Integrated Application of Poultry Manure and Mineral Fertilizer on Soil Chemical Properties, Nutrient Uptake, Yield and growth components of maize

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Abstract: Field experiments were conducted in 2005 and 2006 at Adeyemi College of Education, Ondo in rain forest zone of southwest Nigeria to investigate the residual effect of combined poultry manure (5 and 10 t ha^{-1}) and reduced level of NPK 20: 10:10 (100, 200 and 400 kg ha^{-1}) fertilizer on soil fertility and maize performance one year after application. There was a control experiment without any treatment. The test soil was slightly acidic, low in organic matter, N, P, K and Mg. Poultry manure, NPK fertilizer and their combinations increased significantly ($p<0.05$) soil organic matter, N, P, K, Ca, Mg, Fe, tissue N, P, K, Ca, Mg Zn, Cu, Mn and Fe, plant height, stover, root and grain yields in 2005 while only the single application of poultry manure at 10 t ha^{-1} and its combination with NPK fertilizer increased these parameters on residual basis. The mean increases in grain yield due to application of poultry manure alone varied between 34 and 68%, for NPK fertilizer alone 11 – 57% and for poultry manure combined with NPK fertilizer 77 – 164%. Compared with NPK fertilizer at 400 kg ha^{-1}, use of 100 and 200 kg ha^{-1} NPK fertilizer with poultry manure increased soil organic matter, N, P, Mg; tissue P, K, Ca and grain yield. Integrated application of poultry manure and NPK fertilizer was more effective in increasing nutrient availability and maize performance than sole application of any of the fertilizer materials. Addition of NPK fertilizer to poultry manure increased soil nutrients and performance of maize even one year after their application. [Nature and Science. 2010;8(1):60-67]. (ISSN: 1545-0740).

Key word: NPK 20:10:10, macronutrients, micronutrients, immediate effect and residual effect

1. Introduction

In Nigeria and other tropical countries, research interest recently shifted to utilization of organic wastes as nutrient source in crop production. This is due to high cost and scarcity of mineral fertilizers. However, because of huge quantity of the organic wastes required, it has become necessary to combine different types. It is also necessary to integrate chemical fertilizers into the organic sources to reduce the quantity required and enhance nutrient release. Therefore studies are required into integrated application of organic and inorganic fertilizers. Studies (Uyovbisere and Elemo, 2000) have shown the superior effect of integrated nutrient supply over sole use of inorganic or organic source in terms of balanced nutrient supply, improved soil fertility and crop yield (Awodun *et al*., 2007, Olayinka and Adebayo, 2003; Adeniyan and Ojeniyi, 2005,2006).

The use of combined poultry manure and NPK 20:10:10 fertilizer in south west Nigeria has not received much research attention. Chude (1999) indicated that the NPK 27 – 13-13 produced by Niger state of Nigeria is 25% acidulated; thus the effect of these NPK fertilizers with different formulation ratios on soil nutrients need to be studied. This research focuses on the residual effect of the combined use of poultry manure and NPK 20:10:10 on soil nutrients using maize as test crop. The objective of this study was to determine the effect of combined poultry manure and NPK 20:10:10 fertilizer on soil nutrients, yield and nutrient uptake by maize after one year of application in the field.

2. Materials and Methods

Field experiments were conducted in Ondo on latitude 070 051N and longitude 0400 551E at an elevation of 381.3M above sea level with mean annual rainfall of 1, 575.6mm. The soil is loamy sand, classified as kaolinitic, Alfisol (Oxic tropuldalf) (Harpstead, 1975). The soil from the site used for the experiment had been previously cropped to maize, cassava and yam for over 10 years at

different times with application of chemical fertilizers.

Soil Analysis

Core soil samples were collected from 0 – 20 cm depth and bulked for routine soil analysis and field experiments in March 2005. Organic matter was determined by dichromate oxidation method. Available phosphorus was extracted with Bray- 1 and determined colorimetrically. Exchangeable bases (Ca, K and Mg) were extracted with 1N ammonium acetate at pH 7.0. Potassium was read using flame photometer while Ca and Mg were determined on the atomic absorption spectrophotometer. The micronutrients (Cu^{2+}, Fe^{2+}, $Zn^{2+,}$ and Mn^{2+}, were extracted with HCl and determined by AAS. The final soil nutrient analysis was carried out at the end of the experiment as done in the initial soil analysis. The nutrients determined were organic matter, N, P, K, Ca, Mg, Cu, Fe, Zn and Mn.

Plant Analysis

At 45 days after planting, maize plant per plot was uprooted and severed from the base to separate the shoot from the root. The shoot and root parts of each sampled plant was washed with clean water, bagged in brown envelope and labeled accordingly for nutrient determination. The samples were dried in the oven at 75^{o}C until constant weight was recorded. The dried plant samples were ground with a Willey mill to pass through 0.5mm sieve. The ground samples were digested with 25: 5:5 ml nitric-perchloric – acid mixtures with exception of total N (Ogunwale and Udo. 1978). Total N was determined by Microckjedahl procedure. Phosphorus was determined colormetrically by the vanadomolybdate method. Potassium and Ca were determined on flame photometer while Mg was determined using atomic absorption spectrophotometer. For micronutrients (Fe^{2+}, Cu^{2+}, Zn^{2+} and Mn^{2+}) were read on AAS.

The field experiment was laid out in randomized complete block design with three replications of 4m x 4m plot size to give 71 plants per plot with a spacing of 75cm x 30cm Two levels of poultry manure at 8 and 16kg/plot to represent 5 and 10 t ha^{-1} and three levels of NPK fertilizer at 0.16, 0.32 and 0.64 kg ha^{-1} to represent 100, 200 and 400 kg ha^{-1} were formulated as treatments in 2005. There was a control experiment without any treatment. The site was manually cleared, pegged, measured and ridged.

Poultry manure rates were incorporated into the soil with hoe two weeks before the maize seed were planted. Two maize seed were planted per stand in March 2005 and thinned to one plant per stand to give a total population of 44,444 plants/ha two weeks after planting. NPK 20:10:10 fertilizer at different rate was applied in ring form immediately after the first weeding (2 WAP). Hoe was used to weed the farm at three weeks interval.

Agronomic parameters

At harvest, plant height was measured with tape rule and cobs were harvested from forty maize plants per plot from the middle row of each plot. The harvested maize cobs were dried and shelled. Maize grains per plot were weighed with a weighing balance. Grain yield of maize for the various plots were extrapolated to grain yield per hectare for meaningful comparisons. For the dry matter yield, the remaining maize plants per plot were uprooted; cut from the base to separate the shoot from the root and sun dried until constant weight was obtained. Stover and root dry matter yields were weighed. The yields were expressed in t ha^{-1}.

Residual Effect

The blocks with the treated soils were left untouched for a year for the second year planting. The tallies for treatments identification were kept intact in order to avoid mix up. Two maize seeds were planted in first week of April 2006. No treatment was applied in order to determine the residual effect of the already applied treatments one year after application. Manual weeding was carried out at three weeks interval. All the agronomic parameters such as plant height, stover and root dry matter yields taken in the first year were also carried out one year later together with final soil analysis.

Statistical Analysis

Means were separated using Duncan's Multiple Range Tests at 0.05 level of probability when F – ratio was significant.

3. RESULT AND DISCUSSION

The soil used for the study has sandy, loam texture with high proportion of coarse sand (84%). This could adversely affect the growth of crops because of probable low water and nutrient retention

capacity and also aid in high leaching of the soil nutrients. Hence, relatively poor yield of maize on soil not treated with manures was expected. The low soil OM, N, P, K, Mg status and its acidic nature are expected to benefit from application of poultry manure and also NPK fertilizer (Table 1).

Table1: Initial chemical properties of the soil used for the conduct of the experiment.

pH	OM	N	Ca^{2+}	$.K^{+}$	Mg^{2+}	P	Fe^{2+}	Cu^{2+}	Zn^{2+}	Mn^{2+}
(1:2H_2O)	%	%	--------C mol kg-1--			----------mg kg-1----------				
5.67	1.31	0.06	2.32	0.16	4.88	2.44	0.41	1.30	3.30	4.20

The slightly acidic nature of the soil could be adduced to the coarse nature of the soil which should have enhanced leaching of exchangeable bases and to the cropping history of the site which was heavily cropped with application of various mineral fertilizers especially NPK and ammonium sulphate.).Table 2 indicates that addition of NPK fertilizer to poultry manure increased soil organic matter, N, P, K, Ca, Mg and Fe. Compared with P0F400, Fe was increased with addition of 100 or 200 kg ha^{-1} NPK fertilizer to poultry manure while Cu increased at 5 t ha^{-1} poultry manure only but Zn and Mn were reduced. P10F200 increased Zn and Mn. However, the addition only had residual effect on P, K, Ca, Mg and Fe (P5F100 and P10F200) (Table3).

Table 2: Effect of combined poultry manure and NPK fertilizer on soil chemical properties in 2005

Treatment	OM	N	P	K	Ca	Mg	Fe	Cu	Zn	Mn
	%	%	mg kg^{-1}	----------C mol kg^{-1}----------			----------mg kg^{-1} _----------			
P0F0	1.97c	0.11b	6.00e	0.19b	3.63c	0.63c	1.41a	0.66a	2.25c	18.85d
P0F100	2.19c	0.13b	6.05e	0.31a	3.53c	0.98c	1.12b	0.71a	2.56c	20.36c
P0F200	2.42c	0.13b	6.16e	0.32a	3.53c	0.94c	1.49a	0.75a	3.84b	22.88b
P0F400	3.70b	0.19ab	10.35bc	0.31a	2.13d	0.93c	1.17b	0.62a	5.12a	36.72a
P5F0	3.81b	0.20a	7.73d	0.26ab	5.10a	1.23b	1.60a	0.73a	1.81c	18.16f
P5F100	3.72b	0.19ab	10.00c	0.34a	4.61b	1.33ab	1.25b	0.66a	2.79c	19.22d
P5F200	4.18a	0.22a	11.02b	0.33a	4.40b	1.37a	1.23b	0.62a	2.86c	19.92d
P10F0	4.28a	0.23a	12.03a	0.29b	4.57b	1.13b	1.63a	0.51a	1.64c	17.97d
P10F100	4.41a	0.23a	12.47a	0.36a	4.35b	1.47a	1.30b	0.53a	2.2c	18.35e
P10F200	4.60a	0.25a	11.84	0.37a	4.25bc	1.57a	1.33ab	0.50a	2.10c	18.55e

Means with the same letters are not significantly different according to Duncan Multiple Range Test at 5% level.

Table 3: Effect of combined poultry manure and NPK fertilizer on soil chemical properties one year after application

Treatment	OM	N	P	K	Ca	Mg	Fe	Cu	Zn	Mn
	%	%	mg kg^{-1}	----------C mol kg^{-1}----------			----------mg kg^{-1}----------			
P0F0	1.66b	0.11ab	5.07d	0.23b	2.36d	1.12b	1.71a	0.48c	4.16b	22.05b
P0F100	2.06b	0.10b	5.61d	0.18c	2.06d	1.00b	1.63b	0.96a	3.34c	19.89b
P0F200	1.96b	0.10b	6.15d	0.23b	1.96d	1.11a	1.49c	0.33cd	2.27d	17.15b
P0F400	2.94a	0.14a	5.12d	0.10c	1.47e	1.03b	1.61b	1.02a	4.00b	20.44b
P5F0	2.63a	0.13a	7.85c	0.16c	2.59c	1.13a	1.70a	0.43c	4.96a	23.04b
P5F100	2.72a	0.13a	8.70c	0.24b	2.96b	1.10a	1.77a	0.61b	4.14b	21.32b
P5F200	2.64ab	0.13a	7.56c	0.24b	2.66c	1.06ab	1.52c	0.31d	3.05c	17.43b
P10F0	3.20a	0.16a	11.35b	0.29a	3.69a	1.03b	1.68b	0.91a	3.95b	23.10b
P10F100	3.01a	0.15a	13.41a	0.30a	3.27a	1.14a	1.56c	0.57b	3.19c	18.06b
P10F200	3.07a	0.15a	10.91b	0.29a	2.89b	1.14a	1.74a	0.26d	4.11b	28.62a

Means with the same letters are not significantly different according to Duncan Multiple Range Test at 5% level.

Table 4 indicates that addition of NPK fertilizer to poultry manure increased plant height; stover yield, root dry matter and grain yield significantly (P>0.05). The increases due to addition of 100 and 200kg ha^{-1} NPK fertilizer with poultry manure (P5F100, P5F200, P10F100 and P10F200) varied between 12 to 236% with a mean of 182% on both immediate and residual basis. Table 4 also shows that increases in level of NPK fertilizer increased plant height, grain yield, stover yield and root dry matter. It is shown that NPK fertilizer alone at 100, 200 and 400 kg ha^{-1} (P0F100, P0F200, P0F400) increased grain yield by 61, 73 and 219% respectively with a mean of 118% on immediate basis alone. On residual basis, the increases were 8, 11 and 14% with a mean of 11% (Table 5). Therefore grain yield increased with level of NPK fertilizer compared with control. The mean increases when NPK fertilizer alone, poultry manure alone and poultry manure integrated with NPK fertilizer for both first and second crops were respectively 64, 68 and 120%. Therefore it is advantageous to combine poultry manure with NPK fertilizer for optimum maize production.

Table 4: Effect of combined poultry manure and NPK fertilizer on agronomic parameters of maize

Treatment	Height (cm)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Root dry matter (t ha^{-1})	% increase in grain yield
P0F0	178.45b	1.34e	2.66c	0.84h	0
P5F0	182.42b	2.09d	4.21b	1.07f	56
P10F0	184.17b	3.43b	4.42b	1.52e	156
P0F100	175.77b	2.15cd	2.98c	0.86h	61
P5F100	222.42a	2.84c	4.57b	1.11g	112
P10F100	206.33a	4.50a	5.32a	1.92d	236
P0F200	195.90a	2.32c	3.53c	0.93h	73
P5F200	215.21a	3.45b	4.86b	1.70c	158
P10F200	217.41a	4.31a	5.53a	2.21a	222
P0F400	204.67a	4.27a	5.42a	2.03b	219

Means with the same letters are not significantly different according to Duncan Multiple Range Test at 5% level.

Table 5: Effect of poultry manure and NPK 20:10:10 on agronomic parameters of maize one year after treatments application

Treatment	Height (cm)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Root matter (t ha^{-1})	% increase in grain yield
P0F0	158.56a	1.45d	2.19d	0.36b	0
P0F100	158.67a	1.56d	2.63d	0.47a	8
P0F200	157.11a	1.61c	2.32d	0.42ab	11
P0F400	168.33a	1.65c	2.38e	0.23c	12
P5F0	152.78a	1.90c	2.74d	0.45a	31
P5F100	165.67a	2.34b	3.11b	0.41b	61
P5F200	168.56a	2.06b	2.85c	0.67a	42
P10F0	156.78a	1.88c	2.71d	0.34b	30
P10F100	181.22a	2.78a	3.39a	0.38b	92
P10F200	177.00a	2.02c	2.35d	0.49a	39

Means with the same letters are not significantly different according to Duncan Multiple Range Test at 5% level.

Table 6 showed the effect of combined poultry manure and NPK fertilizer on nutrient concentration in maize. All the treatments increase N, P, K, Mg and Fe above the control. Treatments P10F100 had the highest Ca and Mg concentration in maize tissue. P5F0 and P0F200 recorded the highest Cu and Mn respectively. Iron was high in P5F200.

There were increases in N, P and K in maize concentration in all the treatments that contained the combined poultry manure and NPK 20:10:10 in the second year after treatment application (Table 7) Copper was higher in the treatment that contained 5 or 10t ha^{-1} of poultry manure combined with NPK than the treatments that had no poultry manure. P10F100 and P10 F200 were high in Fe concentration in maize tissue. The treatments with 10 t ha^{-1} in the formulations reduced Mn concentration in maize tissue. Poultry manure application at 5 and 10t ha^{-1} had residual effect at one year on soil organic matter, N, P, Ca, Fe, Cu, Mn, tissue N, P, K, Ca, Mg, Zn, Cu, plant height, stover, root and grain yield. These parameters increased with level of poultry manure. Addition of poultry manure to NPK fertilizer increased the determined nutrients in the soil, growth parameters of maize and grain yield, even on residual basis. Therefore it is ascertained that poultry manure released the macro and micronutrients for maize, which were utilized for growth and grain formation. The study by Ayeni 2008, Ayeni *et al*, 2008 showed that poultry manure increased uptake of N, P, K, Ca, Mg, Zn, Fe and Cu by maize grown on an Alfisol in southwest Nigeria. This is consistent with the present study that poultry manure enhanced nutrient status of maize addition to increasing nutrient in soil. Adeniyan and Ojeniyi (2005 and2006) also observed the effect of poultry manure on soil and maize plant nutrient concentration and grain yield of the second crop unmannered crop after the first manured crop in southwest Nigeria improvement in maize yield, soil and tissue nutrient content recorded in this work is

consistent with findings of other previous studies. Ojeniyi et al (2007) found that poultry manure increased tissue N and K, growth and fruit yield of tomato in southwest Nigeria. In another study, Akanni and Ojeniyi (2007) observed that poultry manure increased uptake of N, P, K, Ca and Mg by tomato plant, aside from increasing the yield components. Application of NPK fertilizer increased significantly soil organic matter, N, P, K, Ca, Mg, Fe Cu, Zn, Mn, tissue N, P, K, Ca, Mg and Fe, plant height, stover, root and grain yield. The increased availability and uptake of Ca, Mg and micronutrients as a result of application of NPK fertilizer can be associated with increased soil organic matter. The soil organic matter is known to form chelate with micronutrients, and is also a source of cations due to the presence of exchange sites on organic colloid. The increased presence of Ca could also be due to Ca content of phosphate fertilizer, which might have been used in formulation of NPK fertilizer. The increased availability of micronutrients: Fe, Cu, Zn and Mn are also attributable to reduced soil pH and acidity associated with use of NPK fertilizer. The micronutrients cations are most soluble and available under acid conditions. In very acid soils, there is a relative abundance of Fe, Mn, Zn and Cu (Brady and Weil, 1999).

The increased availability of N, P, K, Ca, Mg, Fe, Cu, Mn and Zn to maize crop due to application of NPK fertilizer culminated in growth and yield increase. Glass house and field experiments conducted with Alfisol in Ibadan southwest Nigeria suggested that maize required application of N P, K, Ca, Mg, Fe, Cu, Zn and Mn (Kayode and Agboola, 1983).

Compared with poultry manure or NPK fertilizer alone, combination of poultry manure at 10t ha^{-1} with NPK fertilizer at 100 or 200 kg ha^{-1} (P10F100, P10F200) gave higher grain yield and root dry matter. It is suggested that poultry manure added more nutrients than NPK fertilizer. Analysis of poultry manure indicates that poultry manure has Ca and Mg, which are not usually supplied by NPK fertilizer except as impurities. The study by Adediran *et al*., (2005), Adediran and Ojeniyi (2006) showed that poultry manure composed micro and macronutrients. Because of the more balanced nutrition given by poultry manure, it was found that poultry manure at 10 t ha^{-1} gave higher yield than NPK fertilizer at 400kg ha^{-1}. The same trend applied to other yield components such as plant height, stover and root yield. Hence poultry manure at 10 t ha^{-1} impacted more on maize than NPK fertilizer. Addition of NPK fertilizer to poultry manure led to improved plant height, stover, root and grain yield.

As opposed to use of NPK fertilizer alone, its combined use with poultry manure ensured more availability of essential nutrients such as Mg, Cu, Zn, Mn and Fe. Addition of poultry manure to NPK fertilizer assures a more balanced nutrition; and residual effect on the nutrients.

In poultry manure, the trend in yield appeared dictated by uptake. The P10F100 had highest value of tissue N, P, K, Zn, and Mn; the P10F200 had highest tissue Zn and relatively high K. The tissue Mn followed the same trend as grain yield. Nutrients such as N, P, K, Ca, Mg, Fe, Cu, Zn and Mn influenced maize yield. Their high concentrations led to higher grain yield. Kayode and Agboola (1983) had found that dry matter yield of maize was increased by application of N, P, K, Ca, Mg, Fe, Cu, Zn and Mn.

Trend in yield data indicates that to maximize nutrient status and yield of maize, NPK fertilizer should be combined with poultry manure at 5 or 10 t ha^{-1}.

The present work confirms that poultry manure when used with NPK fertilizer ensured availability of more nutrients including micronutrients. Also, the need for NPK fertilizer can be reduced to 100 kg ha^{-1} or 200 kg ha^{-1} as opposed to 400 kg ha^{-1} in maize production. The present work also shows that use of poultry manure at 10 t ha^{-1} was more effective in terms of nutrient availability and maize performance.

Table 6: showed the effect of combined poultry manure and NPK fertilizer on nutrient concentration in maize. All the treatments increase N, P, K, Mg and Fe above the control. Treatments P10F100 had the highest Ca and Mg concentration in maize tissue. P5F0 and P0F200 recorded the highest Cu and Mn respectively. Iron was high in P5F200.

Treatment	N	P	K	Ca	Mg	Zn	Cu	Fe	Mn
	%					mg kg^{-1}			
P0F0	1.42c	0.25b	1.27c	0.21b	0.13bc	46.22e	4.02e	27.67e	14.14d
P0F100	1.55c	0,31b	1.43b	0.21b	0.15b	44.72g	4.03e	26.48e	16.15c
P0F200	1.34d	0.31b	1.63a	0.20bc	0.14b	45.58f	3.98e	27.36e	16.95c
P0F400	1.69a	0.24b	1.20c	0.16c	0.10c	36.72i	4.25d	43.17c	17.35b
P5F0	1.25e	0.30b	1.40b	0.23a	0.15b	42.18h	5.07c	43.17c	11.39e
P5F100	1.59b	0.35b	1.50ab	0.22a	0.17a	49.12d	4.39d	40.10d	14.29d
P5F200	1.63a	0.44a	1.67a	0.22a	0.17a	52.16c	6.19a	48.22b	18.73a
P10F0	1.63a	0.45a	1.63a	0.23a	0.16a	49.65d	4.55c	40.63d	4.73g
P10F100	1.66a	0.46a	1.73a	0.22a	0.17a	54.75b	5.80b	52.24a	7.62f
P10F200	1.61a	0.36bc	1.77a	0.24a	0.17a	56.75a	5.77b	52.95a	9.39e

Means the with the same letters are not significantly different according to Duncan Multiple Range Test at 5% level

4. Conclusion

Poultry manure combined with reduced level of NPK fertilizer increased growth and grain yield of maize, soil and tissue nutrients content of maize than NPK fertilizer alone especially on residual basis. The integrated application especially at 10 t ha^{-1} poultry manure and 100 or 200 kg ha^{-1} NPK fertilizer increased maize yield for the two years of study than single application of NPK fertilizer**.** This experiment shows that integrated application of poultry manure and NPK fertilizer was more effective in increasing nutrient availability and maize performance than sole application of any of the fertilizer materials. Addition of NPK fertilizer to poultry manure increased soil nutrients and performance of maize even one year after their application.

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