Graded replacement of inorganic fertilizer with organic manure for sustainable maize production in Owerri Imo State, Nigeria

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Abstract

An experiment, on the effect of graded replacement of inorganic fertilizer with organic manure on maize production in Owerri Imo State, Nigeria, was conducted at the Teaching and Research Farm of Federal University of Technology, Owerri located on latitude 5º 27′ 50.23″ N and longitude 7º 02′ 49.33″ E at 55 m above the sea level. A randomized complete block design (RCBD) was used and there were 6 treatments namely; control (no manure), 0.4 NPK (nitrogen, phosphorus, potassium) + 0 poultry manure (PM), NPK (0.3) + PM (2.0 t/ha), NPK (0.2) + PM (4.0 t/ha), NPK (0.1) + PM (6.0 t/ha) and NPK (0.0) + PM (8.0 t/ha) replicated four times. Results showed that NPK (0.0) + PM (8.0 t/ha) and NPK (0.1) + PM (6.0 t/ha) performed better in the production of *Zea mays* and had significantly higher maize grain yield, dry matter yield, and leaf area than other treatments. All plots treated with organic and/or inorganic fertilizer had high residue of N, P and K and the meso-nutrients elements – Ca and Mg in the soil after the experiment. Also, there was high weed weight and soil pH increased in all plots that received poultry from 5.65 – 5.71 while plots which received NPK 20: 10:10 declined from 5.65 before the experiment to 4.30 thereafter. [Life Science Journal. 2007; 4(2): 82 – 87] (ISSN: 1097 – 8135).

Keywords: inorganic fertilizer; organic manure graded replacement; maize production

1 Introduction

The production capacity of a soil is determined largely by its chemical and physical properties and soil moisture content, which help in the full utilization of the essential elements in the soil by plant roots. The soil fertility of an area or location is very important and optimum productivity may turn to long-term economic benefits, which will reflect on the yield and yield components based on the perceived knowledge of soil fertility. Soils will not be suitable for crop production if they are stony, swampy or lack essential nutrient elements. Therefore, consideration must be given to the evaluation of soil nutrients before fertilizers may be applied. Soil fertility management is a vital part of successful crop production if such a farm area can be understood but not prone to faulty management.

Fertilizers are substances applied to the soil in order to increase crop yield by providing one or more of the essential plant nutrients. Wastes from plants and animals are referred to as organic manure on the other hand inorganic fertilizers are usually simple chemical compounds manufactured in factory and or obtained by mining which supply essential plant nutrients (Hignette, 1999). The importance of organic fertilizer is that it contains little or no soluble salt and it is applied in a large quantity without the risk of damaging crop roots and also micro organisms in the soil help to break the organic materials into inorganic water soluble forms for plant use (Hignette, 1999).

Maize crop production requires heavy fertilizer for an optimum yield in terms of nitrogen derived from chemical or organic manure (Awotundun *et al*, 1994). It has been noted that, it is impossible to grow healthy and vigorous crops without humus, which is derived from both vegetable and animal materials. As organic manure, poultry manure (PM) has come to serve as one of the most important manure as it consists of higher nitrogen value. PM had been found to be an important resource in sustainable practices like intercropping. Kinsley (1994) reported that manure supplies nutrient composition of PM 75%,

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dry matter 16.33%, ammonium with total N of 25.40% and 20% P_2O_5 kg/ha and 15.42% K_2O kg/ha. According to FAO (1976) continual manure use tends to acidify the soil and also as manure breaks down, it releases various organic acids that assist in making soil minerals available. They are used in maintaining the soils in soil fertility management while organic matter stimulate the biological processes in the soil, which aid in the building up of soil fertility status. Organics in general contain lower nutrient concentrations than inorganic fertilizers, which temporarily deplete in the soil and in plant (Sara, 2005) and this probably is one of the factors causing their use in large quantities.

Many studies have shown that application of inorganic and or organic fertilizers increases plant growth mainly because they contain considerable quantities of plant nutrient, including micro nutrients which have high benefits for plant growth (Ibeawuchi *et al*, 2006). In recent times, the need for inorganic fertilizer increased without similar increases in the supply of the fertilizer product to meet the yearning demand by farmers. Secondly, when it is available, the cost is very exorbitant that the resource poor farmers cannot afford even a bag to apply to their crops.

Based on all these, this experiment was designed to gradually replace the inorganic fertilizer (nitrogen, phosphorus, potassium, NPK) with graded quantities of PM, which is often available in farmers' homes. It is hoped that the combination of both will give a good yield for sustainable maize crop production in Owerri Imo State, Nigeria.

2 Materials and Methods

2.1 Location

The experiment was carried out in the Teaching and Research Farm of the School of Agricultural and Agricultural Technology, Federal University of Technology Owerri (FUTO), located on latitude 5º 27′ 50.23″ North and longitude 7º 02′ 49.33″ East at a height above sea level of 55 m (Handheld Global positioning system). Owerri has a rain forest agro ecology characterized with more than 2,500 mm annual rainfall, 27 – 29ºC annual temperature and 89% – 93% relative humidity. The soil of Owerri belong to the soil mapping unit number 431 that is Amakama-Orji-Oguta Soil Association (Federal Department of Agricultural and Land Resources 1985) and derived from classification the coastal plain sands, Lekwa and White side (1986). The site was a 3 years fallow bush after planting cassava and maize of which fertilizer was applied.

2.2 Land preparation

The experimental site was manually cleared and the dry matter packed off the field. The field was marked out and a randomized complete block design (RCBD) was used. There were 6 treatments replicated 4 times. There were six plots on each block measuring 4×1 m (i.e. 4 m^2) with a 0.5 m gap between plots and 1 m between blocks. Flat tilled land surface were made to define the experimental plots. The total land area used was 231 m^2 (0.0231 ha).

2.3 Treatments

Inorganic fertilizer NPK (20: 10: 10) and organic manure (PM) were used. The PM gradually replaced the NPK 20: 10:10 fertilizer with no application of any organic manure or NPK fertilizer as the control.

The treatments include:

(1) Control (no manure used) 0.0 t/ha
(2) NPK (0.4) + PM (0.0) t/ha
(3) NPK (0.3) + PM (2.0) t/ha
(4) NPK (0.2) + PM (4.0) t/ha
(5) NPK (0.1) + PM (6.0) t/ha
(6) NPK (0.0) + PM (8.0) t/ha

2.4 Planting

The maize seeds Oba super-2 hybrid seed were planted at 30 cm apart in each plot at 2 seed per hole. This was later thinned down to one plant per stand. The treatments were applied immediately after germination of maize the test crop. Manual weeding with hoe was done at 3, 5, and 7 weeks after planting (WAP). Weeding was carefully done and the weeds were separated.

2.5 Data ollection

Data collections include the plant height measurement, leaf area (leaf width × length × 0.75), weed weight, dry matter, and dry grain yield after harvesting the cobs and 1,000 seed weight.

2.6 Plant height measurement

The plant heights of maize (*Zea mays*) were measured with a ruler at weekly interval starting from the second to the sixth (2 – 6) WAP. This was taken from the base to the tip of the last leaf (i.e. 2, 3, 4, 5 and 6 weeks) after planting.

2.7 Leaf area

Measuring the width and length of 4 maize plant leaves got the leaf area and multiplying out with a constant (0.75) and the average of this gave the leaf area. This was taken from the 2nd to 6th WAP.

2.8 Plant tissue analysis

After the experiment, maize plant materials from each plot were collected and bulked per treatment and analysis for % N and ash and cmol/kg for K, Ca and Mg. This was done at the School of Agriculture and Agricultural Technology (SAAT) laboratory.

2.9 Harvest

The maize cobs were harvested 16 WAP when all the plant had turned brown and the grains are expected to contain abut 14% moisture content.

The cob sheets were removed and the maize sun dried thereafter, the grains were shelled and 1,000 seeds were counted out, weighed and recorded.

2.10 Data

Data collected were analyzed using the least significant difference (LSD), the standard error (SE) and standard deviation (SD) according to Wahua (1999).

3 Results

Results showed that there were no significant differences in plant heights at 2 to 4 WAP. However, at 5 and 6 WAP, there were significant height differences with the treatments (NPK 0.0 + PM 8.0) and (NPK 0.1+PM 6.0) t/ha respectively being taller than the other maize plants in the experiment (Table 1). Table 2 showed the results of leaf area (cm^2) 2 – 6 WAP; the leaf area of maize (L × W × a constant (0.75)). This gradually increased with increase in organic manure and all the treatment had significantly broader leaf area (cm^2) than the control. Table 3 showed the results on maize dry matter, maize grain yield and 1,000 seeds in kg after the experiment.

Table 1. Effect of gradual replacement of inorganic manure with organic manure on plant height (cm) 2 – 6 weeks after planting

Treatment t/ha	Week after Planting (WAP)				
	2	3	4	5	6
Control (0.0)	17.50	36.33	67.13	76.6	110.67
NPK(0.4) + PM (0.0)	18.21	49.59	75.22	127.95	168.23
NPK (0.3) + PM (2.0)	19.22	51.08	71.82	132.22	164.42
NPK (0.2) + PM (4.0)	17.90	51.32	74.15	135.04	179.83
NPK (0.1) +PM (6.0)	19.10	51.01	77.34	157.70	175.64
NPK (0.0) + PM (8.0)	18.61	52.95	77.57	158.60	180.21
LSD (0.05)	NS	NS	NS	17.84	20.05
SD	0.85	2.43	3.63	3.65	36.31
SE	0.72	4.95	5.92	13.14	13.31

NS: no significance

Table 2. Effect of gradual replacement of inorganic manure with organic manure on leaf area (cm^2) 2 – 6 week after planting

Treatment t/ha	Week after Planting (WAP)				
	2	3	4	5	6
Control	30	96	135	10	181
NPK(0.4) + PM (0.0)	46	114	149	235	340
NPK (0.3) + PM (2.0)	49	1137	152	280	341
NPK (0.2) + PM (4.0)	40	121	169	220	308
NPK (0.1) +PM (6.0)	54	132	200	286	340
NPK (0.0) + PM (8.0)	68	229	358	358	383
LSD (0.05)	9.31	10.48	64.63	75.20	89.02
SD	1.51	3.09	10.72	28.51	32.69
SE	1.23	3.27	3.27	5.34	5.72

Table 3. Effect of the graded replacement of NPK with organic manure on plant dry matter maize grain yield (kg/ha) and 1,000 seeds in (g) after the experiment

Treatment t/ha	Dry matter kg/ha	Grain yield kg/ha	1,000 seeds weight (g)
Control (0.0)	6125	1120	120.0
NPK (0.4) + PM (0.0)	8200	1320	234.0
NPK(0.3) + PM (2.0)	8200	1530	234.0
NPK(0.2) + PM (4.0)	8920	1540	234.0
NPK(0.1) + PM (6.0)	1080	1810	235.0
NPK(0.0) + PM (8.0)	1090	2170	236.0
LSD (0.05)	13.05	31.30	15.20
SD	1.42	6.54	1.09
SE	2.02	8.28	1.38

On dry matter basis, there were significant differences among all the treatments. However, NPK (0.0)+ PM (8.0) t/ha and NPK (0.1)+PM (6.0) t/ha had higher kg/ha of dry matter per hectare than the other treatments (Table 3). The maize grain yield (kg/ha) and 1,000 seeds weight (g) followed the same pattern (Table 3). The results of the effect of weed on maize plant using graded replacement of NPK with organic manure showed a gradual decline of fresh weed weight as weeding was done at 2 weekly intervals starting from the 3 – 7 WAP (Table 4). Apart from the control plots that received no manure, other plots that received one form of manure or the other had high weed weights with plots treated with NPK 0.4 t/ha having higher weed weights than others.

Table 5 shows the result of plant tissue after the experiment as affect by the applied treatments. All the plots applied with manual treatments were significantly different from the control treatment without any manure application. The plots applied with one form of manure or the other showed no significant differences among themselves with regard to nutrients found in the tissue of maize plants.

The result of soil analysis before and after the experiment is shown in Table 6. There was high residual total %N, P (cmol/kg), K (cmol/kg) in all the plots except in the control plots. There were Ca and Mg (cmol/kg) reduction in all the plots including the control. Also, the soil organic matter increased in all plots after the experiment

Table 4. Weed weight (kg/ha) 3, 5 & 7 weeks after planting 3, 5 & 7

Treatment t/ha	Weeks after Planting (WAP)		
	3	5	7
Control (0.0)	4200	2400	1090
NPK (0.4) + PM 0.0)	5640	4788	1998
NPK(0.3) + PM (2.0)	5444	4544	1608
NPK(0.2) + PM (4.0)	5380	4208	1560
NPK(0.1) + PM (6.0)	5322	4109	1520
NPK(0.0) + PM (8.0)	5320	177.20	275.68
LSD (0.05)	4.34	35.68	79.22
SD	1.70	7.30	48.96
SE	1.44	26.28	79.86

except in control plots, while pH increased in all plots except in plots treated with NPK 0.4 t/ha.

4 Discussion

The results of plant height may be attributed to the gradual release of essential nutrient elements as required by the maize plant. Grain cereals generally love nitrogen for growth and this may probably be because they are determinate crops in that as soon as their influence is produced there is no further production of leaves and yield is determined. There were no significant effects at 2 – 4 WAP in the maize plant heights in the field. This could be attributed to no competition for plant resources (Ibeawuchi, 2004). Whereas at 5 – 6 WAP the maize plants showed significant differences as a result that the applied nutrients had decayed and were made available in the inorganic soluble forms that the plants can make use of them for their fast growth (Hignette, 1999). Maize as a cereal crop loves bright sunlight and the exposure of the leaves to light and the up take of essential nutrients especially N by the leaves of maize plants treated with one form of manure or the other resulting to a broad leaf area (cm^2) at 2 – 6 WAP may be attributed to the synergic action of fertilizer and manure application as against the control (no manure or fertilizer).

Dry matter: Dry matter accumulation is as a result of nutrient uptake. It is one of the measures of plant growth (Noggle and Fritz, 1983) and it reflects the relative growth rate as regard to net assimilation rate (Ibeawuchi, 2004). The result suggests that fertilizer be it organic and inorganic influenced the maize dry matter accumulation and this is a function of crop species and soil fertility (Jones, 1976).

Table 5. Plant tissue analysis after the experiment

Treatment t/ha	Week after Planting (WAP)					
	%N	P cmol/kg	K cmol/kg	%ash	Ca cmol/kg	Mg cmol/kg
Control (0.0)	0.06	0.18	0.22	0.43	0.81	0.31
NPK(0.4) + PM (0.0)	0.13	0.38	0.41	1.00	1.28	0.58
NPK (0.3) + PM (2.0)	0.13	0.43	0.42	0.03	1.29	0.61
NPK (0.2) + PM (4.0)	0.10	0.38	0.39	1.00	1.19	0.59
NPK (0.1) +PM (6.0)	0.11	0.39	0.39	1.00	1.25	0.56
NPK (0.0) + PM (8.0)	0.13	0.39	0.40	1.00	1.30	0.60
LSD (0.05)	0.05	0.29	0.18	0.55	0.39	0.19

Table 6. Soil physical and chemical properties before and after the experiment

		%N	P cmol/kg	K cmol/kg	Ca cmol/kg	Mg cmol/kg	% organic matter	pH
Before		0.13	3.36	1.6	4.99	2.00	3.85	5.65
After Treatment: t/ha	Control (0.0)	0.07	3.14	1.08	4.40	1.65	3.65	5.65
	NPK(0.4) + PM (0.0)	0.14	3.58	1.69	4.85	1.88	3.96	4.30
	NPK (0.3) + PM (2.0)	0.16	3.56	1.66	4.78	1.88	4.67	5.70
	NPK (0.2) + PM (4.0)	0.16	3.53	1.65	4.78	1.88	4.75	5.71
	NPK (0.1) +PM (6.0)	0.17	3.55	1.65	4.77	1.88	4.95	5.71
	NPK (0.0) + PM (8.0)	0.18	3.55	1.66	4.78	1.88	5.30	5.71

On crop, the pattern of dry matter accumulation affected the grain yield and 1,000 maize grain kg/ha (Table 3). It means that nutrients taken up by the maize plants were effectively used and converted to cobs grains stem and leaf tissues respectively. It is of note that dry matter accumulation is a measure of relative yield. This shows that as pH is decreased from 8.65 to 7.30 there may be higher yield both in grain and dry matter (Onweremadu *et al*, 2006) because normal soil pH is a lead for improved soil fertility and up take of nutrients by plants.

Weeds are unwanted plant species and help to reduce plant yield. In this experiment no room was given for weed growth hence the 2 weekly interval weeding. However, the level of soil fertility increased weed manifestation and hence all plots treated with fertilizer or manure had higher weed weight than the control plots without any application. This shows that low fertility soils do not harbour high weed growth (Ibeawuchi, 2004). Weeds therefore, should be given priority attention where organic or inorganic fertilize are applied to avoid crop yield reduction.

The plant tissue analysis showed high uptake of N, P, K and the meso-nutrients Ca and Mg (Ibeawuchi *et al*, 2006). This reflected in the 1,000 maize grain weight when compared with the control plots without any fertilizer or manure application. Results showed that while the 1,000 seeds weight from lots treated with organic and inorganic manure ranged from 234 – 236 g/1,000 a maize seed that of the control was 120 g for 1,000 maize seeds. The results showed that there were residual NPK in the soil while pH increased in all plots treated with organic manure except in the ones treated with NPK 20: 10: 10 (Table 6). This suggests that high doses of organic N causes improvement in soil pH because of in plots treated with PM, the soil pH increased from 5.65 to 5.71 while plots treated with organic manure decreased to 4.30, and this tends to highly acidic soil (Table 6).

The findings of the research showed that NPK (0.0) + PM 8.0 t/ha, NPK (0.1) in the poultry manure 6.0 t/ha performed better in the establishment of *Zea mays* in Owerri southeastern Nigeria.

5 Conclusion

From the investigation carried out so far and the results obtained from all the parameters it indicated that there were significant yield difference between the treated plots and control plots. The results showed synergic effect of graded replacement of the inorganic with organic both in yield and yield components of the *Zea mays* and in soil improvement. Therefore we advise that farmers may combine NPK. Fertilizer with PM for optimum yield especially using 8.0 t/ha poultry manure or NPK 0.1 + 6.0 t/ha poultry other combinations are useable depending on the perceived soil fertility status.

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