



Short communication

Nitrogen use efficiency of maize (*Zea mays* L.): Organic versus inorganic fertilisers effects

AyanfeOluwa Olufemi Emmanuel^{*1} and AdeOluwa Oluseyi Olugbenga²

¹Department of Agriculture, Federal College of Agriculture, P.M.B 5029, Moor Plantation, Ibadan, Nigeria.

²Department of Agronomy, University of Ibadan, Ibadan, Nigeria.

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Abstract

Nitrogen Use Efficiency (NUE) of a crop could be an important index in determining efficiency of a fertiliser. This study presents the investigation of NUE of maize; comparing organic fertiliser and mineral fertiliser NPK. The field trials were conducted in the rainy seasons of 2013 and 2014, using a randomised complete block design with three replicates. Experimental treatments were 0, 60, 90, 120, 150 and 180 kg N ha⁻¹ Accelerated compost (AC) with a commercial name OBD-plus which is a recent material in Nigeria), conventional compost 'CC' (60 kg N ha⁻¹) and NPK 15-15-15 mineral fertiliser (60 kg N ha⁻¹). Data on maize grain yield, Fertiliser N recovery (NR) and Fertiliser Utilization Efficiency (UE) as well as post-cropping soil N were subjected to statistical analysis. The 60 kg N AC treated plots resulted in the highest significant mean NR (54.3%) and UE (42.3 kg kg⁻¹) in the two years, with improved soil N. Therefore, the AC considered in this study would be best applied at 60 kg N ha⁻¹ for maize production in the Alfisols. This would optimize fertiliser utilization and reduce N loss, thus mitigating environmental pollution.

Keywords: Alfisol, compost optimization, effective microorganisms, organic wastes, *Zea mays*

The population of the world has been projected to be 8.3 billion in 2030 (UNDESA, 2015). Feeding such population requires increasing food crop production with pragmatic methods of fertiliser application that would supply optimal nutrients to crop and also protect the soil. However, inappropriate fertiliser application could undermine nutrients' availability and retention in soils (Lory and Massey, 2006; Chen *et al.*, 2009; Dong *et al.*, 2012). Nitrogen is a usual limiting nutrient element for cereal production (Amanullah and Almas, 2009; Wanyama *et al.*, 2015; Zingore, 2016), maize is not exempted. This is because it is needed in higher amount relative to other primary nutrients and the cost per unit quantity is highest among the primary nutrients. Meanwhile, nitrogen being very prone to leaching and volatilisation, could readily pollute water bodies and increase nitrous oxide in the atmosphere, thereby contributing to global warming (Barbanti *et al.*, 2010; Butterbach-Bahl *et al.*, 2013; Ghaly and Ramakrishnan, 2015; Kanter *et al.*, 2016). Therefore, there is a need to evaluate the amount of nitrogen to be applied with the nutrient utilization of a particular crop.

Maize is an important cereal that is widely cultivated globally (Christian *et al.*, 2012) and exhibits high response

to fertiliser among other cereals (Kelly *et al.*, 2005; Kelly, 2006). Hence, there is a need to compare fertiliser types and rates from organic and mineral sources with respect to their influence on Nitrogen use efficiency (NUE) and residual soil nitrogen, using maize as a test crop. Thus, this research work investigated the NUE of maize in response to application of different types and rates of organic fertilisers (compost) and mineral fertiliser.

This trial was conducted at the Federal College of Agriculture, Ibadan, Nigeria (Lat. 7°22.5'N and Long. 3°50.5'E) on an Alfisol (Smyth and Montgomery, 1962). The field trials were conducted in the rainy seasons of 2013 and 2014, between May and July. The treatments were accelerated compost (AC) at 0, 60, 90, 120, 150 and 180 kg N ha⁻¹, conventional compost (CC) at 60 kg N ha⁻¹ and NPK 15-15-15 mineral fertiliser at 60 kg N ha⁻¹. The N rate treatments were calculated based on the N content of the fertilizer materials. Experimental design was randomized complete block with three replicates. The rate (60 kg N ha⁻¹) used for the mineral fertiliser and CC was the recommended rate, while AC was in five levels, being a recent material in Nigeria.

*Email: ayanfeoluwaolufemi@gmail.com

The accelerated compost (*OBD-plus*) evaluated in this study was obtained from Gateway Fertiliser Company, based at Abeokuta in Ogun State, Nigeria. The raw materials comprised of market and abattoir wastes and method of composting involves the artificial introduction of some microorganisms, which speed up the rate of decomposition of organic materials, to enable the compost matures in a month. The conventional compost which serves as a check was obtained from Alesinloye Compost Company, based in Ibadan, Oyo State, Nigeria. The raw materials of the conventional compost comprised of market and abattoir wastes and the composting relies on the microorganisms from the environment alone and takes about two months to mature. The accelerated compost cost ₦120 kg⁻¹ (equivalent of \$0.33 kg⁻¹), while the conventional compost cost ₦70 kg⁻¹ (equivalent of \$0.19 kg⁻¹). The compost treatments were applied a week before planting using drilling method and the mineral fertiliser at two weeks after planting using band method. The land preparation was carried out through ploughing and harrowing. Maize seeds were sown at two seeds per hole but thinned to one, while very few missing stands were supplied. Weeding was

carried out twice before harvesting. Twelve soil samples were randomly collected at the depth of 0 - 15 cm and bulked together from each experimental site (360 m² area of land per site) prior to the commencement of the experiments. The bulked soil samples were air-dried and sieved with 2 mm mesh sieve and another portion with 0.5 mm mesh sieve (for nitrogen and organic carbon analyses). Chemical analyses of the two compost (Table 1) were carried out using standard procedures (Olsen and Dean, 1965; Okalebo *et al.*, 1993; Bremner, 1996; Thomas, 1996).

The physical and chemical analyses of the pre-treated soils were also carried out using standard procedures. Soil pH was determined in distilled water at a 1:2 soil to water ratio using electrometric method (Thomas, 1996). Total N content was determined by the macro-Kjeldahl digestion procedure (Bremner, 1996). Available P was extracted by Bray P 1 method (Bray and Kurtz, 1945), colour developed by the Molybdenum blue colour method (Murphy and Riley, 1962) and the content read with a spectrophotometer (Model CE 2041). Exchangeable bases (Ca, Mg, K and Na) were extracted with 1.0 N ammonium acetate (Hendershot *et al.*, 1993). Thereafter, the amounts of K and Na in the

Table 1: Chemical analysis of the two compost used for the study

Parameter	pH (H ₂ O)	Total Carbon	N	P	K	Ca	Na	C:N ratio	Fe	Cu	Mn	Zn
			----- (g kg ⁻¹) -----							----- mg kg ⁻¹ -----		
AC	5.9	150	10.9	10	3	140	1	14	1321	61	405	146
CC	9.7	170	12	8	17	240	4	14	6053	11	393	1.5

(AC; Accelerated compost, CC; Conventional compost)

Table 2: Physical and chemical characteristics of soil in the experimental field

Parameters	2013	2014
pH (H ₂ O) 1:1	6.2	6.1
Organic C (g kg ⁻¹)	7.2	9.1
Total N (g kg ⁻¹)	0.4	0.9
Avail. P (mg kg ⁻¹)	8	4
Exchangeable cations (cmol kg ⁻¹)		
Ca ²⁺	1.8	1.8
Mg ²⁺	0.7	1.1
K ⁺	0.4	0.4
Na ⁺	0.4	0.5
Ex. Acidity (cmol kg ⁻¹)	0.1	0.1
ECEC (cmol kg ⁻¹)	3.4	3.9
Extractable micronutrients (mg kg ⁻¹)		
Mn	423	157
Fe	191	133
Cu	3	3
Particle size (g kg ⁻¹)		
Sand	840	876
Silt	108	24
Clay	52	100
Textural class (USDA)	Loamy sand	Loamy sand



filtrates were determined using flame emission photometer (Jenway PFP7 Model), while Ca and Mg were determined using EDTA titration method (Pawar *et al.*, 2009). Exchangeable acidity was extracted with 1 N KCl (Thomas, 1982) and determined by titration with 0.01N NaOH using phenolphthalein indicator. The Effective Cation Exchange Capacity (CEC) was calculated as the total sum of exchangeable bases and total exchangeable acidity (Chapman, 1965).

Extractable micronutrients (Fe, Cu, Mn and Zn) were extracted by Mehlich III method (Mehlich, 1984) and reading done on Atomic Absorption Spectrophotometer (AAS) (Model Buck scientific NV 210/211). Organic Carbon was determined by the procedure of Walkley and Black using the dichromate wet oxidation method (Nelson and Sommers, 1996). Particle size distribution analysis was carried out by Bouyoucos hydrometer method (Gee and Or, 2002) using sodium hexametaphosphate as the dispersing agent.

The results of the analyses are shown in Table 2. The analyses showed that the soil in both years were low in N; 0.4 g kg⁻¹, P; 8 and 4 mg kg⁻¹ and organic carbon; 7.2 and

9.1 g kg⁻¹, marginal in K; 0.4 cmol kg⁻¹ (FFD, 2012) and the textural class was loamy sand according to USDA textural triangle (Soil Survey Division Staff 1993).

The plot size was 3.3 x 3.3 m, planting spacing was 75 x 25 cm and one plant per stand was maintained. The space between the plots and blocks were 0.5 and 1 m respectively. The maize variety used as test crop was an extra early maturing hybrid; TZEE1 14 x TZEE1 57 x TZEE1 12. Data were collected on grain yield, while N content and uptake were determined (Bremner, 1996; Sharma *et al.*, 2012)

The Fertiliser N Recovery (NR) was obtained by difference method of Varvel and Peterson (1990) and Fertiliser Utilization Efficiency (UE) by Schenk (2006) as follows:

$$\text{Fertiliser N Recovery (NR)} = (\text{NF}) - (\text{NC}) / \text{R} \times 100 \%$$

NF = Total N uptake in maize from N fertilized plots

NC = Total N uptake in maize from unfertilized plots

R = Rate of fertiliser N applied

$$\text{Fertiliser Utilization Efficiency (UE)} = (\text{YF}) - (\text{YC}) / \text{R kg kg}^{-1}$$

Where YF = Yield from N fertilized plots

Table 2: NUE of maize in response to AC in a field trial in 2013

Treatments	Applied N (kg ha ⁻¹)	Grain yield (kg ha ⁻¹)	N-content (%)	N-uptake (kg ha ⁻¹)	Fertiliser N recovery (%)	Utilization efficiency (kg kg ⁻¹)
Control	0	2292	1.5	34.4	-	-
60 kg N ha ⁻¹ NPK	60	3954	1.8	71.2	61.4	27.7
60 kg N ha ⁻¹ CC	60	3643	1.2	43.7	15.6	22.5
60 kg N ha ⁻¹ AC	60	4042	1.7	68.7	57.3	29.2
90 kg N ha ⁻¹ AC	90	2942	1.4	41.2	7.6	7.2
120 kg N ha ⁻¹ AC	120	4176	1.6	66.8	27.1	15.7
150 kg N ha ⁻¹ AC	150	4139	1.8	74.5	26.8	12.3
180 kg N ha ⁻¹ AC	180	4413	1.9	84.3	27.8	24.5
LSD (0.05)		609		9.9	14.5	9.1

(NPK; NPK 15-15-15, AC; Accelerated Compost, CC; Conventional Compost

LSD (0.05); Least significant difference at 5 % probability)

Table 3: NUE of maize in response to AC in a field trial in 2014

Treatments	Applied N (kg ha ⁻¹)	Grain yield (kg ha ⁻¹)	N-content (%)	N-uptake (kg ha ⁻¹)	Fertiliser N recovery (%)	Utilization efficiency (kg kg ⁻¹)
Control	0	1917	0.8	15.0	-	-
60 kg N ha ⁻¹ NPK	60	2968	1.2	35.5	34.3	49.5
60 kg N ha ⁻¹ CC	60	2759	1.1	30.5	25.9	46.0
60 kg N ha ⁻¹ AC	60	3325	1.3	45.7	51.2	55.4
90 kg N ha ⁻¹ AC	90	3958	1.6	63.2	53.5	44.0
120 kg N ha ⁻¹ AC	120	3020	1.2	36.6	18.0	25.2
150 kg N ha ⁻¹ AC	150	3526	1.4	49.8	23.2	23.5
180 kg N ha ⁻¹ AC	180	3394	1.4	46.9	17.8	18.8
LSD (0.05)		451		12.4	17.0	7.2

(NPK; NPK 15-15-15, AC; Accelerated Compost, CC; Conventional Compost

LSD (0.05); Least significant difference at 5% probability)



YC = Yield from unfertilized plots and
R = Rate of fertiliser N applied

The post cropping soil was analysed to determine the soil total nitrogen using Kjeldahl digestion procedure (Bremner, 1996). The data obtained were statistically analysed using ANOVA at $\alpha_{0.05}$.

The NUE of maize in response to the different fertilizer treatments in 2013 is shown in Table 2. The plot treated with NPK at 60 kg N ha⁻¹ resulted into the highest NR (61.4%), which was not significantly ($p < 0.05$) different from AC, 60 kg N ha⁻¹ (57.3%), while CC, 60 kg N ha⁻¹ had the least value (15.6%). The AC, 60 kg N ha⁻¹ had highest UE (29.2 kg kg⁻¹), but the difference was not significant compared with other treatments, except 90 – 150 kg N ha⁻¹ AC with 7.2 – 15.7 kg kg⁻¹. In 2014 trial (Table 3), AC, 90 kg N ha⁻¹ resulted into the highest NR (53.5%) but was not significantly different from 60 kg N ha⁻¹ AC (51.2%), while AC, 180 kg N ha⁻¹ had the least value (17.8%). The highest UE of 55.4 kg kg⁻¹ was obtained from AC, 60 kg N ha⁻¹, though not significantly different from NPK, 60 kg N ha⁻¹ (49.5 kg kg⁻¹), it was higher than other treatments. On the average, the plot treated with AC, 60 kg N ha⁻¹ had the highest significant NR (54.3%) and UE (42.3 kg kg⁻¹) in the two years, followed by NPK, 60 kg N ha⁻¹ plot (47.9 and 38.6 kg kg⁻¹, respectively). In terms of post cropping soil total N (Figure 1), the AC, 60 kg N ha⁻¹ resulted into values

of 1.4 and 1.2 g kg⁻¹ in 2013 and 2014, respectively, which compared favourably with other levels of AC (1.4 – 2.0 and 1.0 – 1.4 g kg⁻¹, respectively) and CC (1.3 and 1.0 g kg⁻¹) but significantly higher than the NPK with 0.8 and 0.9 g kg⁻¹ in 2013 and 2014, respectively.

The AC at 60 kg N ha⁻¹ treated maize resulted into optimum NR (among the different rates of AC) of 54.3%, which was more than double of each of the AC, 180 kg N ha⁻¹ and CC, 60 kg N ha⁻¹ and also better than the NPK in the two years. Also, in terms of UE, AC at 60 kg N ha⁻¹ treated maize gave the highest value among all the treatments and the UE decreased with other AC rates, in the two years. This result is in agreement with the finding of Pikul *et al.* (2005) where N application rates was inversely proportional to NUE. Thus, synchronization between N supply and its demand would increase NUE thereby reducing N losses (Rizwan *et al.*, 2003). The mean NR of 54% recorded in the two years by AC, 60 kg N ha⁻¹ treatment was higher than the 33% reported for the world cereal production (Magen and Nosov, 2008) and was at par with 58% reported for maize by Niaz (2015). This rate would reduce potential nutrient losses from accelerated compost as a soil amendment (Lory and Massey, 2006). The mean UE of 42% from 60 kg N ha⁻¹ AC is within the range of 40 to 60% reported for maize by Mosier (2002), and higher than the highest obtained for maize by Niaz (2015). The ability of organic fertilizer to improve post-cropping

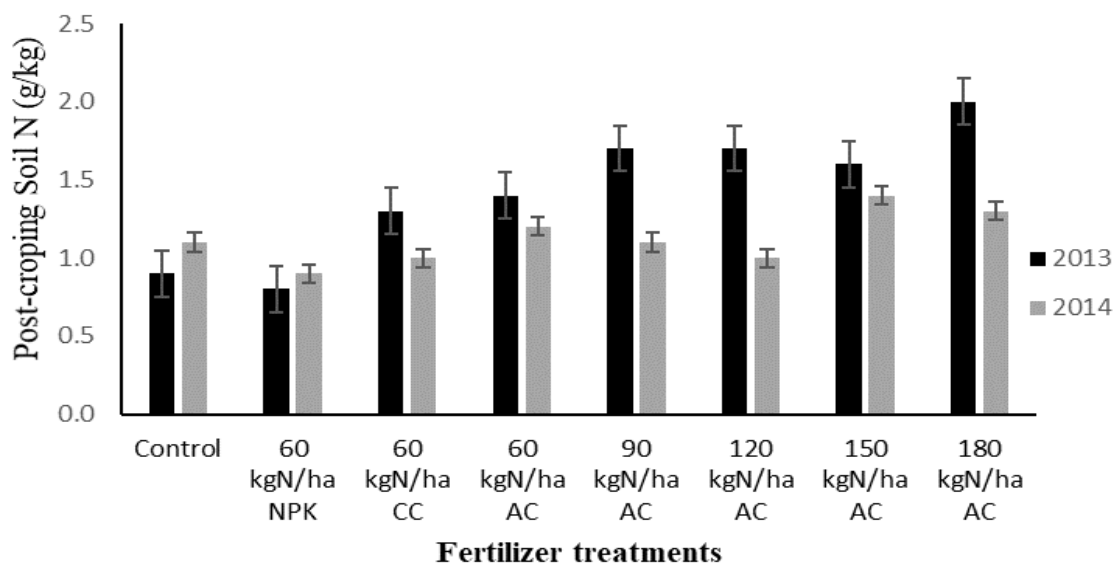


Figure 1: Effects of different rates of accelerated compost on post cropping soil total N

Legend: NPK; NPK 15-15-15, AC; Accelerated Compost, CC; Conventional Compost
Bar is Least Significant Difference (LSD) at $\alpha_{0.05}$.



soil N better than mineral fertilizer is on course, because N release is gradual in organic fertilizers, as the material would have to go through mineralization over time, thereby conserving the N in the soil (Tejada and Gonzalez, 2007; George, 2011; AdeOluwa and AyanfeOluwa, 2015). This confirmed the potential of organic fertilizers to decrease the emission of nitrous oxide from fertilizer input, thereby mitigating global warming (AyanfeOluwa *et al.*, 2014). This result is similar to earlier findings of other authors where post cropping soil N was improved by organic fertilisers (Natsheh and Mousa, 2014; Shehzadi *et al.*, 2014; Anwar *et al.*, 2015; Moyin-Jesu, 2015; Billah *et al.*, 2018).

Conclusion

The study concluded that 60 kg N ha⁻¹ accelerated compost resulted into the optimum NUE of maize and residual soil nitrogen and hence, recommended for improved maize production and reducing nitrogen loss.

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