AJFAND ONLINE
Volume 10 No. 3
March 2010
ISSN 1684 5374
AFRICAN JOURNAL OF FOOD AGRICULTURE NUTRITION AND DEVELOPMENT

GROWTH, YIELD AND NPK UPTAKE BY MAIZE WITH COMPLEMENTARY ORGANIC AND INORGANIC FERTILIZERS

Makinde EA[*1] and OT Ayoola[2]

Eyitayo Makinde

*Corresponding author. Email: eamakinde@yahoo.com

[1]Federal College of Agriculture, I.A.R &T, P.M.B 5029.Moor Plantation, Ibadan, Nigeria

[2]Institute of Agricultural Research and Training, Obafemi Awolowo University, P.M.B 5029. Moor Plantation, Ibadan, Nigeria.

AJFAND ONLINE
Volume 10 No. 3
March 2010
ISSN 1684 5374
AFRICAN JOURNAL OF FOOD AGRICULTURE NUTRITION AND DEVELOPMENT

ABSTRACT

High and sustainable crop yields in the tropics have been reported to be only possible with judicious combination of mineral fertilizers and organic amendments. Fertilizing croppings to achieve this has usually been a difficult task to achieve. The growth and yield of maize cultivated with a complementary application of organic and inorganic fertilizers was assessed compared with sole organic and sole inorganic fertilizers between April and July 2003 and 2004 at Ibadan, Nigeria, in the degraded tropical rain forest zone. There was a no-fertilizer treatment as the control. The organic fertilizer was an equal mixture of composted domestic waste and stale cow dung, applied at 10 tonnes ha^{-1}. Urea and Single super phosphate were applied as the inorganic fertilizer to supply 70 kg N and 13 kg P_2O_5 ha^{-1} respectively. The mixture of organic and inorganic fertilizer treatment consisted of half the rates used for sole organic and sole inorganic fertilizer treatments: 5 tonnes organic mixture was applied, with 35 kg N and 6.5 kg P_2O_5. Maize plant height at 8 weeks after planting was highest with inorganic fertilizer application while the leaf area was highest with organic fertilizer application. Stover yield and cob yields were also highest with inorganic fertilizer. Complementary application of organic and inorganic fertilizers however had similar plant heights; stover yield as well as cob yields with inorganic fertilizer. Nitrogen appeared chelated with organic fertilizer application. Plant ear – leaf Nitrogen was highest (1.68%) with inorganic fertilizer while the control plots had a Nitrogen content of 1.12% which was higher than 0.84% and 0.98% N from sole organic and a complementary application of organic and inorganic fertilizers, respectively. Plant P content was increased by 136% and 15% with organic and inorganic fertilizers, respectively, but was reduced by 15% with complementary application of organic and inorganic fertilizers. The K content was highest with inorganic fertilizer (1.91%). Complementary application of organic and inorganic fertilizers had a K content of 1.70% while the organic – fertilized leaves had 1.53%. Stover nutrient uptake was highest for N and K with inorganic fertilizer while the P was highest with organic fertilizer application. Cultivating maize with complementary organic and inorganic fertilizers gives a comparable cob yield as inorganic fertilizer and has nutrients higher than from sole organic fertilizer application.

Key words: Maize, Fertilizer type, Nutrient uptake

INTRODUCTION

The ever - increasing population of many countries of the world has necessitated the development of intensive agriculture technologies to sustain food yield. Soil fertility maintenance is essential in achieving and maintaining high crop yields over a period of time. Fertilizer application has usually been the major means of supplying plant nutrients. Use of mineral fertilizers has proven to be more convenient than the use of organic fertilizers that have traditionally been used since pre- industrial age. The impact of increased use of mineral fertilizers has been high but the resulting soil physical degradation, and increased soil acidity level and soil nutrient imbalance have drawn the attention of researchers back to the use of manures that are also known as organic fertilizers.

Several organic materials have been reported as suitable soil amendments for increasing crop production. The potential of cow dung, poultry droppings, refuse compost and farmyard manure as suitable soil amendments in the tropics has been reported [1, 2, 3, 4]. Application of organic materials as fertilizers provides growth-regulating substances and improves the physical, chemical and microbial properties of the soil [5, 6, 7,8]. Sole use of organic manures to sustain cropping has, however, been reported inadequate, as they are required in rather large quantities to meet crops' nutrient requirements because of their relatively low nutrient content [9].

Several field research reports have indicated that high and sustainable crop yields are only possible with integrated use of mineral fertilizers with organic manure [10, 11, 12, 13]. Complementary application of organic and inorganic fertilizers increases nutrient synchrony and reduces losses by converting inorganic nitrogen into organic forms [14]. It is also important not only for enhancing the efficiency of the fertilizers, but also in reducing environmental problems that may arise from their use [13].

This research was conducted to assess the performance of maize fertilized with complementary organic and inorganic fertilizers.

MATERIALS AND METHODS

Experimental details

Field experiments were carried out between April 2003 and July 2004 at the Federal College of Agriculture, Ibadan (lat.7° 22½'N and long.3° 50½'E), Nigeria, in an area previously supporting rainforest. The area has a bimodal rainfall pattern with a long rainy season between March and July, and a shorter rainy season from September to early November, after a short dry spell in August. Total rainfall between April and September was about 1,073 mm in 2003 and 754 mm in 2004. Average monthly temperature ranged from 23.5°C in August to a maximum of 26.2°C in April. Mean monthly relative humidity ranged from 85% in April to 92% in August, 2004. The soil site was a Plinthic Luvisol that had been under cultivation with cassava (*Manihot esculenta* Crantz), melon (*Citrullus vulgaris* L.) and maize for three years prior to establishment of the trial. The top 30 cm of the soil had a pH in H_2O of 6.8. The site

was cleared manually without burning and the residue mechanically plowed into the soil and the soil disked. Prior to planting, six core samples were taken from the top 30 cm of the soil to have a composite sample that was air – dried and crushed to pass through a 2-mm sieve, before laboratory determination of selected physical and chemical properties. The results of the analysis are presented in Table 1. Particle size distribution was determined by the hydrometer method [15]. Sodium hexametaphosphate was used as the dispersing agent. Soil pH was determined in distilled water at 1:1 soil to water ratio. Organic Carbon was determined by the Walkley-Black method [16]. The Total N was determined by the micro-Kjeldahl method. Percentage Organic Matter was derived by multiplying % organic carbon by 1.72 [17]. Available P was determined by the Bray's P1 test, using 0.03 NH_4F in 0.02N HCl as extractant and measuring the extracted P colorimerically by the molybdenum blue method [18]. Exchangeable bases were determined by extraction with neutral normal NH_4OAC at soil: solution ratio, 1:10. The soil used for the experiment was slightly alkaline at pH 6.1. The organic matter content of the soil was low at 2.9% (Table 1). The total N content and the available P and the exchangeable K contents were also low. It had 0.17%N; 1.70 ppm P and 0.34 cmol kg^{-1}K.

The manure used had a pH of 8.2. The organic matter content was 30.6% while the total N, available P and exchangeable K contents were 1.78%, 0.46% and 0.17%, respectively (Table 1). The N applied ranged from 69 to 178 kg ha^{-1} while the P ranged from 13 to 46 kg $ha^{-1}$and K applied was 17.0 and 8.5 kg ha^{-1} for the sole organic and the complementary application of organic and inorganic fertilizer treatments, respectively. No K was applied in the inorganic fertilizer treatment (Table 2).

Experimental Design

The experiment was laid out in a randomized complete block design with four replicates. Maize was planted with three different fertilizer types. The treatments were: Organic fertilizer; Inorganic fertilizer; A mixture of organic and inorganic fertilizer and a No – Fertilizer control. Plot size was 4.5 x 4m with a metre margin round each plot. The organic fertilizer was an equal mixture of composted domestic waste and stale cow dung, applied at 10 tonnes ha^{-1}[19]. Urea and Single super phosphate were applied as inorganic fertilizers to supply 70.kg N and 13 kg P_2O_5 ha^{-1}, respectively. The mixture of organic and inorganic fertilizer treatment consisted of half the rates used for sole organic and sole inorganic fertilizer treatments: 5 tonnes organic mixture was applied, with 35 kg N and 6.5 kg P_2O_5.

The organic fertilizer was uniformly spread on the plots and manually- worked into the soil using a hand hoe, two weeks before planting. The inorganic fertilizer was applied at planting. DMR-LSR white maize variety was used. The variety was Downy mildew and Streak resistant but late – maturing. The maize was established at 2seeds / hole at 50 cm spacing on rows 75 cm apart (53,333 plants ha^{-1}). The plots were weeded manually, at 3 and 6 weeks after planting (WAP).

Data Collection
Data were taken from 3 plants per plot to assess the growth and the yield of the maize. Plants not from the border rows with average, representative appearance were selected. Plant heights were assessed with a meter rule from the ground level to the topmost leaf at 8 WAP. Leaf area was determined for intact leaves by the length–width method [20]:

Leaf Area = 0.75 (Leaf length × Leaf width).

The leaf width was determined at the mid portion that had the maximum width.
The leaf subtending the cob was detached at cob-initiation to determine the plant nutrient analysis and uptake. Stover yield was taken after harvesting by cutting the maize stalk at the ground level and gathered together to obtain the total yield per plot. Plant uptake was estimated as a product of leaf concentration of a nutrient and the stover yield.

Data Analysis
The analysis of variance (ANOVA) was carried out to determine the differences in parameters. Significantly-different mean values were compared using Duncan's Multiple Range Tests (DMRT) at 5% significance level.

RESULTS

Plant Height: Average maize plant height at 8 WAP was highest with either sole inorganic fertilizer or a complementary application of organic and inorganic fertilizers. Plants from either of the fertilizers were 232 cm tall (Table 3). They were significantly taller ($P \leq 0.05$) than plants from sole organic fertilizer that were 226cm tall. Maize plants from the unfertilized plots (225 cm) were only comparable with plants fertilized with sole organic fertilizer.

Leaf area: Average plant leaf area was highest with organic fertilizer application. It had average leaf area of 326 cm^2. They were significantly higher ($P \leq 0.05$) than leaves from plants fertilized with complementary application of organic and inorganic fertilizers that had an average area of 288 cm^2. Plant leaf areas from sole organic and from complementary application of organic and inorganic fertilizers were similar ($P \leq 0.05$) with 282 cm^2 leaves observed with sole inorganic fertilizer application (Table 3).

Stover yield: Plant stover yield was highest with sole inorganic fertilizer application (7.02t ha^{-1}). Complementary application of organic and inorganic fertilizers gave comparable stover yield ($P \leq 0.05$) of 6.95 t ha^{-1}. The comparable stover yields from both complementary application of organic and inorganic fertilizers and from sole inorganic fertilizer were significantly higher ($P \leq 0.05$) than stover yields from sole organic fertilizer (4.00t ha^{-1}) and from the un-fertilized plants (3.93t ha^{-1}).

Cob yield: This followed the same pattern as the stover yield. Respective yields of 2.27 and 2.26t ha^{-1} got from sole inorganic and from complementary application of organic and inorganic fertilizers were significantly higher($P \leq 0.05$) than cob yields from sole organic fertilizer (2.20 t ha^{-1}), which was even significantly higher ($P \leq 0.05$) than 2.08 t ha^{-1} obtained from the unfertilized control plots (Table 3).

Plant Nutrient Content: An analysis of the ear – leaf shows that the N contents of leaves fertilized with either sole organic fertilizer (0.84%) or combined with inorganic fertilizer (0.98%) were lower, relative to N of leaves from sole inorganic fertilizer(1.68%). However, leaves from the control plots had 1.12% N (Fig.1).

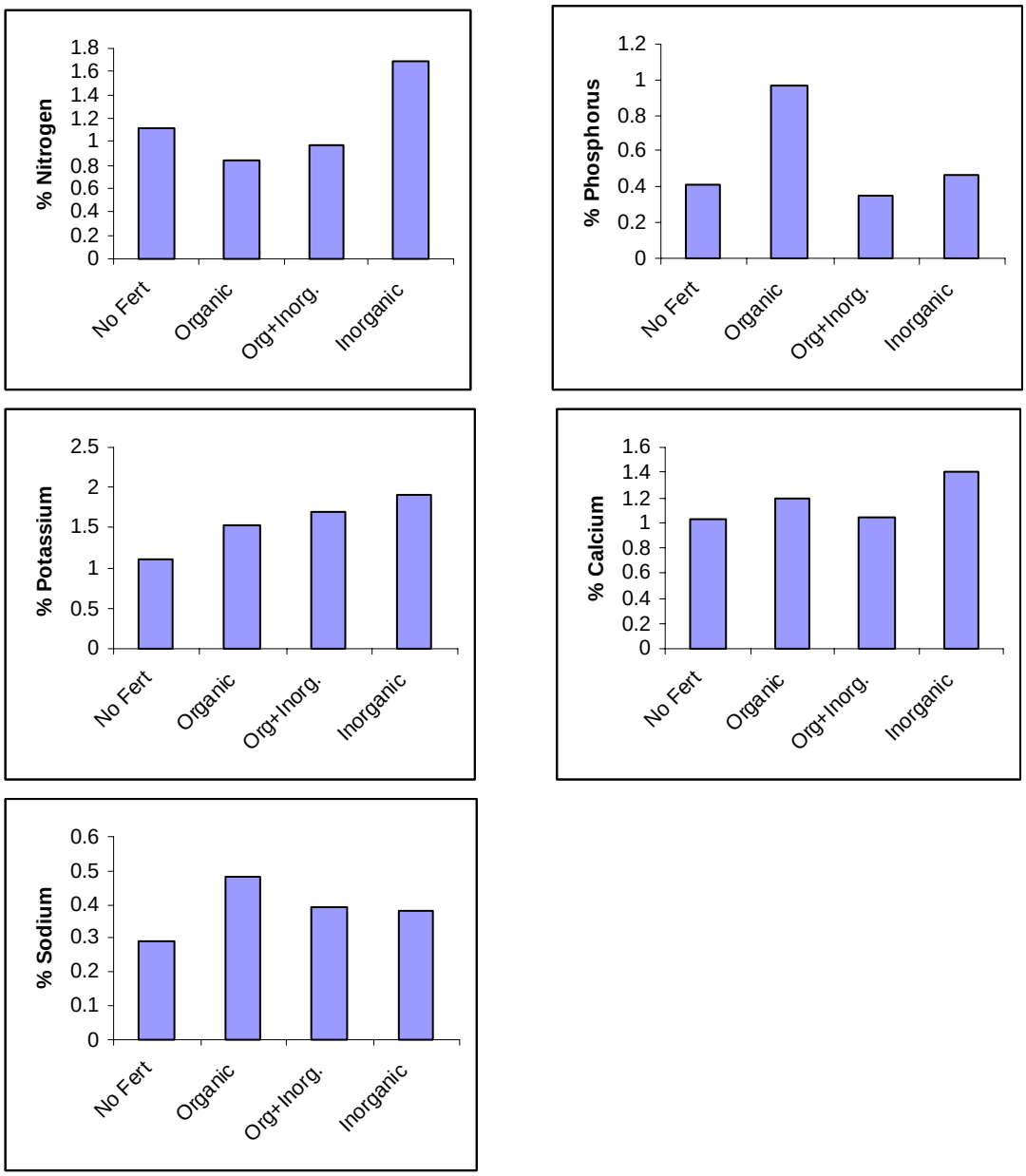

Figure 1: Maize Ear Leaf Analysis with Organic and Inorganic Fertilizer Application

The high P content of the organic fertilizer is also reflected in the P content of the ear leaves. Plants fertilized with sole organic fertilizer had the highest P content of 0.97% while plants fertilized with inorganic fertilizer had 0.47%. A higher amount of phosphorous was supplied with sole organic fertilizer application, relative to complementary organic and inorganic fertilizer application. Consequently, the P contents of the leaves were higher than from a combined application of organic and inorganic fertilizer (Fig.1).

The K content of the manure was low. Consequently, the leaf K contents of crops fertilized with sole organic fertilizer were lower, relative to complementary organic and inorganic fertilizers and also to sole inorganic fertilizer application (Fig. 1). Maize fertilized with sole inorganic fertilizer had the highest content of 1.91% K while those from a complementary application of organic and inorganic fertilizers were 1.70% K. Plant leaves from the sole organic fertilizer had a K content of 1.53%. This is an indication that Potassium is contributed more from the inorganic fertilizer than from the organic fertilizer. Plants from the control plots also had a K content of 1.11% which is an indication of additional contribution from the weathering of the base rock complex (Fig.1).

Nutrient Uptake: Total plant uptake of N was highest with inorganic fertilizers (118 Kg ha^{-1}). This was followed by combined application of organic and inorganic fertilizers (68 Kg ha^{-1}). Since the ear leaf N content from organic fertilization was low, the total nutrient uptake was low. It was even lower than observed from the control unfertilized plots.

Plant uptake of Phosphorus ranged from 16 Kg ha^{-1} from the control plots to 39 Kg ha^{-1} from the organic fertilizer plots. Inorganic fertilized plants had an uptake of 33 Kg ha^{-1}while about 24 Kg $ha^{-1}$was the total stover uptake from the combined application of organic and inorganic fertilizers (Fig.2).

Potassium uptake was highest (174 Kg ha^{-1}) from sole inorganic fertilizer. It was followed by 118 Kg $ha^{-1}$from a combined application of organic and inorganic fertilizers (Fig.2). Despite the fact that K was not supplied in the inorganic fertilizer, it still gave the highest stover uptake. The Ca and the Na uptake followed the same pattern as K.

Generally, uptake of nutrients was better with sole application of inorganic fertilizer. Sole use of organic fertilizer gave values similar with observed from the unfertilized plants. It even reduced the N content. However, a combined use of organic and inorganic fertilizers gave a higher N and K values. The low content of the P is an indication that a higher dose than the 13 kg ha^{-1} should be applied. Uptake of N can be better by application of a dose higher than the 70 kg ha^{-1} used.

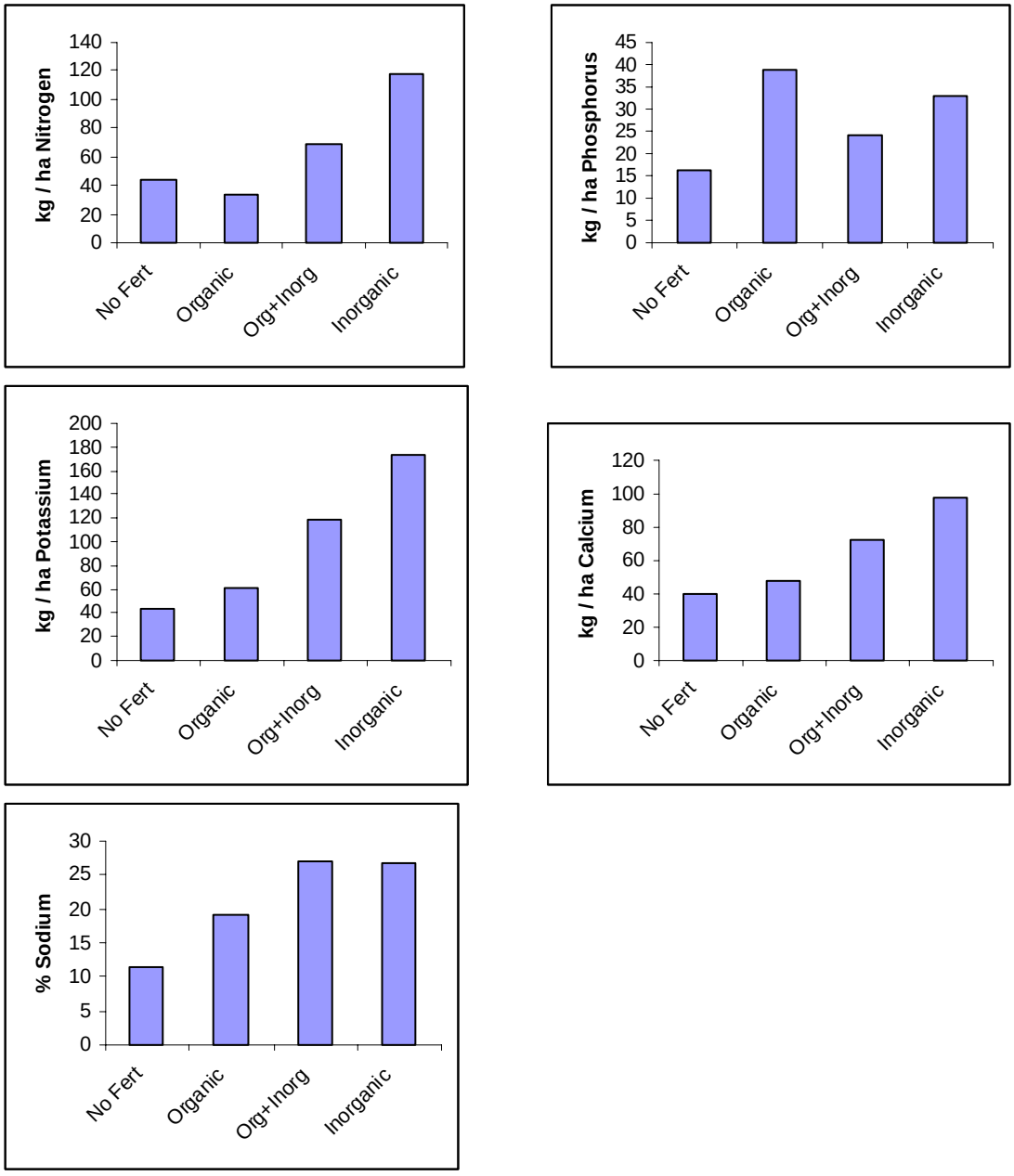

Figure 2: Stover Nutrient Uptake (Kg ha^{-1}) with Organic and Inorganic Fertilizer Application

DISCUSSION

The rather low values generally observed for the soil nutrient contents inferred that the soil was not fertile. This consequently makes the soil appropriate for a study on response to fertilizer. Inorganic fertilizers are known to have the peculiarity of fast release of their nutrient contents. Nutrients supplied from the inorganic fertilizer seemed to be released fast enough at 8WAP to give significantly taller plants. Even nutrients supplied from the complementary application of organic and inorganic fertilizers seemed enough to have plants not significantly shorter than plants treated with sole inorganic fertilizer application. Organic fertilizers are known to have the characteristic nature of slow release of nutrients. The observed shorter plants from the organic - fertilized plants can be attributed to the slow release nature of the fertilizer, as assessed at 8WAP. A similar observation has been made in other studies [21]. Maize plant heights with inorganic fertilizer and a complementary application of inorganic and organic fertilizers were observed to be similar and were significantly greater than those from organic fertilizer application. While the nutrients that would have been released fast from both sole inorganic fertilizer and from complementary application of organic and inorganic fertilizers seemed effective for the growth of maize in height, the slowly – released nutrients from both sole organic fertilizer and from complementary application of organic and inorganic fertilizers seemed effective for the development of the leaves. Nutrients supplied in the complementary application of organic and inorganic fertilizers gave higher (although not significant) leaf areas than from sole inorganic fertilizer. However, sole organic fertilizer application seemed to supply enough nutrients to effect the development of significantly higher leaf areas than either the sole inorganic fertilizer application or the reduced organic fertilizer complemented with inorganic fertilizer. In a study of the residual influence of early season fertilization on cassava growth and yield, cassava leaf area with organic fertilizer application has been earlier reported to be comparable with either sole inorganic fertilizer application or a complementary application of inorganic and organic fertilizers [22].

The observed comparable stover yields from both complementary application of organic and inorganic fertilizers and from sole inorganic fertilizer is a further indication that the nutrients supplied from the complementary application were effective enough as those supplied with sole inorganic fertilizer.

An earlier study had reported maize grain yields from sole inorganic fertilizer and from complementary application of inorganic and organic fertilizers to be comparable and significantly higher than yields from sole organic fertilizer application [23]. It was also observed that organic fertilizer application did not benefit the yield of maize significantly. The observed significant lower yield from organic fertilizer application supports the observation that organic fertilizers are better used for sustaining continuous cropping for 2 – 3 years than inorganic fertilizers [24].

It appears some nitrogen chelation occurred with organic fertilizer application. This is a characteristic nature of organic fertilizers. The applied N was, therefore, not made

totally available to the crops and so, plants fertilized with organic fertilizer had even lower values than observed from the unfertilized plots. It is known that inorganic fertilizers release their nutrients rather fast for the plants to utilize. This accounts for the observed high value of the N content of crops fertilized with inorganic fertilizer. Nitrogen leaching and gaseous emissions have been reported lowest with reduced N applications [25]. This accounts for the low N applied in the inorganic fertilizer treatment having the highest N content. Despite the fact that K was not supplied in the inorganic fertilizer, it still gave the highest stover uptake. This can be attributed to contribution from the weathering of the base rock complex.

CONCLUSION

The study has shown that maize yields from sole organic fertilizer application are significantly lower than yields from either sole inorganic fertilizer or a combined application of organic and inorganic fertilizers. Yields from a combined application of organic and inorganic fertilizers are not significantly lower than yields from sole inorganic fertilizer application. Plant nutrient contents are also not significantly different.

The comparable yields realized from sole inorganic fertilizer and a complementary organic and inorganic fertilizer application infers that farmers can use less quantity of inorganic fertilizers, complemented with organic manures to cultivate maize and still realize comparable yields, as from sole inorganic fertilizer application.

Table 1: Pre – Cropping Soil and Manure Chemical Analysis

	Soil Sample	Organic Manure
pH (H_20)	6.1	8.2 %
Organic Matter	2.9 %	30.6 %
Organic Carbon	1.7 %	17.8 %
Total – N	0.2 %	1.8 %
Available – P	1.7 ppm	0.5 %
Exchangeable – K	0.3 cmol kg^{-1}	0.12 %
Exchangeable –Ca	3.7 "	0.7 %
Exchangeable – Na	0.5 "	0.7 %
Exchangeable – Mg	0.5 "	0.01 %
Exchangeable Acidity	0.1 "	
ECEC	5.1 "	
Sand	724 g kg^{-1}	
Silt	131 "	
Clay	145 "	

Table 2: Estimated Quantities of NPK Applied

	Nitrogen	Phosphorus	Potassium
		Kg ha^{-1}	
Organic Fertilizer	178.0	46.0	17.0
Org +Inorg Fertilizers	123.5	29.5	8.50
Inorganic Fertilizer	69.0	13.0	00.0

Table 3: Maize Growth and Yield with Organic and Inorganic Fertilizer Application

	Plant Height at 8WAP (cm)	Plant Leaf Area (cm^2) at 8WAP	Stover Yield ($t\ ha^{-1}$)	Cob Yield ($t\ ha^{-1}$)
No Fertilizer	223b [Z]	272b	3.93b	2.08c
Organic Fertilizer	226b	326a	4.00b	2.20b
Org +Inorg Fertilizers	232a	288b	6.95a	2.26a
Inorganic Fertilizer	232a	282b	7.02a	2.27a

[Z] values followed by same letter in a column are not significantly different: $P \leq 0.05$, DMRT

REFERENCES

1. **Sobulo RA and O Babalola** Improved organic fertilizer and soil condition. **In**: *Towards efficiency fertilizer use in Nigeria*. Federal Ministry of Agriculture, Water Resources and Rural Development, Lagos, 1992; 90-110.

2. **Ismail AS, EL-Sebaay AS, Salehu SA and AF Abdel-Wahab** Effect of application of mineral and organic amendment of nodulation of cowpea, growth and certain chemical properties of calcareous soil. *Ann. Agric. Sci.* 1996 (Special Ed): 23-39.

3. **Olayinka A** Carbon mineralization from poultry-manure straw sawdust amended Alfisol. *Ife. J. Agric 1996;* **18 (1, 2**):26-36.

4. **Olayinka A, Adetunji A and A Adebayo** Effect of organic amendments on nodulation and nitrogen fixation of cowpea. *J. Plant Nutr.1998;* **21 (11)**: 2455–2464.

5. **Sharma AR and BN Mittra** Effect of different rates of application of organic and Nitrogen fertilizers in a rice-based cropping system. *J. Agric. Sc (Cambridge). 1991;* **117**: 313-318

6. **El – Shakweer MHA, El – Sayed EA and MSA Ewees** Soil and plant analysis as a guide for interpretation of the improvement efficiency of organic conditioners added to different soils in Egypt. *Com. Soil Sc. Plt. Anal*. 1998; **29**: 2067-2088.

7. **Schjonning P, Christensen BT and B Carstensen** Physical and chemical properties of a sandy loam receiving animal manure, mineral fertilizer or no fertilizer for 90 years. *Euro J. Soil Sci. 1994;* **45**: 257-268.

8. **Belay A, Classens AS, Wehner FC and JM De Beer** Influence of residual manure on selected nutrient elements and microbial composition of soil under long–term crop rotation. *S. Afric. J. Plt. Soil. 2001;* **18**: 1-6.

9. **Palm CA, Myers RJK and SM Nandwa** Combined use of organic and inorganic nutrient sources for soil fertility maintenance and replenishment. **In**: *Replenishing soil fertility in Africa.1997;* RJ Buresh, PA Sanchez and F Calhoun (Eds). Special Publication. No. **51**. 193- 217. Madison. WI. Soil Science Society of America.

10. **Raman KB, Singh MP, Singh RO and USP Singh** Long-term effects of inorganic and organic-inorganic Nitrogen supply system on yield trends of rice-wheat cropping system. *J. Appl. Bio. 1996;* **6 (1, 2**): 56-58.

11. **Singh NP, Sanchez RS, Pandey PC and RS Bishi** Effects of Decade long fertilizer and manure application on soil fertility and productivity of rice-wheat system in a Mollisol. *J. Ind. Soc. Soil Sci*. 1999; **47 (1**): 72-80.

12. **Satyanarayana VM, Vera Prasad PV, Murphy VRK and KJ Boots** Influence of integrated use of farmyard manure and inorganic fertilizer on yield and yield components of irrigated lowland rice. *J. Plt Nutr*. 2002; **25** (**10**): 2081 – 2090.

13. **Bayu W, Rethman NFG, Hammes PS and G Alemu** Effects of Farmyard Manure and Inorganic Fertilizers on Sorghum Growth, Yield and Nitrogen use in a Semi-arid area of Ethiopia. *J. Plt. Nutr*. 2006**; 29 (2):**391-407.

14. **Kramer AW, Doane TA, Horwath WR and CV Kessel** Combining fertilizer and organic inputs to synchronize N supply in alternative cropping systems in California. *Agric. Eco. Envir.* 2002; **91:** 233-243.

15. **Bouyocous GJ** A recalibration of the hydrometer method for mechanical analysis of soils. *Agron. J. 1951;* **43**: 434-438.

16. **Walkley A and IA Black** An examination of the Degtjaref method for determining soil organic matter and a proposed modification of the chronic acid titration. *Soil Sci. 1934;* **37**: 29-38

17. **Broadbent FE** The soil organic fraction. *Advs. Agron. 1953;* **5**: 153-183.

18. **Bray AH and LT Kurtz** Determination of Total, Organic and Available forms of Phosphorous in soils. *Soil Sci. 1945;* **59**: 45- 59.

19. **Federal Procurement and Distribution Division (FPDD)** - Fertilizer use and Management Practices for Crops in Nigeria 1989; Enwenzor WO, Udo EJ, Usoroh NJ, Ayotade KA and JA Adepetu (Eds). 1-4.

20. **Saxena MC and Y Singh** A note on leaf area estimation of intact maize leaves. *Ind. J. Agron*. 1965; **10**: 437 – 439.

21. **Ayoola OT and EA Makinde** Fertilizer treatment effects on performance of cassava under two planting patterns in a Cass.ava – based cropping system in South – west Nigeria. *Res. J. Agric. Bio. Sci.2007;* **3 (1):** 13 – 20.

22. **Makinde EA and OT Ayoola** Residual influence of early season crop fertilization and cropping system on growth and yield of cassava. *Amer. J. Agric. Bio. Sci. 2008;* **3 (4):** 712 – 715.

23. **Makinde EA, Agboola AA and FI Oluwatoyinbo** The effects of organic and inorganic fertilizers on the growth and yield of maize in a maize – melon intercrop. *Moor J. Agric. Res*. 2001; **2**:15 – 20.

24. **Agbim NN** Potentials of cassava peel as a soil amendment. II. Field evaluation. *J. Envir. Qlty*.1985; **14**: 411 – 415.

25. **Guo Huaming, Guanghe Li, Zhang Dayi, Zhang Xu and Lu Chang'ai** Nitrogen balance and dynamics as affected by water table and fertilization management in Celery cropping system of South – western China. *Afric. J Agric Res. 2007;* **2 (4)**:139 – 149.