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RESEARCH ARTICLE

The effect of organic and inorganic fertilizers on the production of maize in Minna, southern guinea savanna zone of Nigeria

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Abstract

This study assessed the impact of sole organic and inorganic fertilizers and combinations of both on maize production under rain-fed farming conditions during the 2023 cropping season on four farmers' fields in around Minna in Niger State, Nigeria. The treatments consisted of five (5) nutrient combinations: T1 = Control (No fertilizer Input), T2 = NPK (15:15:15) only, at the rate of 150 kg ha^{-1} representing farmers' usual practice in the area, T3 = Office Chérefien des phosphates (OCP) special blend NPK (20:10:5+1Zn +2Ca) fertilizer {OCP (NPK)}at the manufacturer's recommended rate of 600 kg ha^{-1}, T4 = Cow dung (CD) at the rate of 5 t ha^{-1}, T5 = CD (2.5 t ha^{-1}) + NPK (15:15:15) at the rate of 75 kg ha^{-1}, T6 = CD (2.5 t ha^{-1}) + OCP (NPK) fertilizer at the rate of rate of 300 kg ha^{-1}. The experiment was laid down in a Randomized Complete Block Design (RCBD) with each of the 4 farmers' fields serving as a replicate. Soil analysis revealed moderately to slightly acidic pH levels with low levels of Soil Organic Carbon (SOC), Nitrogen (N), and Phosphorus (P) across all fields. Statistical analysis showed significant differences in plant height and Leaf Area Index (LAI) between each of the fertilizer treatments and the unfertilized (control) treatment at different weeks after planting.

Though there were no statistically significant differences between the NPK (15:15:15), OCP (NPK) treatments and their combinations with CD, the OCP (NPK) sole treatment nevertheless consistently resulted in the tallest plants, largest LAI, heaviest average seed weight and the highest maize yield at full maturity (1.92 t ha^{-1}), demonstrating a significant improvement over the untreated control and the sole cow dung treatments. These findings suggest that proper combinations of mineral fertilizers, such as OCP (NPK), and organic amendments, like cow dung, can lead to sustainable maize production under rain-fed farming conditions in the study area. Integrating organic and inorganic fertilizers in agricultural systems can contribute to sustainable crop production, ensuring food

Keywords: Fertilizer; Cow dung; OCP Special-Blend NPK; Maize; yield.

1. Introduction

Maize (*Zea mays*) with an average production capacity of about 2.5 t ha^{-1} in Nigeria (Kamara *et al.*, 2014) holds immense importance as a staple crop in Sub-Saharan Africa, particularly in Nigeria, where it plays a crucial role in providing affordable animal feed, especially for the poultry and fish industries, thus ensuring food security and supporting livelihoods. However, achieving sustainable maize production requires effective soil fertility management to improve nutrient availability and facilitate crop growth and yield. In Minna, farmers have traditionally relied heavily on generic NPK 15:15:15 fertilizer, with limited use of organic fertilizers due to their slow nutrient release pattern. This practice has resulted in consistently low maize yields over the years (Kamara *et al.*, 2020), exacerbated by the rising costs of inorganic fertilizers, which have become increasingly unaffordable for farmers and consequently applied at below-recommended

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rates. Understanding the soil fertility status and nutrient levels is essential for introducing tailored management strategies, such as combining a special blend of NPK fertilizer with organic manure like cow dung (Eneji and Abdullahi, 2017). The choice between organic and inorganic fertilizers significantly influences soil health, environmental sustainability, and crop productivity. While organic fertilizers release nutrients slowly, they however contribute to the improvement of soil structure. On the other hand, inorganic fertilizers provide readily available nutrients but may pose risks such as soil degradation and water pollution. Due to the cost constraints associated with inorganic fertilizers, farmers in Minna have been applying them at levels below 150 kg/ha, leading to reduced yields per hectare. To address these sustainability challenges, researchers have explored various agricultural practices, including integrated fertilizer management on farmers' fields. This study aims to compare the effects of OCP special blend (20:10:5+1Zn +2Ca) (NPK) fertilizer at manufacturer's recommended rates and generic NPK (based on farmers' usual practices in the area) in combination with organic fertilizers on maize growth and yield across four replicates in Minna, providing valuable insights into sustainable fertilizer management practices to optimize production while preserving the environment (OCP Africa, 2022).

2. Materials and methods

2.1. Experimental Sites

The study areas to be used for the on-farm demonstration plots in Niger State is Gidan Mangoro village in Bosso Local Government Area (LGA) Minna, Southern Guinea savanna zone of Nigeria, (Latitude 9^{o} 41" N and Longitude 6^{o} 30" E). The Climate around Minna is sub humid tropical, with mean annual rainfall of 1284 mm. The mean maximum temperature remains high throughout (33.5°C) particularly in February to March (Accurate Weather, 2023) and an annually distinct dry season of about five months which occurs from November to March. The rainy season occurs between the months of April and September, while the dry season falls between the months of October and March. The physical features around Minna consist of granites, migmatites, gneisis and schists. Inselbergs of "Older Granites" and low hills of schists rise conspicuously above the plains and bedrock is deeply weathered and constitutes the major soil parent material. The soils around Minna are mostly classified at the Order level as Alfisols (Lawal, *et al.*, 2012).

2.1.1. Site Selection

The farmers' fields for this trial were selected based on the following criterion after interaction with the farmers in the area:

- Farmers who have used their land for crop cultivation more than five years.
- Farmers who are willing to lease their land for free, maintain the plots during the period of the trial and collect the final grain yield harvest.
- Farmers with history of maize production with reduced yield in the last five years.

2.1.2. Soil Sampling

Soil samples were collected on each of the selected farmers' fields at a depth of 0 - 20 cm using a soil auger along a zig-zag transect (also referred to as "W" transect) at intervals of 5 m. The soil samples from each farm were collected in a plastic bucket and mixed thoroughly with hand trowel to form a composite from which sub-set was collected and labelled properly for laboratory analysis. All soil samples collected from the various sites were transported to Federal University of Technology, Minna, air dried, particles of leaves and sticks removed and gently crushed. The samples were thereafter transported to the Nigeria Institute of Soil Science (NISS) Analytical Laboratory in GoniGora, Kaduna for analysis (Subbiah and Asija, 1956)

2.2. Sources of Experimental Materials

Maize seeds (var. Oba Super 11) was purchased from Pioneer seeds Depot at the Niger State Agricultural and Mechanization Development Authority (NAMDA) Farm Centre in Minna.

Bags of generic NPK (15:15:15) fertilizer were obtained from NISS, and OCP special blend NPK fertilizer fortified with zinc (Zn) and calcium (Ca) (20 : 10 : 5 + 1Zn + 2Ca) were obtained from OCP, Africa Fertilizer Company, while cowdung was collected from the animal pen of the department of Animal Production, FUT, Minna.

2.3. Treatments and Experimental Design

The treatments consisted of five (5) nutrient combinations: T1 = Control (No fertilizer Input), T2 = NPK (15:15:15) only, at the rate of 150 kg ha^{-1} representing farmers' usual practice in the area, T3 = OCP special blend NPK (20:10:5+1Zn +2Ca) fertilizer {OCP (NPK)}at the manufacturer's recommended rate of 600 kg ha^{-1}, T4 = CD at the rate of 5 t ha^{-1}, T5 = CD (2.5 t ha^{-1}) + NPK (15:15:15) at the rate of 75 kg ha^{-1}, T6 = CD (2.5 t ha^{-1}) + OCP (NPK) fertilizer at the rate of rate of 300 kg ha^{-1}. The 150 kg $ha^{-1}$of NPK (15:15:15) supplied 22.5 kg N ha^{-1}, 22.5 kg P_2O_5 ha^{-1} and 22.5 kg K_2O ha^{-1}. While 600 Kg of OCP (NPK) supplied 120 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} and 30 kg K_2O ha^{-1}

The experiment was laid out in a Randomized Complete Block Design (RCBD) with each of the 4 farmers' fields constituting a replicate. The net plot size was 6 m x 6 m giving an area of 36 m^2.

2.4. Agronomic Practices

At each farm site, land was cleared and ridges measuring 6 meters long with an inter-row spacing of 75 cm were made manually with local hoes to give a net plot size of 36 m^2 (6 m x 6 m). The plots were laid out using measuring tape, garden line and pegs. Cured cow dung was transported and applied as per treatment on the ridges two weeks before planting. The cowdung was incorporated by mixing with soil on the surface of the ridges. Three seeds of maize were then planted on the ridges at a spacing of 25 cm within rows. Plants were thinned to one per stand at two weeks after planting. Immediately after thinning, the full dose of 150 Kg NPK (15:15:15) fertilizer was applied to plants inT2 in bands beside each maize stand. Also, the first dose of 300 Kg of OCP (NPK) fertilizer was applied to plants in T3, while the second dose of the fertilizer was applied at 5 weeks after planting. Insect pest (Army worm) infestation was effectively managed using appropriate insecticide. Manual weeding was done on each field when necessary to keep the experimental field weed-free. Signboards were used to identify experimental sites, and each treatment plot.

2.5. Data Collection

Six plants from the two inner rows (net rows) of each plot were randomly selected and tagged for data collection. The data collected were plant height, leaf area index, number of leaves, 100 seed weight and grain yield.

2.6. Statistical Analysis of Data

All measured and calculated variables were subjected to analysis of variance (ANOVA) using the statistical package Minitab (version 21.1). Treatment means were separated using Fisher Pairwise Comparisons at 5% level of significance

3. Results

The soil analysis results from Table 1 indicate consistent textural class across all the locations, but significant variations in pH and soil fertility status among the 4 farmers' fields. Observations based on Chude *et al.* (2011) reveal the following: The soil pH ranged from 5.93 in field 1 to 6.21 in field 3, indicating a range from moderately acid to slightly acid, respectively. This acidity might be attributed to continuous cropping practices involving acid-forming soil amendments like nitrogenous fertilizers and organic manure, complete crop removal during harvesting, and the inherent acidic nature of the parent materials in Minna, classified as acid igneous rock originating from a basement complex.

Table 1. Soil physical and chemical properties of the four farmers' fields used in Maize cultivation in Minna, Niger State.

Farmers' Fields	1	2	3	4
Soil Parameters				
Particle size distribution (%)				
Clay	7	7	7	7
Silt	28	28	28	33
Sand	65	65	65	60
Textural Class	SL	SL	SL	SL
pH (H_2O) 1:2.5	5.93	6.06	6.21	6.12
pH (0.01M $CaCl_2$) 1:2.5	5.82	5.75	5.90	5.82
EC(dsm^{-1})	0.032	0.029	0.031	0.028
SOC (gKg^{-1})	0.22	0.34	0.40	0.23
N(g Kg^{-1})	0.021	0.025	0.020	0.018
Available P (mg Kg^{-1})	4.41	4.66	3.43	3.43
Exchangeable Bases (cmol Kg^{-1})				
Ca	4.95	5.17	5.20	5.17
Mg	0.57	0.56	0.56	0.57
K	0.02	0.02	0.02	0.02
Na	0.33	0.31	0.33	0.31
Exchangeable Bases (cmol Kg^{-1})	5.87	6.06	6.11	6.07
Exchangeable Acidity (cmol Kg^{-1})	0.50	0.50	0.50	0.50
ECEC (cmol Kg^{-1})	6.37	6.56	6.61	6.57
Micro Nutrients (mg Kg^{-1})				
Mn	30.45	34.51	35.42	15.29
Cu	0.20	0.14	0.20	0.20
Fe	0.91	0.90	0.73	1.51
Zn	3.68	4.11	4.19	3.70

SL= Sandy loam, ECEC= Effective Cation Exchange Capacity

Soil Organic Carbon (SOC) and Nitrogen (N) levels were notably low across all fields. Phosphorus (P) levels were also uniformly low in all fields, the lowest values recorded in maize fields 3 and 4 at 3.34 mg kg^{-1}. Such low P levels suggest that the response to P treatment might not significantly differ among the demonstration plots.

Exchangeable Ca and Mg were relatively high and medium, respectively, Ca levels ranged from 4.95 to 5.18 cmol kg^{-1} across farmers' fields, while Mg values varied from 0.56 to 0.57 cmol kg^{-1}. Exchangeable potassium (K) was consistently low in all farmers' fields, maintaining a value of 0.20 cmol kg^{-1}, while Na showed a medium levels, ranging from 0.31 to 0.33 cmol kg^{-1}.

Manganese (Mn) was notably high, ranging from 15.29 mg kg^{-1} in field 4 to 35.42 mg kg^{-1} in field 3. Similarly, Zinc (Zn) levels were high in all fields, with the highest value of 4.19 mg kg^{-1} in field 3. However, Copper (Cu) showed medium levels in fields 1, 3, and 4. Iron (Fe) was consistently low across all fields, with the highest value recorded at 1.51 mg kg^{-1} in field 4.

The impact of various fertilizer treatments in table 2 illustrates the effect on maize plant height in centimeters at 6, 8 and 10 Weeks after Planting (WAP). Statistical analysis revealed significant differences ($p \leq 0.05$) in mean plant height at 8 and 10 WAP. While no significant difference was observed at 6 WAP, the treatment with sole OCP (NPK) fertilizer exhibited the tallest plants (130.95cm), surpassing the unfertilized (control) plants height of 103.46 cm. At 8 and 10 WAP, the OCP (NPK) treatment consistently produced the tallest plants (208.69 cm and 217.98 cm, respectively), significantly exceeding the heights of plants in the control plots. Throughout the study period, the control consistently showed the shortest plants. Other treatments, such as sole NPK (15:15:15) or combined with cow dung also resulted in increased plant height compared to the control, albeit to a lesser extent than the OCP (NPK) treatment.

Table 2. The effect of Organic and Inorganic fertilizers on plant height (cm) of maize at 6, 8 and 10 WAP

Treatment	6 WAP	8 WAP	10 WAP
CONTROL	103.46a	135.23b	154.09c
NPK (15:15:15)	121.68a	163.79ab	178.75bc
OCP (NPK)	130.95a	208.69a	217.98a
COWDUNG	112.27a	156.59b	173.28bc
COWDUNG + OCP (NPK)	124.22a	177.53ab	190.45ab
COWDUNG + NPK (15:15:15)	125.31a	172.31ab	189.41ab

Means with the same letters on the same column are not significantly different at $p \leq 0.05$

The effect of Organic and Inorganic fertilizers on Leaf Area Index (LAI) of maize plants at 6, 8, and 10 WAP is displayed on table 3. Initially, at 6 WAP, no statistically significant differences were observed. However, the OCP (NPK) treatment showed the highest mean LAI at 6 WAP (341.18 cm^2), followed by Cowdung treatment (243.48 cm^2), while the control group had the lowest LAI (221.08 cm^2). Progressing to 8 WAP, the OCP (NPK) treatment maintained its lead with the highest LAI at 334.87 cm^2, and was however, only significantly different from the control, which displayed a lower LAI at 206.90 cm^2. However, at 10 WAP, there were no significant differences among the treatments.

Table 3. The effect of Organic and Inorganic fertilizers on Leaf Area Index (cm^2) of Maize at 6, 8 and 10 WAP

Treatment	6 WAP	8 WAP	10 WAP
CONTROL	221.08a	206.90b	334.85a
NPK (15:15:15)	224.09a	251.77ab	422.93a
OCP (NPK)	341.18a	334.87a	460.20a
COWDUNG	243.48a	278.06ab	381.40a
COWDUNG + OCP (NPK)	300.15a	288.52ab	382.96a
COWDUNG + NPK (15:15:15)	283.61a	271.40ab	403.09a

Means with the same letters on the same column are not significantly different at $p \leq 0.05$

The effect of Organic and Inorganic fertilizers on 100 seed weight and yield of Maize at full maturity is shown in table 4. While the seed weight did not exhibit significant differences at ($p \leq 0.05$), the treatment with OCP (NPK) fertilizer resulted in the heaviest average seed weight (250 g), notably surpassing all other treatments. Conversely, the NPK (15:15:15) treatment demonstrated the lowest average seed weight (22.74 g), closely followed by the Cowdung + NPK (15:15:15) and Control treatments (23.09 g and 23.22 g respectively).

Table 4. The effect of Organic and Inorganic fertilizers on 100 seed weight (g) and grain yield (t ha^{-1}) of Maize at full maturity

Treatment	100 Seed Weight (g)	Yield (t ha^{-1})
CONTROL	23.22a	0.64b
NPK (15:15:15)	22.74a	1.03ab
OCP (NPK)	250a	1.92a
COWDUNG	26.09a	0.62b
COWDUNG + OCP (NPK)	25.81a	1.14ab
COWDUNG + NPK (15:15:15)	23.09a	1.05ab

Means with the same letters on the same column are not significantly different at $p \leq 0.05$

With respect to grain yield, the OCP (NPK) treatment yielded the highest maize grain yield at full maturity (1.92 t ha^{-1}), indicating a significant improvement over the Control (0.64 t ha^{-1}) and Cow dung treatments (0.62 t/ha). The other treatments, including NPK (15:15:15), Cowdung + OCP (NPK), and Cowdung + NPK (15:15:15), produced intermediate yields ranging from 1.03 t ha^{-1} to 1.14 t ha^{-1}.

4. Discussion

The effect of Organic and Inorganic fertilizers on growth and yield of maize

The observed significant effects on the growth and yield parameters of maize are likely attributable to the application of sole organic and inorganic fertilizers and combinations of both on maize production. Inorganic fertilizers are known for their ability to release nutrients in the right quantities and at the appropriate times for plant uptake (Thakur, *et al*., 2010, Ojo, *et al.*, 2018 and Vimal, *et al.*, 2020). This is similar to the effect on grain yield and other yield parameters under observation. The grain yield of maize was 1.9 t ha^{-1} when 600 Kg ha^{-1} of OCP (NPK) was applied and this significantly outperformed plants in the Control plots and those that received 5 tons ha^{-1} of cowdung. Conversely, the residual effect of organic fertilizer may take longer to manifest, as decomposition and mineralization processes are necessary to occur first for crops to fully benefit from it (Sharma, *et al.*, 2013; Rasheed, *et al.*, 2021). As such, the growth parameters in the first year may not reflect the immediate impact of organic fertilizer application (Reganold and Wachter, 2016)

Interestingly, the results suggest that organic fertilizer application alone did not significantly benefit the growth and yield of maize in this trial. This findings aligns with those of previous research indicating that organic fertilizers may be more suited for sustaining continuous cropping over multiple years rather than providing immediate benefits comparable to inorganic fertilizers (Makinde and Ayoola, 2010). Organic manures are known to have positive effects on soil quality, promoting nutrient release and availability to plants over time (Birkhofer *et al.*, 2008; Karami, *et al.*, 2012). These findings underscore the complex interactions between fertilizer types, soil properties, and crop responses (Adeleye *et al.*, 2019). While inorganic fertilizers may provide more immediate and targeted nutrient availability, organic fertilizers contribute to long-term soil health and sustainability. Integrating both types of fertilizers in agricultural systems can help optimize nutrient management strategies, improve crop productivity, and enhance soil quality over the long term. This is in line with other research outcomes where inorganic fertilizer application had no consistent significant effects on maize plant height at 2 and 4 weeks of growth (Adekiya *et al.*, 2018). Consistent significant differences were however observed as from 6 weeks of growth under the various fertilizer treatments.

5. Conclusion

In conclusion, the notable effects observed on maize grain yield and growth parameters in this study are primarily credited to the application of various fertilizer combinations, highlighting the effectiveness of integrated fertilizer management as a preferable approach for enhancing soil health. However, the slower release and manifestation of benefits from organic fertilizers suggest that the observed growth parameters in the initial year may not fully capture their impact. The discovery that organic fertilizer application did not significantly enhance maize growth and yield is consistent with prior researches, indicating that organic fertilizers may be more effective when used alongside inorganic fertilizers to promote both short and long-term soil health and sustainability, rather than providing immediate benefits comparable to inorganic fertilizers.

Recommendation

Further research is necessary to delve into the mechanisms behind the varying impacts of organic and inorganic fertilizers on crop growth and yield. This comprehension is vital for establishing sustainable agricultural methods that enhance productivity while preserving soil fertility and environmental health.

Authors' Contributions

All authors contributed in this research.

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Institutional Review Board Statement

All Institutional Review Board Statements are confirmed and approved.

Data Availability Statement

Data presented in this study are available on fair request from the respective author.

Ethics Approval and Consent to Participate

Not applicable

Consent for Publication

Not applicable.

Conflicts of Interest

The authors disclosed no conflict of interest starting from the conduct of the study, data analysis, and writing until the publication of this research work.

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