RESPONSE OF MAIZE (ZEA MAYS) TO ORGANIC AND INORGANIC FERTILIZER SOURCES ON SOIL UNDER INTENSIVE CONTINUOUS CULTIVATION

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ABSTRACT

A field experiment was carried out during the wet season of 2019 at the experimental plot of the Institute of Agricultural Research and Training (I.A.R&T), Moor Plantation, Ibadan. The aim is to examine the response of maize to organic and inorganic fertilizer on soil under intensive continuous cultivation. Initial soil samples were collected randomly from experimental plots and analyzed. The experiment was carried out using four treatments, organic, inorganic, organic plus inorganic, and control with each replicated three times. Each plot has a dimension of 3m x 4m. Agronomic parameters observed were plant height (cm), number of leaves (leaf area index, LAI), stover's weight, ear weight, and yield of grain. After harvesting, soil samples were collected to measure changes in soil properties. Calcium, magnesium, and sodium improved significantly after the application of organic and inorganic - compared to other treatments. The result shows that plot treated with organic plus inorganic fertilizer (poultry manure + NPK) had the highest yield of 1.03t/ha compared to inorganic (NPK) 0.87t/ha, organic (poultry manure) 0.71t/ha and control which had no treatment has the least yield of 0.15t/ha. Therefore, inorganic plus organic were recommended for optimum and sustainable production on degraded soil.

Keywords: Maize, continuous cultivation, organic fertilizer, nutrient impoverishment, inorganic fertilizer

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INTRODUCTION

Maize (*Zea mays*) belongs to a member of the grass family called Poaceae. Maize is the third important cereal crop in the world next to rice and wheat and it has the highest potential among cereals (Muthukumar, et al., 2007). About 785 million tonnes of maize grain is produced worldwide annually (Fabunmi et al., 2015). In Nigeria, about 12,000 tonnes is produced annually (Statista, 2022). This low production in Africa is the reason why Africa imports 28% of its maize grain consumption from countries outside the continent (IITA, 2009).

Land degradation is the major consequences of direct interference of human activities in the natural phenomenon (Cooke, 1992 and Amusan, 2005). Loss of natural fertility of soil because of loss of nutrients remains the single most important bio-physical factor constraining food security in Africa (Sanchez et al., 1997). The speed and extent of land degradation depend on different factors such as soil type, environmental factors and land use type. Several studies have reported that the decrease in maize yield is associated with soil degradation under continuous cultivation. The sole use of organic and inorganic sources of fertilizer has been suggested as the most feasible option for addressing the soil fertility crisis especially in Sub-Saharan Africa (Amoding et al., 2011). A prolonged continuous cultivation is likely to result in the breakdown of soil structure which makes them more prone to erosion and loss of nutrients. The problems associated with the single approach application of organic or inorganic fertilizers such as nutrient leaching, destruction of soil physical properties, release of greenhouse gases has made the combination of organic plus inorganic fertilizers a viable option in improving maize crop productivity in Nigeria. Total dependence on inorganic fertilizers may be accompanied by a fall in soil organic matter, increased soil acidity, and degradation of soil physical properties and structure and increased erosion (Ojeniyi, 2002). On the other hand, total dependence on organic fertilizer may be restricted in use due to competing alternative uses, bulkiness (i.e. the amount needed to achieve optimum crop productivity), slow release of nutrients, and the quality of organic material. (Usman et al., 2015). However, the combined use of organic plus inorganic fertilizers would ensure that the problems associated with the sole use of organic or inorganic fertilizers are relatively reduced as the combination of organic and inorganic fertilizers would complement each other.

For sustainable crop production, integrated use of inorganic and organic fertilizer has proved to be highly beneficial. Several researchers have demonstrated the beneficial effect of combined use of inorganic and organic fertilizers to achieve sustainable soil productivity under intensive continuous cultivation in Nigeria (Adepetu, 1997). The combined use of organic and inorganic fertilizers has proved a sound soil fertility management strategy in many countries, however there is need to research how this management practice can mitigate against the deficiencies of soil under intensive continuous cultivation. The objective of this study is to determine the response of maize (*Zea mays*) to organic and inorganic fertilizer under intensive continuous cultivation

MATERIALS AND METHODS

Study area

The study was carried out at the Institute of Agriculture Research and Training IAR&T. The study location falls within latitude 7° 22’38N and longitude 3° 50’21E. Ibadan has a tropical humid climate with a bimodal rainfall distribution. The mean and annual rainfall is 1289.2 mm recorded for a period of 16 years (Alabi and Ibiyemi, 2000). Rainfall peaks occur in June and September; annual temperature ranges from 21.3^{0}C to 31.2^{0}C. There are two cropping seasons, an early (March/April to early August) and late (Mid-August to October/November) seasons.

The soil used for the experiment belongs to Typic Kanhaplustalf (Soil Survey Staff, 2010) and classified locally as Iwo series (Smyth and Montgomery, 1962). Iwo series is a gravelly soil derived from coarse grained, granite and gneiss, which was classified in the order of Alfisol (Harpstead, 1973).

Layouts and Treatments

The land has been under cultivation for about two decades and maize yields have become marginal. The land was cleared mechanically by ploughing after which it was marked into five blocks according to the treatments. The treatments include poultry manure (**5** tonnes/ha), poultry manure (**2.5** tonnes/ha) + NPK 20-10-10 (150kg/ha), NPK 20-10-10 (300kg/ha), Urea (92kg/ha) and the control without poultry manure or fertilizer. The total land area is 10 m x 35 m (350 m^2) with each plot having a dimension of 10 m x 8 m (80 m^2). The experiment was laid out in a

Randomized Complete Block Design where Four treatment levels were imposed and replicated four times.

Soil Sample and Preparation

The soil sample was collected from the site before planting and at harvesting the soil samples were collected from different plots with the use of soil auger at three (3) different spots from 0 – 15 cm depth, the samples were bulked, air dried and there after passed through a 2.00 mm sieve after a gentle crushing in a mortal. Processed soil samples were subjected to laboratory analysis where particle size and chemical routine analysis were carried out. Soil pH was determined in 0.01 mol L^{-1} $CaCl_2$ solution in 1:2 soil – solution ratio. Total nitrogen was determined using the Kjeldahl method as described by Bremner and Mulvaney (1982). Plant available phosphorus was determined by Bray 1 method (Bray and Kurtz, 1945).

Exchangeable cations were determined in a neutral normal ammonium acetate extract of soil and from the filtrate, calcium and magnesium content was determined using the Atomic Absorption Spectrophotometer (AAS) while sodium and potassium content were read on the Flame Photometer. Soil organic matter (SOM) content was determined by Walkey and Black method (1934).

Fertilizer Application

The organic manure (poultry manure) was applied to the plot two weeks before seeds were sown at the rate of 5tonness/ha (4.4kg/plot) which was broadcast on the plot before planting for easy incorporation into the soil at recommended rate. Three seeds were sown per hole and later thinned to two seedling plants per stand. At 2 weeks after planting, four (4) plant stand were randomly selected and tagged from each plot for data collection. At 3 weeks after planting, NPK fertilizer (20:10:10) were applied at the rate of 120kg N/ha (4.8kg N/plot), combined organic and inorganic were also applied using the aggregated rate. All the necessary cultural management practices like weeding, thinning, spraying, harvesting, etc. were carried out as required. The agronomic parameter measured includes plant height, numbers of leaves, stovers weight, ear weight, and grain yield.

At 3 weeks after planting, sharpshooter (Profenofos-40%, Cypermethrin-4%, Emulsifier-10%, and solvent 4%) at 40g/15L and Neem leaves extract were used to combat Armyworm (*Spodoptera exempta*) infestation. Also other cultural practices such as weeding were carried out at 2 weeks' intervals.

Maize growth and yield parameters

Morphological parameters in terms of plant height and number of leaves of maize and the yield data were taken.

Plant height and Number of leaves

Five stands were measured per plot at five (5) and Seven (7) Weeks after Planting (WAP). The plants were randomly selected from each plot. Plant height was measured from the soil surface level to the tip of the tassel using a cm-graduated measuring tape. Number of leaves were also recorded by physical count of leaves present on a maize plant.

Maize grain yield

Harvesting took place at 12 WAS. Stover and ear weight were estimated by measuring the weight of randomly selected plant stand from each plot. Maize grain yield was determined by dividing the harvested grain weight by the plot area. The final grain yield was recorded at 15 % moisture content.

Data analysis

Data collected were subjected to analysis of variance (ANOVA) using GenStat Discovery Edition 4,10.3DE statistical software, and where the F-value was found to be significant, the means were separated at $P \leq 0.05$ level of significance using Fisher least significant differences (LSD).

RESULTS AND DISCUSSION

Pre-planting soil analysis

The physico-chemical analysis of the soil before planting is shown in Table 1. The result shows that the soil contained high amount of sand (783.2g/kg), with 94.5g/kg of silt and 122.3g/kg clay.

The soil is slightly acidic (5.97). The P was low, while N was medium. The level of N in the soil can be attributed to the effects of past intervention such as the use of organic and inorganic fertilizer which was aimed at increasing crop yield through application of fertilizer containing only N, P and K.

Effect of fertilizer sources on growth parameters

Table 2 shows the performance of the plant in terms of plant height, the number of leaves at 5 weeks after planting (WAP), and 7 WAP in response to organic and inorganic fertilizers. No significant difference was observed in plant height among the treatments at 5 and 7 WAP however, the control plot, where no amendment was applied had the least mean plant height in both weeks. At 5 WAP, the mean plant heights on organic manure, inorganic, and organic fertilizer plots were higher than the control by 25.8, 28.6, and 21.4%, respectively. At 7 WAP, the mean plant heights obtained on organic manure, inorganic, and organic fertilizer plots were higher than the control by 24.4, 22.9, and 18.5%, respectively.

The number of leaves at 5 WAP did not differ among each other irrespective of the treatments but at 7 WAP, significant difference ($p < 0.05$) was observed in the number of leaves (Table 2). The number of leaves observed under organic manure, inorganic, and organic fertilizer treatments were the same value and did not differ from one another but were significantly higher than the control plot in both weeks after planting. The values obtained were in ratio 8 to 7 and 10 to 7 in 5^{th} and 7^{th} WAP. The significant difference in number of leaves under the treatment than control shows that there was a positive response to fertilizer application. Leaves are very vital for plants photosynthesis. Hence, a higher number of leaves should translate to higher yield which is expected to correlate with higher grain yield. Therefore, the application of an appropriate proportion of fertilizer can boost production on degraded soil and help increase the nutrients content of degraded soils thereby increasing its sustainability.

Effect of fertilizer sources on yield parameters

The results in table 3 shows that the stover weight of combined organic and inorganic fertilizer treatment was higher (but not significant) than other treatments. It was closely followed by sole organic fertilizer treatment while the least weight stover weight was obtained on the control plot.

On the other hand, the ears' weight of inorganic fertilizer treatment was higher but not significantly different to other treatments as shown in Table 3. The control treatment in which no amendment was added had the least ears weight.

The maize grain yield as influenced by different treatments is shown in Table 3. Though the grain yield from plots treated with organic manure fertilizer was statistically higher than the control but not so with yield from inorganic and organic fertilizer treatments.

In a similar study, Olatunji and Ayuba (2012) observed that a combination of poultry manure and NPK 20—10—10 gave the highest grain yield. In a similar study, Adepetu (1997) observed that a combination of organic and inorganic fertilizers is required for increased grained yield and sustainable soil productivity under intensive continuous cultivation. Also, studies carried out in southwest Nigeria by Eneji et al., (1997) and Ojeniyi (1999) recommended combinations of farmyard manure and NPK fertilizer for sole and intercropped maize. Reporting from several authors, tropical countries especially Nigeria, must not assume that the soil can be made productive by chemical fertilizer alone but by combining organic and inorganic fertilizers that can build up soil organic matter.

Effect of fertilizer sources on soil chemical properties

Except for Ca, K and CEC which showed significant improvement in the soil under all the treatments compared to the control (no fertilizer application), all other parameters measured showed no significant improvement from the application of the fertilizers (Table 4). The combined use of organic and inorganic fertilizer and the sole use of organic fertilizer may have improved the availability of soil macro and micro nutrients more than in sole inorganic fertilizer and control. This might be attributed to the increased soil CEC and slow-release characteristics of organic fertilizers. It also improves soil structure and reduces nutrient losses hence increases, Ca, K, Mg, as well increase in pH. On the other hand, mineral fertilizers are fast releasing and quickly absorbed and utilized by plant. The pH of the soil was improved from 5.9 to about 6.1. This might not be far from the buffer influence of organic manures on soil pH. Total carbon content in plots treated with organic fertilizer were higher but not statistically significantly different from that in the control and sole inorganic plots. This trend was similar for most of the soil parameters like Total N, Available P, Magnesium and Iron except for manganese which recorded highest value in control immediately followed by poultry manure then NPK and the lowest in combine organic and inorganic treated plot. This finding is consistent with the findings of Ojeniyi (2002) who identified that the application of organic manure can significantly increase nutrient availability in the soil.

CONCLUSION

The result obtained from this research have proved that the application of organic and inorganic fertilizer increased the yield of maize relative to control. This would help reduce the bulkiness of sole organic manure application and also reduce the high cost of inorganic fertilizer. The combined organic and inorganic fertilizer could reduce the possible acidic effect of nitrogen while improving nutrient status of the soil and ensuring a balanced plant nutrition as well as preventing environmental impact of synthetic fertilizer. The use of the combination of organic and inorganic fertilizer is therefore recommended for yield and soil fertility improvement in soils under intensive continuous cultivation.

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APPENDICES

Table 1: Physical and Chemical properties of the soil before planting

Parameter	Value
pH (H_2O)	5.97
Total N (g/kg)	0.15
Available P (mg/kg)	8.6
Exchangeable bases (cmol/kg)	
Ca	2.16
Mg	1.62
K	1.00
Na	0.28
Exchangeable acidity H^+	0.11
ECEC	4.33
Particle size (g/kg)	
Sand	783.2
Silt	94.5
Clay	122.3
Textural Class	Sandy Loam

Table 2: Response of organic and inorganic fertilizer on plant height and number of leaves

Treatment	5 WAP		7 WAP	
	Plant height (cm)	No of Leaves	Plant height (cm)	No of Leaves
Poultry manure & NPK	45.3	8	112.3	10a
NPK	46.3	8	111.0	10a
Poultry manure	43.7	8	107.0	10a
Control	36.0	7	90.3	7b
Lsd	Ns	Ns	Ns	2*

Means with the same letter(s) in each column are not significantly different at $p < 0.05$ using Duncan Multiple Range Tests. Ns: No significant, *: Significant at $p < 0.05$, WAP = Week after planting

Table 3: Response of organic and inorganic fertilizer on stover weight, ear weight and yield

Treatment	Stover weight	Ear weight (t/ha)	Grain yield (t/ha)
Poultry Manure & NPK	8.9	4.3	1.03a
NPK	6.1	4.7	0.87ab
Poultry manure	7.3	4.5	0.71ab
Control	4.3	3.5	0.15b
	ns	ns	*

Means with the same letter(s) in each column are not significantly different at $p < 0.05$ using Duncan Multiple Range Test. Ns: No significant at p = 0.05

Table 4: Effect of fertilizer sources on soil chemical properties

Treatment	pH H2O	Ca cmol/kg	Mg cmol/kg	K cmol/kg	Na cmol/kg	H^+	TC g/kg	N g/kg	CEC	P mg/kg	Mn mg/kg	Fe mg/kg
Poultry manure & NPK	6.0	1.95a	1.57	0.38c	0.32	0.11	15.0	1.40	4.3a	9.81	64.2	180.9
NPK	6.1	1.87a	1.53	0.28b	0.31	0.10	12.8	1.20	4.09a	9.78	72.9	150.8
Poultry manure	6.2	2.55a	1.63	0.37c	0.33	0.10	14.4	1.30	4.98b	9.94	91.9	175.8
Control	6.1	1.70b	1.37	0.23a	0.30	0.11	10.1	0.93	3.76a	8.34	92.5	149.8
	ns	*	ns	*	Ns	ns	ns	ns	*	ns	ns	ns

Means with the same letter(s) in each column are not significantly different at $p < 0.05$ using Duncan Multiple Range Test

Ns: No significant at $p < 0.05$, * means significant at $p < 0.05$.