EFFECT OF ORGANIC AND INORGANIC FERTILIZERS ON POP CORN (Zea mays L.) PRODUCTION AND SOIL PHYSICAL AND CHEMICAL PROPERTIES

Abstract

A field experiments were conducted at Teaching and Research Farm of Federal University ofWukarito examine the effect of organic and inorganic fertilization on maize productivity and soil properties improvements. The experiment was laid out in Randomized Complete Block Design (RCBD), with four treatments and three replications. Popcorn is used as test crop in this experiment. The results showed that maize growth parameters such as plant height, number of leaves and leaf area were significantly affectedat 5% probability*level. Treatment Poultry droppings + NPK had the highest values in all the yield parameters and was significantly different from the control in both cropping seasons. Soil total organic C and total N, P, K contents increased when inorganic fertilizers were applied alone or in combined with organic manures. However, soil pH increased due to application of organic fertilizer as it provides exchangeable cations such as Ca, Mg etc.Therefore, this study suggests that an appropriate proportion oforganic fertilizer with inorganic fertilizer not only for higher yield maize productionwith an assurance of improve and maintain the soil fertility and should be adopted.*

Key words: inorganic fertilizer, poultry droppings,popcorn, yield, soil properties.

1.0 Introduction

In sub-Saharan Africa (SSA), maize (Zea mays L.), also referred to as corn, is the most important grain crop.It is a primary staple item that contributes significantly to SSA's improved food security and reduction of poverty (Zuma *et al.*, 2018). Since most civilizations around the world evolved around grains rather than tuber crops, maize has always been chosen over all other crops, including cassava (Fakorede, 2001).The plant maize is incredible and has a remarkable ability to surprise people.One seed, for example, can yield more than 500 kernels when sown.It is a plant that outperforms other crops in yield per hectare and efficiently uses sunshine.Infact, during times of famine, maize—which is quickly turning into an industrial crop—is the first to be harvested for food.Mahiz is an Arawak-Carib name from South America that is the source of the name corn. In America, it's sometimes referred to as Indian corn or maize (Purseglove, 1992).Because of the thickness of the endosperm, popcorn (Zea mays L. everta) is a unique variety of flint maize that, when cooked, can pop into edible flakes. Because of the endosperm's special ability to withstand steam pressure until it reaches explosive proportions, the kernel pops when heated (Acquaah, 2007). It is one of the types of maize that is most commonly grown worldwide, especially in Nigeria (Mani and Dadari, 2003).Starch makes up to 80% of the carbohydrates in maize, which is utilized as feed, industrial raw materials, and food. Crude protein makes about 10% of the grain. Apart from its nutritional value, maize also has phytochemicals including carotenoids, phenolic compounds, and phytosterols that can prevent chronic illnesses (Demeke, 2018 and Shah, 2016). The plant, known as variable yields, can thrive in a variety of agroclimatic zones around the globe. Maize is the crop with the greatest potential for growth in the widest range of environments. The value and application of maize differ from nation to nation; while it is still widely used as animal feed in many industrialized countries, the advent of the new hybrid, saccharata, has led to its increased use as a vegetable, particularly in wealthy nations (Almaz *at al.*, 2017). It is grown for both food and food in many Asian countries, and is consumed as food in the majority of African and Latin American countries. Worldwide, about 25% of the product is eaten as food (Akanbi *at al.*, 2000). One of the most essential needs for humans is food. For over 1.2 billion people in Latin America and SSA, it is a staple diet that is vital. Known for its versatility, maize may be utilized for a broad variety of purposes, more so than any other cereal. Its pieces can be used for both food and non-food goods (IITA, 2009).

Food, especially maize, needs to be easily accessible for Nigeria to meet its population's needs and achieve its food production goals. Production and food security may be compromised by low soil fertility.Despite its nutritional and commercial value, its yield is much below crop potential. Numerous factors, mostly inadequate soil fertility, can contribute to this low yield (Almaz et al., 2017).Cropproductivity in the past has pushed the use of inorganic fertilizers to increase soil fertility in tropical regions.The use of inorganic fertilizers has not been beneficial for agriculture, since it is frequently linked to decreasing crop yields, soil acidity, and nutrient imbalances (Abayomi and Adebayo, 2014). These issues are in addition to the high cost of living and the scarcity of inputs.Globally, the usage of organic fertilizers has increased due to the desire to employ renewable energy sources and lower the cost of plant fertilizer (Diacono and Montemurro, 2010). The growth and harvest of biodiversity as well as the restoration of ecosystems and soil-based economic activity have benefited from the recycling of animal dung for use as an affordable organic fertilizer. Animal dung has a high organic matter (OM) content, and adding it to agricultural soils often enhances the soil chemistry, soil structure, and nutrient availability(Komakech *at al*., 2015).By improving nutrient uptake, water retention capacity, full perforated area, aggregate stability, resistance to erosion, keeping temperatures from rising, and lowering soil compaction, organic amendments reduce organic matter (OM).For crops like maize to grow well, they require nutrients like N, P, K, Mg, Ca, Na, and S.For a plant to develop and reproduce properly, these nutrients are functional and must be provided at the appropriate time and in the appropriate amount (Savci, 2012). Nonetheless, there's been a resurgence of interest in using natural fertilizers effectively and efficiently to preserve soil fertility and maize production sustainability (Asfaw, 2022). In addition to providing plant nutrients, organic fertilizers such as animal and chicken dung have increased agricultural output in African nations. In addition to providing plant growth hormones like auxins, organic fertilizer serves to enhance the amount of microorganisms that have a specific effect on shielding plants from soil-borne insects and germs like nematodes (Dozier Iii *et al*., 2003).Additionally aiding in soil improvement and providing much-needed plant nutrients are organic fertilizers. It functions as a disruptive agent against unstable soil pH fluctuations and improves cation exchange capacity (Onwu and Waizah 2023). When compared to the use of inorganic fertilizers, it has been discovered that organic fertilizers offer more economic benefits. In addition, more research is required in comparison to the development and production of plants grown organically or with the use of inorganic fertilizers because of the growing popularity of organic products. Thus, the goal of this study was to assess how organic and inorganic fertilizers affected the growth, potential production of maize and soil sustainability in northeastern Nigeria.

2.0 Materials and Methods

2.1 Experimental Sites

The experiment was conducted at Teaching and Research Farm, Federal University Wukari, Taraba State, Nigeria (Latitude 7^{o} 50'N and Longitude 9^{o} 46' E, altitude 189 m). The soil of experimental site belongs to soil types are Alfisols(FAO), (FDALR, 1990) in 2022 and 2023 cropping seasons. This is a Southern Guinea Savanna zone of Nigeria with average annual rainfall of 1,205 mm with temperature ranges from 27^{0}C to 37^{0}C (Kehinde, 2015).

2.2 Treatments and experimental design

The experiment comprises of four treatments: control (0 t ha^{-1}),poultry droppings (PD) (5 t ha^{-1} of poultry droppings,NPK (200 kg ha^{-1} of NPK 15:15:15), and NPK +PD (50% poultry droppings and NPK that is 2.5t ha^{-1} of poultry droppings, 100 kg ha^{-1}of NPK 15:15:15).The field experiment was laid out in a Randomized Complete Block Design (RCBD) replicated three (3) timeseach plot size was a 3m x 4m with a distance of 0.50m between each plotsand 1 m between replications which produced total number12 plots. The poultry droppings use was without litters.

2.3 Land preparation, sowing and fertilizer application

The land was occupied by calopo, *Imperetacylnidrica*, andsome other common weeds, the land had been undercontinuous cultivation for the past three years withoutapplication of either inorganic or organic fertilizers. Theland was cleared and stumps manually and thereaftermanually ridged. Maizeseed (popcorn) were sown at a spacing of25 cm within rows and 75 cm between rows at three seedsper hole and were thinned to two seedlings per hole, twoweeks after sowing. The poultry manure wasincorporated into the soil 2 week before sowing while NPK was applied 2 weeks after sowing (WAS). At 6 WAS, the plot with NPK was top dressed with 50 kg ha^{-1} urea while plot with 50% poultry droppings and NPK was top dressed with 25 kg ha^{-1} urea. Weeding was done manually at 3 and 6WAS.

2.4 Poultry manure and soil analysis

Poultry manure without litter was obtained from the livestock session ofthe Teaching and Research Farm, Federal UniversityWukari, Taraba State, Nigeria. The sample was air dried,crushed through a 2mm sieve and subjected to laboratoryanalysis following standard procedure in order to determinethe chemical properties (IITA 1989). Prior to thecommencement of the experiment, top soil samples of 0 -20 cm deep were collected randomly from five spots usingsoil auger from the experimental plot and mixed together toform a composite sample. After harvest, top soil samples of0 - 20 cm deep were collected randomly from threespotswithin a plot and mixed together to form a compositesample of each treatment. It was air dried, sieved with a 2mm mesh-size sieve and taken to the laboratory todetermine the soil's physicochemical properties(particle size, pH, organic carbon, total nitrogen, available phosphorus, magnesium, calcium, sodium, potassium and cation exchange capacity) usingstandard laboratory procedures (Olsen *et al*, 1954: Jackson, 1973: Page *et al*, 1982: Dirk and Hargarty 1984 andOkalebo*et al*, 2002).

2.5 Data collection and statistical analysis

Five plants were randomly tagged from two middle rows ineach plot for sampling and data collected for vegetativegrowth and yields assessment were: vegetative growth - plant height, number of leaves and leaf area (leaf length × maximum width × factor (0.75)whileyield attributes – number of daysto 50% flowering, cob length, cob diameter, 100 grain weight and grain weight.

Data collected from the experimentalfield were subjected to analysis of variance (ANOVA) andsignificantly different mean values were compared usingDuncan Multiple Range Test (DMRT) at 5% probabilitylevel.

3.0 Results and Discussion

3.1 Physiochemical properties of the soil before planting and organic manure

Before cropping, the physiochemical characteristics of the soil (20 cm depth) at the experimental field revealed that the soil textural classification was sandy loam, with pH values of 6.23 and 6.25 for both years indicating a slightly acidic nature The low fertility of the soil was further indicated by the low levels of exchangeable cations, total nitrogen, organic carbon, and available phosphorus (Table 1).In order to improve soils for crop production, low-nutrient soils must be supplemented with soil amendments, such as organic or inorganic fertilizer.Applyingorganic manure is anticipated to improve the low fertility status and acidity of the soil (Table 1).Since soil texture affects basic cation retention and leaching ease, the high amount of sand in the experimental site likely contributed to the low soil nutrient levels (Wapa and Oyetola, 2014). This suggests that basic cations would be more readily leached.Increasing land used intensity and ongoing cropping are contributing factors of the low NPK level found in the soil

Table 1. Physiochemical properties of the soil before planting and organic manure

Parameters	Soil 2022	Soil 2023	Organic manure source(poultry droppings)
Sand (%)	71.80	75.20	
Silt (%)	20.08	17.80	
Clay (%)	8.12	7.00	
Textural class	Sandy loam	Sandy loam	
(H2O)	6.23	6.25	
Organic carbon (%)	0.57	0.54	4.20 (%)
Total Nitrogen (%)	0.02	0.02	3.11 (%)
Available P (mg/kg)	6.60	6.53	10.09 (%)
Exe Mg (Cmolkg-1)	0.60	0.59	4.12
Exe Ca (Cmolkg-1)	3.02	3.01	5.61
Exe K (Comlkg-1)	0.40	0.38	1.74
Exe Na(Comlkg-1)	0.26	0.28	2.16
CEC (Cmolkg-1)	4.28	4.26	

3.2 Effect of organic and inorganic fertilizers on plant height (cm)

The response of maize to the treatments on the plant height is presented in Table 2. At 2 WAS in both years, the lowest values were recorded for control and NPK plants and highest values for PD plants. Plants provided with NPK +PD weresignificantly ($p<0.05$) taller than the other levels of manure andcontrolplants.Similartrend was observed at 6 WASin both years. The steady increase in height of maize plantswithplots that received treatments suggests that quantityoffertilizer applied affects nutrients availability for uptake byplants which promoted vigorous plant growth through efficientphotosynthesis(Islam, 2002 and Meena*et al*,2017). This observation is consistent with findings of Fanuel (2013) who reported that because of, more photosynthetic activities of the plant on the account of an adequate supply of nitrogen since it is an essential requirement for plant growth.

Table 2:Effect of organic and inorganic fertilizers on plant height (cm)

Treatments	2WAS		4WAS		6WAS	
	2022	2023	2022	2023	2022	2023
NPK	14.45[c]	13.92[c]	36.25[b]	36.79[b]	56.25[b]	54.93[b]
NPK+PD	15.11[b]	15.01[b]	45.57[a]	45.57[a]	65.57[a]	66.46[a]
PD	16.27[a]	16.99[a]	35.53[b]	37.04[b]	55.53[b]	53.98[b]
Control	14.20[c]	14.01[c]	28.65[c]	28.65[c]	48.65[d]	45.37[d]

WAS = weeks after sowing PD = Poultry droppings
Means sharing similar letter in a column do not differ significantly at *p*=0.05

3.3 Effect of organic and inorganic fertilizers on number of leaves
The number of leaves per plant (Table 3) was not significantly affected by all treatments at p<0.05 at 2 WAS in both years. At 4 WAS in 2022 cropping season, all the treatments were statistically similar. While in 2023 cropping season at 4 WAS number of leaves per plant was significantly affected at p<0.05 with treatment PD teller than others. At 6 WAS in 2022 cropping season NPK+PD recorded the highest number of leaves per plant 9.02 leaves per plant and significantly different from other treatments. In 2023 cropping season there was no significant different among treatments.

Table 3: Effect of organic and inorganic fertilizers on number of leaves

Treatments	2WAS		4WAS		6WAS	
	2022	2023	2022	2023	2022	2023
NPK	3.87[a]	4.01[a]	5.80[a]	5.50[b]	7.96[b]	7.73[a]
NPK+PD	4.00[a]	4.00[a]	5.90[a]	5.90[b]	9.02[a]	8.97[a]
PD	4.00[a]	4.00[a]	6.07[a]	6.57[a]	8.03[b]	8.12[a]
Control	3.97[a]	4.02[a]	5.95[a]	5.70[b]	7.72[b]	8.00[a]

WAS = weeks after sowing PD = Poultry droppings
Means sharing similar letter in a column do not differ significantly at *p*=0.05

3.4 Effect of organic and inorganic fertilizers on leaf area (cm^2)
The data revealed that leaf area increased consistently for the 6 WAS irrespective of treatments (Table 4). At 2 WAS in both cropping seasons there was no statistic difference among the treatments. The results revealed at 4 WAS in 2022 that the leaf area (44.87 cm^2) recorded with (NPK + PD) was significantly higher than other treatments.The control recorded the lowest leaf area but at par with NKP and PD and recorded a leaf area 33.41 cm^2. The trend was similar to what was obtained in 2023. At 6 WAS in 2022, treatment NPK + PD recorded the largest leaf area (309.91 cm^2) and statistically higher than all other treatments. This was followed by PD with leaf area of 259.07 cm^2 and statistically higher than NPK and control. The least leaf area was obtained at the control (210.54 cm^2) which was also statistically lower than all treatments. Similar trend was observed in 2023. The significant in leaf area may be attributed to better utilization of available nutrient resources which might have enhanced leaf area. The results confirm findings of Suthar *et al.,* (2014) and Meena *et al.,* (2017).

Table 4: Effect of organic and inorganic fertilizers on leaf area (cm^2)

Treatments	2WAS		4WAS		6WAS	
	2022	2023	2022	2023	2022	2023
NPK	11.79^{a}	11.29^{a}	34.91^{b}	35.21^{b}	243.26^{c}	234.17^{c}
NPK+PD	12.13^{a}	12.73^{a}	44.87^{a}	45.66^{a}	309.91^{a}	312.54^{a}
PD	12.21^{a}	11.27^{a}	35.15^{b}	36.21^{b}	259.07^{b}	258.11^{b}
Control	11.62^{a}	11.22^{a}	33.41^{b}	34.24^{b}	210.54^{d}	209.4^{d}

WAS = weeks after sowing PD = Poultry droppings
Means sharing similar letter in a column do not differ significantly at *p*=0.05

3.5 Effect of organic and inorganic fertilizers on days to 50% flowering, cob diameter and length

Organic manure and inorganic fertilizer showed significant effect on days to 50% flowering (Table 5). The result revealed that maximum number of days to 50% flowering (58.65) was observed from control treatment, which was statistically similar with NPK treatment. Minimum number of days to 50% flowering (52.21) was observed from PD treatment which was statistically similar with NPK + PD treatment. Similar trend was observed in 2023. The reduced period of flowering from the timeof sowing in plants supplied with organic manure and inorganic may be due to the ready availability of some plant nutrients(Egbe *et al*. 2022). The use of organic manures accelerated the flowering than chemical fertilizer and control was alsoreported by Abu-Zahara (2012).

Organic manure and inorganic fertilizer showed significant effect on cob diameter of maize (Table 6). The figure shows that maximum cob diameter (5.03 cm) was observed from NPK + PD treatment which was statistically similar with all others treatment except control treatment. The minimum cob diameter (3.96 cm) was observed from control treatment which was statistically similar with NPK and PD treatments. Similar trend was observed in 2023.

The experiment result revealed that maximum cob length (15.13cm) was observed from NPK + PD treatment, which was statistically higher thanother treatments followed by NPK and PD that were same statistically.Shortestcob length (11.50cm) was observed from control treatment which was statistically lower than other treatments. Similar trend was observed in 2023.Woldesenbet andHaileyesus (2016) found similar result of cob length which supported the presentstudy.

Table 5: Effect of organic and inorganic fertilizers ondays to 50% flowering,cobdiameter andlength

Treatments	Days to 50% flowering		Cob diameter (cm)		Cob length (cm)	
	2022	2023	2022	2023	2022	2023
NPK	56.21^{a}	55.61^{a}	4.02^{ab}	4.42^{ab}	13.20^{b}	13.20^{b}
NPK+PD	52.88^{b}	52.84^{b}	4.97^{a}	5.03^{a}	15.13^{a}	14.83^{a}
PD	52.21^{b}	52.11^{b}	4.18^{ab}	4.28^{ab}	13.12^{b}	13.31^{b}
Control	58.65^{a}	57.98^{a}	3.96^{b}	3.76^{b}	11.50^{c}	11.11^{c}

WAS = weeks after sowing PD = Poultry droppings
Means sharing similar letter in a column do not differ significantly at *p*=0.05

3.6 Effect of organic and inorganic fertilizers on100 grain weight and grain yield

The results showed that compared treatments the application of organic and inorganic fertilizer significantly increased the yield of maize ($p < 0.05$). The records of 100 grain seed and grain yield per hectare are presented at Table 6. For the mass of 100 seeds in 2022, the heaviest grains were from NPK+PD and significantly higher than other treatments. This was followed by treatment PD and significantly higher than NPK and control treatments. The control had lowest mass and also statistically lower than all the treatments. Similar trend was observed in 2023. The highest grain yield per hectare was from NPK+PD (1934 kg ha^{-1}) and statistically the same with PD but higher than NPK and control. The lowest grain yield was recorded at the control which was lower statistically than other treatments. In 2023 cropping season, similar observation was recorded.The combined application of organic-inorganic fertilizers can provide quick-acting nutrients for crop growth, andeffectively increase fertilizer efficiency and ensure the continuous supply of soil nutrients (Diacono and Montemurro, 2010). Similarly, Yang *et al*. (2014) reported that combinations of organic and inorganic nitrogen are likely to increase achievable yields and improve soil fertility with maize production. This might be due to all organic fertilizers being used as base fertilizers which increased soil organic carbon contents, soil water availability, and aeration (Choudhary *et al*., 2018; Li *et al*., 2020). Welbaum *et al*. (2004) and Li *et al.* (2012) reported that when organic fertilizers incorporation can delay the senescence rate of crop roots and leaves, prolong the photosynthetic time of crops, increase the grain quality of ears by prolonging the grain filling time, and finally increase the yield.

Table 6: Effect of organic and inorganic fertilizers on100 grain weight and grain yield

Treatments	100 grain weight (g)		Yield (Kg ha^{-1})	
	2022	2023	2022	2023
NPK	13.91^{c}	14.04^{c}	1759^{b}	1782^{b}
NPK+PD	19.92^{a}	19.26^{a}	1934^{a}	1975^{a}
PD	15.50^{b}	15.75^{b}	1807^{ab}	1841^{ab}
Control	10.92^{d}	9.92^{d}	954^{c}	1054^{c}

3.7 Effect of organic and inorganic fertilizers on physiochemical properties of the soil

Table 7 shows the influence of organic and inorganic fertilizers on soil physiochemical properties. Application of PD and NPK+PD increased soil pH organic matter content total nitrogen, available phosphorus, exchangeable cations (Calcium, Magnesium and potassium) and cation exchange capacity compared with plots without poultry manure in the two cropping seasons. Demelash*et al.* (2014)reported increased Ca and Mg content withapplying organic-inorganic fertilizers treatments; this could be responsible for the increase in soil pH.Treatments PD and NPK+PD had total – N values 0.18, 0.16; and 0.19, 0.15 cmol kg^{-1} in 2022 and 2023 respectively while plots with NPK had 0.08 and 0.05 cmol kg^{-1} and control 0.02 and 0.02 cmol kg^{-1} in 2022 and 2023 respectively. The content of nitrogen and phosphorus in the PD+NKP treatment was higher than in the controland NKP treatments, the same trend as organic carbon. Liu *et al*. (2015) and Cai and Qin (2006) research show that organic fertilizer incorporation can increase total organic carbon capacity by improving agricultural root biomass and exudates. Chen *et al*. (2015) studies indicate that soil nutrient content increases after organic fertilizer incorporation and the increase rate is mainly affected by the type and amount of organic fertilizer. Organic fertilizer incorporation increased crop yields, and soil organic matter and nutrient content were improved, consistent with the research of Gao *et al*. (2015) and Choudhary *et al*. (2018).

Table 7: Effect of organic and inorganic fertilizers onphysiochemical properties of the soil

Treatments	pH H2O	OC	N	P	K	Ca	Mg	Na	CEC	San	Silt	Clay
		____(%) ___		mg kg^{-1}	____________ cmol kg^{-1} __________					______% _______		
					2022 after harvest							
NPK	5.64	0.03	0.08	8.03	0.42	4.01	0.32	0.23	4.98	75.02	18.11	6.87
NPK+PD	6.33	1.48	0.16	13.11	0.51	4.43	1.24	0.61	6.79	73.57	19.82	6.61
PD	6.74	1.63	0.18	16.88	0.64	5.68	1.38	0.80	8.50	72.21	19.40	8.39
Control	6.12	0.64	0.0 2	7.05	0.39	3.94	0.28	0.20	4.81	75.21	18.18	6.61
					2023 after harvest							
NPK	5.67	0.04	0.05	8.08	0.41	4.01	0.40	0.25	5.07	74.25	19.4	6.35
NPK+PD	6.34	1.41	0.15	12.97	0.49	4.39	1.28	0.66	6.82	73.22	18.35	8.43
PD	6.67	1.68	0.19	16.91	0.58	5.67	1.36	0.84	8.45	72.51	19.20	8.29
Control	6.06	0.59	0.02	6.89	0.40	4.00	0.24	0.19	4.83	75.17	18.4	6.43

Conclusion

This research revealed that use of NPK+PD is beneficial to maize productionand maintaining the soil nutrient balance. Based on the resultsof this study combination of inorganic and organic fertilizerswith an application of NPK+PD is recommended to increase the yield of maize andimprove soil fertility. The higher grain yield of maize was obtainedfrom the NPK+PD.Finally, this study suggests thatjudicious use of organic fertilizer along with inorganic fertilizernot only for higher maize yield production with an assurance ofprovides enough nutrients and shouldbe adopted with similar soil type and agro-ecologies.

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