA had no significant ($p<0.05$) effect on the plant height at 2, 4 6 and 8 WAS for 2021. However, for the second year 2022 the application of HA had no significant ($p<0.05$) effect on the plant height at 4 and 6 WAS, but was significant ($p<0.05$) at 2 and 8 WAS. At 2WAS treatment ½ of NPK + 30kg of humic acid produced the tallest plant with mean value of 11.76, while the shortest plant is the control with mean value of 8.30. At 8 WAS treatment 120kgNPK/ha produced the tallest plant with mean value of 81.22, while the shortest plant is the control with mean value of 65.96, all plants increase was observed across the treatments, this increase is statistically not significant.

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

Properties	Values
P^H (H_20)	5.75
P^H (Cacl)	4.85
E.C	60
% Organic Carbon	0.287
% Total Nitrogen	0.032
Available P (mg/kg)	6.84
Exch. Acidity (cmol/kg)	0.25
Exch. H+ (cmol/kg)	0.25
Exch. A+++ (cmol/kg)	0
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
Fe (mg/kg)	54
Cu (mg/kg)	0.52
Zn (mg/kg)	0.61
Sand (%)	94.4
Silt (%)	2.6
Clay (%)	3
Textural Class	Sand
Particle Density (g/cm^3)	2.65
Bulk Density (g/cm^3)	1.73
Porosity (%)	35

From the result of effect of HA on Number of Leaves as represented in the Table 4 below, the application of HA had no significant ($p<0.05$) effect on the Number of leaves at 2, 4 6 and 8 WAS for 2021. However, for the second year 2022 the application of HA had no significant ($p<0.05$) effect on the Number of leaves at 2, 4 and 6 WAS, but was significant ($p<0.05$) at 8 WAS. At 8 WAS treatment 120kgNPK/ha produced the highest number of leaves with mean value of 13.83, while the least number of leaves is the control with mean value of 12.17, all plants increase was observed across the treatments, this increase is statistically not significant.

From the result of effect of HA on Stem girth maize as represented in the Table 5 below, the application of HA had no significant ($p<0.05$) effect on the plant height at 2, 4 6 and 8 WAS for 2021. However, for the second year 2022 the application of HA had no significant ($p<0.05$) effect on the plant height at 2 and 6 WAS, but was significant ($p<0.05$) at 4 and 8 WAS. At 4 WAS treatment HA_{30}+2/3RNPK acid produced the wildest stem with mean value of 0.81, while the least is the control with mean value of 0.41. At 8 WAS treatment 120kgNPK/ha produced the wildest girth with mean value of 1.46, while the least is the control with mean value of 1.18, all plants increase was observed across the treatments, this increase is statistically not significant.

From the result of effect of HA on Yield parameters as represented in the Table 6 below, the application of HA had significant ($p<0.05$) effect on the fresh biomass for both year 2021 and 2022. Treatment 120kgNPK/ha produced the heaviest biomass with mean value of 235.00 and 224.17 for 2021 and 2022, while the least mean value 115.83 and 115.83 was observed from the control. The application of HA had significant ($p<0.05$) effect on the Dry biomass for both year 2021 and 2022. Treatment 120kgNPK/ha produced the heaviest Dry biomass with mean value of 66.67 and 64.50 for 2021 and 2022, while the least mean value 35.83 and 33.33 was observed from the control. The application of HA had significant ($p<0.05$) effect on the Fresh Cob for both year 2021 and 2022. Treatment 120kgNPK/ha produced the Highest fresh cob with mean value of 226.83 and 225.50 for 2021 and 2022, while the least mean value 135.00 and 130.83 was observed from the control. The application of HA had significant ($p<0.05$) effect on the Dry Cob for both year 2021 and 2022. Treatment 120kgNPK/ha produced the Highest Dry cob with mean value of 114.33 and 110.33 for 2021 and 2022, while the least mean value 72.50 and 70.00 was observed from the control.

From the result of effect of HA on yield parameters as represented in the Table 7 below, the application of HA had significant ($p<0.05$) effect on the Cob length for both year

Table 3: Effect of Humic Acid on Plant Height (cm) in Anyigba during the 2021 and 2022 cropping Season

Treatments	2021				2022			
	Weeks After Planting (WAP)				Weeks After Planting (WAP)			
	2	4	6	8	2	4	6	8
Control	7.14	31.3		97.26	8.30^{c}	33.24	54.36	65.96^{c}
10kgHA/ha	7.35	30.38	63.49	96.94	10.12^{abc}	37.04	57.67	75.16^{ab}
20kgHA/ha	9.14	32.5	67.69	108.94	9.87^{abc}	34.82	57.94	72.51bc
30kgHA/ha	7.4	28.85	58.69	92.86	9.52^{bc}	33.98	55.35	71.23bc
120kgNPK/ha	7.96	38.7	72.15	106.86	11.51^{ab}	35	63.23	71.23^{bc}
HA_{30}+1/3RNPK	8.55	32.85	65.08	104.88	10.95^{ab}	35.13	58.99	81.22^{a}
HA_{30}+1/2RNPK	7.47	31.44	62.07	97.99	11.76^{a}	35.55	58.74	70.69^{bc}
HA_{30}+2/3RNPK	6.9	31.4	64.12	99.51	9.82^{abc}	34.07	56.68	73.23^{bc}
LSD (0.05%)	Ns	Ns	Ns	Ns	*	Ns	Ns	*
SEM CV (%)	21.88	16.83	11.48	9.23	10.82	6.78	7.49	5.79

Means with the same letter(s) are not statistically significant at 5% level of test

NS = not significant at 5% level of test

* = significant at 5% level of test

Table 4: Effect of Humic Acid on Number of leaves per maize plant in Anyigba (2021 and 2022 Rainy Season).

Treatments	2021				2022			
	Weeks After Planting (WAP)				Weeks After Planting (WAP)			
	2	4	6	8	2	4	6	8
Control	4.5	6.92	9.17	11.75	4.58	7.67	9.08	12.17^{c}
10kgHA/ha	4.25	7.25	8.58	12.33	4.58	7.83	9.25	12.92^{bc}
20kgHA/ha	4.08	7.08	9.42	12.33	4.58	7.83	9.17	13.08^{ab}
30kgHA/ha	4.5	6.83	9.06	12.25	4.17	7.67	9.17	13.08^{ab}
120kgNPK/ha	4.33	7.17	9.75	13.17	4.83	7.67	9.5	13.83^{a}
HA_{30}+1/3RNPK	4.25	7.08	9.5	12.75	4.58	7.83	9.08	13.08^{ab}
HA_{30}+1/2RNPK	4.33	6.92	9.42	12.25	4.58	8.43	9.58	13.25^{ab}
HA_{30}+2/3RNPK	4.17	7.42	9.25	12.17	4.42	7.93	9.42	13.58^{ab}
LSD (0.05%)	Ns	Ns	Ns	Ns	Ns	Ns	Ns	*
SEM CV (%)	9.46	10.63	8	7.29	5.3	4.58	5.14	3.28

Means with the same letter(s) are not statistically significant at 5% level of test
NS = not significant at 5% level of test
* = significant at 5% level of test

Table 5: Effect of Humic Acid on maize stem girth in Anyigba (2021 and 2022 Rainy Season)

Treatments	2021				2022			
	Weeks After Planting (WAP)				Weeks After Planting (WAP)			
	2	4	6	8	2	4	6	8
Control	0.57	1.01	1.35	1.63	0.41	0.68^{d}	0.78	1.18^{e}
10kgHA/ha	0.7	1.14	1.44	1.71	0.45	0.71^{cd}	0.97	1.23^{de}
20kgHA/ha	0.6	0.95	1.48	1.52	0.44	0.71^{cd}	0.83	1.29^{cd}
30kgHA/ha	0.57	0.96	1.36	1.55	0.44	0.73^{bcd}	0.87	1.32^{bc}
120kgNPK/ha	0.76	1.16	1.6	1.71	0.49	0.81^{a}	1.31	1.46^{a}
HA_{30}+1/3RNPK	0.58	0.99	1.44	1.69	0.44	0.74^{bc}	1.27	1.30^{bc}
HA_{30}+1/2RNPK	0.66	1.13	1.48	1.69	0.43	0.79^{ab}	1.26	1.38^{b}
HA_{30}+2/3RNPK	0.63	1.07	1.43	1.61	0.44	0.81^{a}	1.27	1.36^{bc}
LSD (0.05%)	Ns	Ns	Ns	Ns	Ns	*	Ns	*
SEM CV (%)	17.81	14.98	9.39	7.9	5.74	4.39	26.9	3.16

Means with the same letter(s) are not statistically significant at 5% level of test
NS = not significant at 5% level of test
* = significant at 5% level of test

2021 and 2022. Treatment 120kgNPK/ha produced the longest cob with mean value of 18.71 and 15.16 for 2021 and 2022, while the least mean value 14.98 and 11.74 was observed from the control. The application of HA had significant ($p<0.05$) effect on Cob Diameter for year 2021. Treatment 120kgNPK/ha produced the wildest girth with mean value of 4.36, while the least mean value 14.98 was observed from the control. However, the application of HA had no significant ($p<0.05$) effect on Cob Diameter for year 2022. The application of HA had significant ($p<0.05$) effect on the 100-seed weight for both year 2021 and 2022. Treatment HA_{30}+2/3RNPK and 120kgNPK/ha produced the heaviest weight with mean value of 25.00 and 21.67 for 2021 and 2022, while the least mean value 20.33 and 17.17 was observed from the control. The application of HA had significant ($p<0.05$) effect on the Yield (t/ha) for both year 2021 and 2022. Treatment 120kgNPK/ha produced the Highest yield with mean value of 4.12 and 4.00 for 2021 and 2022, while the least mean value 2.25 and 2.23 was observed from the control.

Discussion

The results of this study indicated that humic acid application did not significantly affect the growth of maize due to some reasons, Humic acid 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, absorbability, ion exchange and complication chelating properties. It is released from humic acid up to 20 kg HA ha^{-1} and requires almost 60 days to complete the process (13) because it is a slow release fertilizer of N (14). Similarly. (15). Stated, 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. Slow-release fertilizer releases nutrients gradually with time, and it can be an inorganic or organic form. Also, (16) reported that urea-humate more stable and suggest a slow release of its nitrogen. Interaction of humic-acid with urea is not permanent; nitrogen can be released into the available forms. However the application of HA30+2/3RNPK showed a better result for all the parameters measured from vegetative to yield. Humic acid is an economically available organic macromolecular matter that can improve soil nutrients, stimulate plant growth, regulate plant metabolism and promote the absorption of nutrients by plants (17). We found that adding humic acid to NPK can significantly improve the total nitrogen accumulation of maize. In addition, humic acids have a large specific surface area, complex surface structure and numerous functional groups, and therefore possess strong adsorbability, hydrophilicity and complexation chelating properties and are faintly acid, which can improve soil physical and chemical properties, enhance the ability of soil to retain nutrient ions, promote mineral nutrient absorption and improve the fertilizer utilization efficiency (18). (19) showed that the contents of NH_4^+ -N and NO_3^--N in soil 28 and 42 days after rice planting increased due to the addition of humic acid in urea. (20) found that humic acid urea fertilizer significantly increased nitrogen absorption and NUE compared with N treatment alone. The response of cob length, cob diameter,

Table 6: Response of maize yield parameters to Humic acid application in Anyigba (2021 and 2022 Rainy Season)

Treatments	2021				2022			
	F.B	D.B	F.C	D.C	F.B	D.B	F.C	D.C
Control	115.83^{e}	35.83^{e}	135.00^{d}	72.50^{d}	115.83^{d}	33.33^{d}	130.83^{d}	70.00^{d}
10kgHA/ha	147.33^{cd}	43.33^{de}	162.50^{cd}	75.83^{d}	142.33^{cd}	40.83^{cd}	158.17^{cd}	73.67^{d}
20kgHA/ha	167.50^{bcd}	50.83^{cd}	170.83^{c}	83.33^{cd}	163.33^{bc}	48.33^{bc}	166.67^{c}	79.83^{cd}
30kgHA/ha	180.00^{abc}	52.50^{bc}	176.67^{bc}	91.67^{bc}	175.83^{bc}	50.00^{b}	172.17^{bc}	88.33^{bc}
120kgNPK/ha	235.00^{a}	66.67^{a}	226.83^{a}	114.33^{a}	224.17^{a}	64.50^{a}	222.50^{a}	110.33^{a}
HA_{30}+1/3RNPK	193.17^{abc}	55.00^{bc}	185.00^{bc}	93.33^{bc}	196.83^{ab}	52.17^{b}	180.83^{bc}	90.17^{bc}
HA_{30}+1/2RNPK	200.83^{abc}	55.83^{bc}	190.83^{bc}	95.00^{bc}	189.50^{ab}	53.00^{b}	185.50^{bc}	91.83^{bc}
HA_{30}+2/3RNPK	213.33^{ab}	59.17^{ab}	207.50^{ab}	102.50^{b}	206.17^{ab}	56.00^{b}	203.17^{ab}	99.50^{ab}
LSD (0.05%)	*	*	*	*	*	*	*	*
SEM CV (%)	15.8	8.21	9.79	7.39	13.68	8.9	9.94	7.75

Means with the same letter(s) are not statistically significant at 5% level of test
* = significant at 5% level of test
F.B = fresh biomass (g), D.B = dry biomass (g), F.C = fresh cob (g), D.R = dry cob (g)

Table 7: Response of maize yield parameters (continued) to humic acid application in Anyigba (2021 and 2022 Rainy Season)

Treatments	2021				2022			
	C.L	C.D	100SW	Yield (t/ha)	C.L	C.D	100SW	Yield (t/ha)
Control	14.98^{b}	3.88^{b}	20.33^{b}	2.25^{e}	11.74^{c}	3.66	17.17^{c}	2.23^{d}
10kgHA/ha	16.57^{ab}	4.05^{ab}	22.67^{ab}	2.71^{de}	12.77^{bc}	3.74	19.00^{b}	2.69^{cd}
20kgHA/ha	16.90^{ab}	4.26^{ab}	24.00^{ab}	2.86^{cde}	13.11^{bc}	3.86	20.67^{ab}	2.82^{cd}
30kgHA/ha	17.26^{ab}	4.30^{ab}	23.67^{ab}	3.25^{bcd}	14.19^{ab}	3.88	20.33^{ab}	3.08^{bcd}
120kgNPK/ha	18.71^{a}	4.36^{a}	24.67^{a}	4.12^{a}	15.16^{a}	4.11	21.67^{a}	4.00^{a}
HA30+1/3RNPK	17.13^{ab}	4.24^{ab}	22.00^{ab}	3.40^{bc}	13.80^{ab}	3.92	20.27^{ab}	3.31^{abc}
HA30+1/2RNPK	18.35^{a}	4.30^{ab}	24.00^{ab}	3.49^{bc}	14.07^{ab}	3.95	20.50^{ab}	3.41^{abc}
HA30+2/3RNPK	17.98^{a}	4.28^{ab}	25.00^{a}	3.78^{ab}	14.17^{ab}	3.96	21.33^{a}	3.77^{ab}
LSD (0.05%)	*	*	*	*	*	Ns	*	*
SEM CV (%)	4.99	3.75	5.8	10.59	7.63	5.81	4.62	9.73

Means with the same letter(s) are not statistically significant at 5% level of test
* = significant at 5% level of test
C.L = cob length (cm), C.D = cob diameter (cm), 100SW = 100-seeds weight (g)

100-seed weight, and seed yield to nitrogen may be attributed to factors such as the efficiency of root uptake, the storage capacity of the vegetative parts, the recycling of nutrients from vegetative tissues to developing kernels, and the dynamics of kernel sink potential (21). Integration of humic acid with NPK fertilizer has proven beneficial through high rate of nutrient absorption by maize plant, as it improves the yield and quality. Humic acid has been found to enhance the nutrient status of the soil, potentially reducing the need for NPK fertilizers, which in turn could significantly lower soil pollution (22). Various studies have demonstrated that the application of nitrogen combined with humic acid can lead to improvements in yield and other yield components. Yield components were increased by applying 120 kg NPK/ha and HA30+2/3RNPK. This can be attributed to the fact that NPKs are part of the essential nutrients that aid meristematic growth and other plant physiological activities. These subsequently lead to the efficient absorption of water and nutrients, as well as the capture of sunlight and carbon dioxide. These activities support higher photosynthetic activities for the production of adequate photoassimilates, which will subsequently be translocated to different sinks for the production of higher total dry matter (23). Improvement of vegetative parts brought a better effect on yield parameters such as fresh biomass (g), dry biomass (g), fresh ear (g), dry ear (g), ear length (cm), ear diameter (cm), weight of 100 seeds (g) and yield (t/ha). In the same vein, success in achieving higher yields can also be attributed to the availability of potassium nutrition, which is part of the fertilizer used.

Conclusion and Recommendation

The results of the experiment showed that maize responded well to the treatments with 120 kg NPK/ha and HA30 + 2/3 RNPK in the measured growth and yield parameters. Adding 2/3 fraction of the recommended mineral fertilizer in addition with humic acid proved to be the best HA loading rate in terms of maize yield in both cropping seasons. This yield is statistically at par with the yield gotten when the recommended mineral fertilizer rate was applied in the study location. In order to reduce the problems associated with excessive mineral fertilizer use, treatment - HA30 + 2/3 RNPK could be recommended for optimum maize production in the study area. Further studies are needed to determine the optimal level of sole humic acid application rate for the yield of maize in the study location.

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