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Soil Chemical Properties and Growth Parameters of Maize(*Zea mays*) as influenced by Integrated Composted Animal Manure and NPK fertilizer in an Acidic Ultisol

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Abstract

A greenhouse-scale study was conducted at Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria to determine the effects of composted animal manure (poultry, pig and goat droppings) and N.P.K (15:15:15) fertilizer on maize height, biomass yield and soil chemical properties. The trial involved six treatments viz: control (received no amendments), NPK 15:15:15 (400kg/ha), NPK 15:15:15 fertilizer (200kg/ha) + 10% of compost (1kg/10kg of soil), NPK 15:15:15 (200kg/ha) + 20% of compost (2kg/10kg of soil), 10% of compost manure and 20% compost manure. The treatments were laid out in a completely randomized design and replicated three times. The results obtained showed that T5 (10% of compost) gave the highest increase in plant height, which was significant from the second week till the seventh week after planting. Stem girth and number of leaves T5 also gave the highest values all through the greenhouse period; T3 (200kg/ha of NPK 15: 15: 15 fertilizer + 10% of compost, gave the highest increase in biomass yield of maize, followed by T4 (200kg/ha of N.P.K 15:15:15 fertilizer + 20% compost). After harvest, T4 also gave the highest values for Soil pH (6.77), total nitrogen (0.23%), organic matter (3.41%), Exchangeable calcium and potassium (11.20 and 0.64 cmol/kg respectively). All the values were significantly higher than the control and the other treatments considered. It was concluded from the result that compost manure application either solely or in combination with N.P.K (15:15:15) fertilizer performed best in the growth and biomass yield of maize. It also improved the soil chemical properties in the study area.

Key words: soil chemical properties, growth parameters, composted manure, acidic ultisol

Introduction

In the rainforest agro-ecology of Southeastern Nigeria, low fertility is the major factor limiting crop production in the sense that precipitation often exceeds evaporation; high weathering and leaching of metal cations from soils result in soil acidity and low soil fertility in this region (Agbede *et al.,* 2015). The poor soil fertility status results in decline in crop yields hence, there is the need to supplement the amount of nutrients needed by crops for optimal performance. Inorganic fertilizer has been found to improve crop yield and soil chemical properties such as pH, total nutrient content and nutrient availability, although its continuous use is hindered by its scarcity, high cost, nutrient imbalance and soil acidity (Ojeniyi, 2000). The advantage of using inorganic fertilizer is that the nutrients they supply are usually specific and released rather fast (Ezekiel and Nnah, 2015), mineral fertilizers usually do not have significant residual effects after the year of application and have sometimes been reported to increase soil acidity and nutrient imbalance.

Compost manure is an excellent organic fertilizer, as it contains high nitrogen, phosphorus, potassium and other essential nutrients (Oyewole, 2011). In contrast to chemical fertilizer, it adds organic matter to soil, which improves soil structure, nutrient retention, aeration, soil moisture holding capacity and water infiltration. In the past years, inorganic fertilizer was advocated for crop production to ameliorate low inherent fertility of soils in the tropics since it provides readily available nutrients for plant. However, their continuous use in the tropics has led to enhancement of soil acidity, easy leaching of nutrients, nutrient imbalance, low organic matter status, reduced crop yield, and degradations of soil physical properties (Kotschi, 2015). A combination of organic and mineral nutrients has been advocated, as the integration of organic sources and synthetic sources of nutrients not only supply essential nutrients but also have some positive interaction with chemical fertilizers to increase their efficiency and thereby increase crop production (Han *et al*., 2016).

Maize (*Zea mays*) is the third most important cereal crop in the world after wheat and rice with respect to area and productivity (Ranere *et al.,* 2009). It is a widely planted crop in most countries of the world and is among the most important common grain crops grown in Nigeria (Kamara et al., 2020). It has two growing seasons a year: early (March) and late (August) season. It is not only a source of food and feed, but is also utilized as a major ingredient of industrial products (Moshin *et al.*, 2012;

Harris *et al.*, 2007). Maize can be grown with sole or organic fertilizers or in combination of both. According to IITA (1990), high and sustained crop yield can be obtained with judicious and balanced inorganic fertilization combined with organic manures.

Researchers have shown that complementary use of organic and inorganic fertilizer has a proven sound soil fertility restorative strategy in many countries of the world (Adeniyan and Ojeniyi, 2005; Unagwu *et al.*, 2012). Some researchers have reported on the effectiveness of the integration of organic and inorganic fertilizers in crops such as cassava and sweet potatoes in the study area. However, there still exists a dearth of knowledge on the effect of the combination of NPK fertilizer and composted poultry, pig and goat manures on the growth of maize.

Therefore, the objective of this investigation was to determine the effects of composted animal manure and NPK (15:15:15) fertilizer on the growth parameters of maize and some selected soil chemical properties

Materials and Methods

Description of the study area

The experiment was conducted at the greenhouse- Michael Okpara University of Agriculture, Umudike, (latitude 05^0 29^1N; longitude 07^0 33^1E and elevation of 122m above the sea level). The area falls within the tropical rainforest zone, annual rainfall averages 2177mm and the monthly temperature ranges between 20^0C and 36^0C. Relative humidity ranges from 50-95% (National Root Crop Research Institute Umudike Meteorological station 2011).

Soil sampling procedure

Representative soil samples were randomly collected (at the depth of 0-20 cm) from the Eastern farm of the Michael Okpara University of Agriculture, Umudike. The soil of the area was used for planting cassava. The soil samples were air-dried and sieved through a 2mm mesh to remove roots and stones.

Treatment and treatment preparation

The treatment comprised of
T1 = Control-No fertilizer/manure
T2 = NPK 15:15:15 fertilizer-400kg/ha approximately 2g/pot

T3 = NPK 15:15:15 (200kg/ha, approximately 1g per pot) + 1kg compost per pot (10% compost)
T4 = NPK 15:15:15 (200kg/ha) + 2kg compost per pot (20% compost)
T5 = Compost manure - 1kg/pot (10% compost)
T6 = Compost manure - 2kg/pot (20% compost)

Poultry droppings, pig manure and goat manure were obtained from the livestock farm of Michael Okpara University of Agriculture, Umudike. The organic materials were mixed in the ratio of 1:1:1 of the poultry droppings, pig manure and goat manure The mixed organic materials were composted under shade for a period of three months, during which adequate moisture and aeration were ensured by the addition of water and stirring with a wooden stick at regular intervals. At the end of the composting period, the composted organic material (manure) was used as soil amendment.

Experimental procedure and test crop

Ten kilograms (10kg) of the composite air dried soil sample was weighed into 12-litre capacity plastic pots. The treatments were applied on dry basis (at two weeks before planting for the compost and they were replicated three times to give eighteen (18) experimental units. The pots with their contents (soil and treatments) were arranged in a completely randomized design (CRD). The test crop was maize of Oba super 4 variety and was sourced from National Seeds Council, Umudike. The maize was sown at 2 seeds per pot. These were thinned to one stand at two weeks after sowing. The maize plant was grown in the greenhouse for eight weeks. The following maize growth parameters were measured: plant height, number of leaves and stem girth, measured weekly starting from the second week through the eighth week.

Laboratory analysis

Some selected physical and chemical pre-treatment and post-harvest soil properties were determined. They included: soil particle size, which was determined by the hydrometer method (Day 1965), soil pH was determined using a 1:2.5 (soil: water/KCl) with the aid of a pH meter. Organic carbon was determined by the Walkley and Black (1934) wet oxidation method modified by Nelson and Sommers

(1996). Total nitrogen was determined by the micro kjehldal digestion and distillation method (Jackson, 1964). Available phosphorus was determined using Bray and Kurtz (1945) bray 2 method and read up using a spectrophotometer. Exchangeable bases were determined by leaching the soil samples with 1N ammonium acetate at pH 7 to extract the basic cations (Ca^{2+}, Mg^{2+} K^{+} and Na^{+}); potassium and sodium were read with a flame photometer while calcium and magnesium were determined using complexiometric titration (EDTA) method (Jackson, 1958). Effective cation exchange capacity (ECEC) was calculated as the sum of exchangeable bases (Ca, Mg, Na, K) and exchangeable acidity expressed in centimole per kilogram. Percent base saturation was determined using the equation.

$$\text{Base saturation} = \frac{\text{Total exchangeable Bases}}{\text{ECEC}} \times \frac{100}{1} \ldots\ldots\ldots\ldots\ldots\text{eqn 1}$$

Analysis of the chemical composition of the compost

Nitrogen was determined Kjeldahl method as modified by Udo et al. (2009). 0.2 g of the organic material was weighed into 100 ml digestion tube, 3g of catalyst tablet was added, followed by conc. H_2SO_4. The mixture was heated at 380^0C for 5-8 hours, allowed to cool and then transferred into 100 ml volumetric flask and made up to mark with distilled water. 10 ml of the aliquot was pipette into kjeldahl distillation flask and 10 ml of 5N NaOH solution was added. After distillation, 35 ml of the distillate was collected in 10 ml Boric acid solution and titrated with standardized 0.01N H_2SO_4 solution, and the volume of the acid used for the titration recorded.

Phosphorus, potassium, calcium, magnesium and sodium contents of the compost were determined by the method of Chapman (1961) as modified by Udo *et al.* (2009). 1g of sample was weighed into 50 ml porcelain crucibles, placed into a muffle furnace and heated at 550^0C temperature for about 5-9 hours. Samples were allowed to cool and then dissolved with 5 ml of 2N HCl, stirred and filtered into 50 ml volumetric flasks and made up to mark with distilled water. The aliquot obtained was analyzed by spectrophotometer using the Ammonium Vanadate-Molybdate yellow colour method. Potassium and sodium were read up using flame photometer, while calcium and magnesium were determined by titration using EDTA method.

Statistical Analysis

The data generated were compared with one-way analysis of variance (ANOVA). The means of the soil properties and plant parameters were separated using the Fisher's Least Significance Difference (FLSD) at 5% level of probability using the Genstat Package.

Results and Discussion

Some selected Physical and Chemical Properties of the experimental Soil

Some physical and chemical properties of the soil used for this study are presented in Table 1.The soil was sandy loam, having a pH of 4.6 signifying strong acidity (Hazelton and Murphy, 2011). Organic carbon and total nitrogen were low (1.10% and 0.10% respectively), while available phosphorus was moderate (20.0 mgkg^{-1}), based on the rating given by Akinrinde and Obigbesan (2000) this result shows the need of the soil for some amendment.

Table 1: Physical and chemical properties of the soil used for the experiment

PARAMETER	VALUES
Sand (g/kg)	798.00
Silt (g/kg)	74.00
Clay (g/kg)	128.00
Soil texture	Sandy loam
Soil pH (H_20)	5.50
Soil pH (1N KCl)	4.60
Total Nitrogen (%)	0.10
Organic carbon (%)	1.10
Available P (mg/kg)	20.0
Exchangeable K (cmol kg^{-1})	0.24
Exchangeable Na (cmol kg^{-1})	0.21
Exchangeable Ca (cmol kg^{-1})	3.80
Exchangeable Mg (cmol kg^{-1})	2.20
Exchangeable acidity (cmol kg^{-1})	1.38
ECEC (cmol kg^{-1})	7.83
Base saturation (%)	82.37

Chemical composition of the composted animal manure used for the study

The chemical properties of the compost used in this study are shown in Table 2. It reveals that compost contains nutrient elements that will be useful to the growth of the maize used for this experiment.

Table 2: Chemical Composition of the Compost

Parameters	Values
pH (H_2O)	6.80
Total Nitrogen (%) `	1.23
Phosphorus (%)	0.88
Calcium (%)	0.78
Potassium (%)	2.40
Magnesium (%)	0.60
Sodium (%)	0.55

Effect of Compost Manure and NPK (15:15:15) Fertilizer on maize height

Table 3 shows the effect of compost manure and NPK (15:15:15) fertilizer on maize height. The applied amendments significantly ($p<0.05$) increased the maize height over the control all through the weeks of measurement, except for the second and eighth week where no significant differences were observed among the treatments. At the 3rd week after planting (WAP), T6 had the highest significant maize height, however, the value of 18.33 cm obtained from pots that received T6 were statistically at par with values of 18.30 cm, 17.17 cm and 16.23 cm gotten from T5, T4 and T3 respectively. All the three treatments contained compost. Compost has been reported to be an excellent organic fertilizer containing high nitrogen, phosphorus and potassium and other essential nutrients (Oyewole, 2011). It could have supplied more nutrients to the maize plant to cause a better increase in the height of the plant.

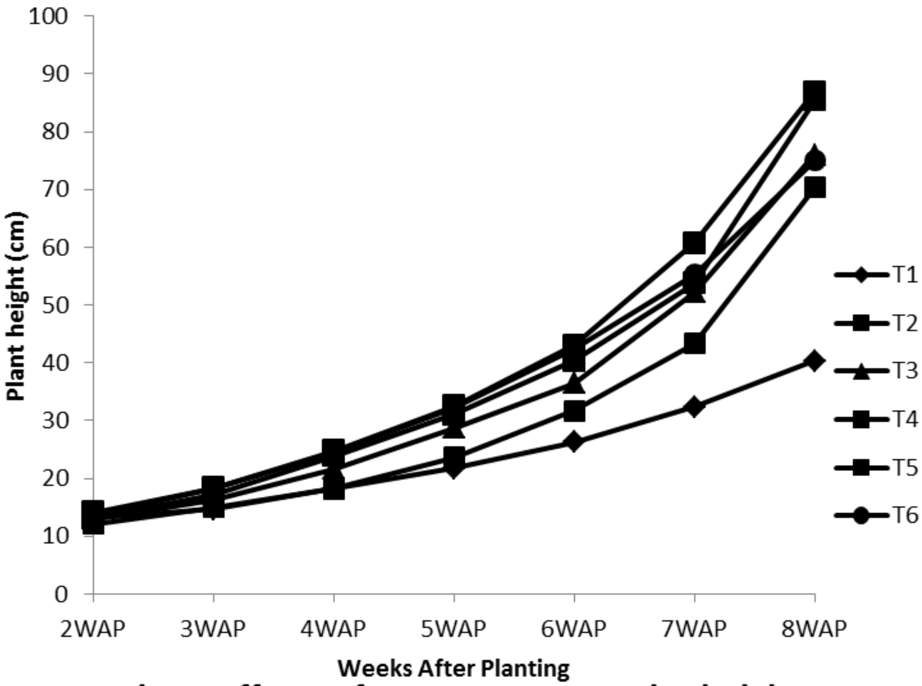

Fig. 1: Effects of treatments on maize height at weeks after planting

The Effect of treatments on stem girth of maize at weeks after planting

Table 4 shows the effect of compost and N.P.K 15:15:15 fertilizer on the stem girth of maize at WAP. At 2nd and 3rd WAP, T5 (10% of compost) had a significant ($p < 0.05$) stem girth increase over the other treatments. At 4th WAP however, T5 still gave the highest stem girth increase over the other treatments (4.03 cm), but the value was not statistically different from 3.97, 3.90 and 3.60 cm obtained from T4, T6 and T3 respectively. At 5th, 6th and 8th WAP, T3 gave the highest stem girth increases, which were significantly ($p<0.05$) higher than the control and T2. This is in line with the findings of Atere and Olayinka (2013) who reported that compost improved soil chemical properties and growth of maize in an Ultisol in southwestern Nigeria.

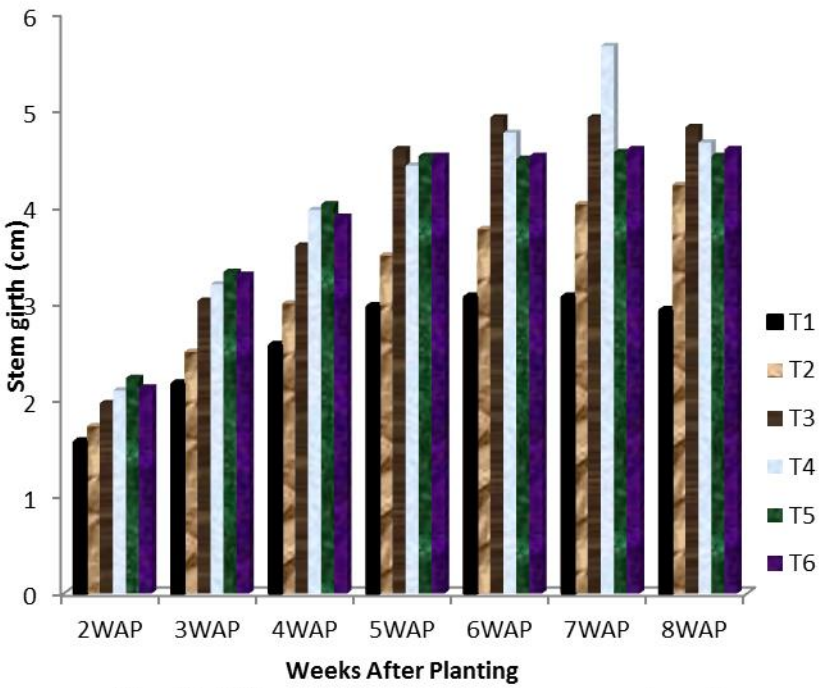

Fig. 2: Effects of treatments on maize stem girth at weeks after planting

Effect of treatments on the number of leaves of maize at weeks after planting

Table 5 shows the effect of compost and N.P.K 15:15:15 fertilizer on the number of leaves of maize at WAP. The applied treatments increased the number of leaves from 2 weeks to 8weeks after planting. Compost applied at 10% (T5) gave the highest number of leaves from the 2nd to the 4th week of the experiment (5.33, 6.33 and 8.00 respectively). These values were significant ($p<0.05$) over the control and sole application of NPK. From the 5th to 8th WAP however, treatments T3, T4, T5 and T6 gave statistically similar values which were significantly higher ($p<0.05$) than the control (The treatments T3- T6 contained compost). Compost could have supplied some essential nutrients especially nitrogen, phosphorus and potassium required for maximum production. This could have led to the significant increase in the number of leaves, especially the supply of nitrogen. Law-Ogbomo *et al.* (2013) in their work on combined and sole application of compost and NPK reported an increase in soil nutrients as a result of application of same.

Table 5: The Effect of treatments on the number of leaves of maize at weeks after planting

Treatment	2WAP	3WAP	4WAP	5WAP	6WAP	7WAP	8WAP
T_1	4.00	5.00	6.67	7.00	7.67	8.33	8.67
T_2	4.67	4.67	6.33	7.33	8.67	10.33	11.67
T_3	4.67	6.00	6.67	8.00	9.33	10.69	11.67
T_4	5.00	6.00	7.33	8.33	9.33	10.33	12.67
T_5	5.33	6.33	8.00	8.33	9.33	10.33	13.00
T_6	5.00	6.00	7.33	8.33	9.00	10.00	13.00
$LSD_{(0.05)}$	0.73	1.19	0.94	1.11	1.19	1.39	1.97

WAP= weeks after planting

Effects of Compost and NPK (15:15:15) Fertilizer on the Biomass Yield of Maize

Table 6 shows the effects of compost and NPK (15:15:15) fertilizer on the biomass yield of maize. Compost applied at 10% + 200kg/ha of NPK 15:15:15 fertilizer (T3) gave the highest value (78.3 g) of followed by T4 (200kg/ha of N.P.K 15:15:15 fertilizer + 20% of compost). Ayalew, (2013) reported similarly in his work on effect of urea and compost on Amaranthus.

Table 6: Effects of Compost manure and N.P.K 15:15:15 fertilizer on the biomass yield of maize

Treatment	Biomass Yield of Maize (g)
T_1	17.1
T_2	43.9
T_3	78.3
T_4	76.1
T_5	72.7
T_6	68.0
LSD(0.05)	24.92

The Soil Chemical Properties after Harvest

The effects of treatments on soil chemical properties are presented in Table 7. T4 significantly ($P<0.05$) increased the soil pH over the control and all other treatments. The significant increase in pH may be because of the release of basic cations by the com posted manure. Ali *et al.* (2007) reported that organic materials when decomposed, are capable of neutralizing acid soils.

Composted manure (20%) combined with 200kg/ha NPK fertilizer (T4) significantly improved soil available phosphorus and total nitrogen over the control and all other treatments. The same trend was observed with the soil organic matter and the exchangeable bases. The significant increase in total nitrogen by T4 could be attributed to the direct addition of nitrogen through organic and inorganic fertilizer application. Lukman *et al*. (2015) had similar result when they studied the effect of combined NPK and cow dung on soil chemical properties in sudan savanna of Nigeria. The increase in available phosphorus and the exchangeable bases by T4 could be attributed to the nutrient content of the compost (Table 2). Ali *et al.* (2007) earlier reported that organic materials are capable of releasing soil nutrients after decomposition

Table 7: The Effect of treatments on soil chemical properties after harvest

Treatment	pH (H_20)	pH (1N KCl)	Av.P mg/kg	%TN	% OM	Ca	Mg	K	Na	EA	ECEC	%BS
T_1	5.10	4.03	17.10	0.08	1.58	2.87	1.47	0.18	0.16	1.59	6.26	74.66
T_2	5.67	4.63	21.93	0.13	1.58	4.20	2.37	0.30	0.22	1.23	8.33	85.19
T_3	6.27	5.27	25.43	0.18	2.61	7.00	3.33	0.45	0.31	0.75	11.99	93.71
T_4	6.77	5.70	31.30	0.23	3.41	11.20	4.33	0.64	0.39	0.09	16.66	99.44
T_5	5.77	4.80	21.60	0.15	2.65	5.20	2.87	0.29	0.22	1.15	9.74	88.14
T_6	6.03	5.07	24.00	0.18	3.23	6.30	3.27	0.39	0.29	1.03	11.28	90.72
LSD(0.05)	0.19	0.30	2.21	0.01	0.12	1.01	0.40	0.03	0.02	0.08	1.29	0.87

CONCLUSION

Soil chemical properties and growth parameters of maize (*Zea mays*) were influenced by integrated composted animal manure when combined with N.P.K fertilizer in an acidic ultisol. Compost applied at 20 % in combination with 200 kg/ha NPK fertilizer gave the highest increase in soil nutrients, while 10% of compost manure + 200kg/ha NPK 15:15:15 fertilizer improved the growth and biomass yield of maize above other treatments. It can therefore be concluded that the application of composted animal manure either solely or in combination with N.P.K 15:15:15 fertilizer led to optimum growth of maize and are therefore recommended for the cultivation of maize and improvement of soil chemical properties in the study area.

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