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RESPONSES OF MAIZE GROWTH AND GRAIN YIELD TO DIFFERENT SOURCES AND TIME OF APPLICATION OF NITROGEN FERTILIZER

Omisore, J. K.[1] and Y. A. Abayomi.[2]

[1]*National Centre for Agricultural Mechanization P. M.B 1525 Ilorin, Kwara State, Nigeria.*

[2]*Department of Agronomy, University of Ilorin, Ilorin, Kwara State Nigeria.*

Abstract

Soil fertility decline has been identified as one of the major biophysical constraints affecting agriculture in the sub Saharan Africa, including Nigeria. Even though, the use of chemical fertilizer is the most convenient way of improving soil fertility, the high cost and poor distribution of chemical fertilizer have made the commodity inaccessible to resource poor farmers. Consequently, there is a negative balance in nutrient budgets of soils in the country. Ironically large amount of organic wastes abound that can be turned into fertilizers for crop production at possibly low cost. However, the extent to which different type and form of organic sources of N fertilizer could be used for sustainable crop production has not been adequately evaluated in Nigeria. This study was therefore designed to evaluate the responses of maize (*Zea mays* L) to different types and forms of organic manure as sources of N applied at different periods of crop growth. Field experiments were conducted over two cropping seasons at the National Centre for Agricultural Mechanization Research Farm Ilorin, using a Randomized Complete Block Design arranged as a 7 x 4 factorial combinations with 3 replications. The treatments consisted of 7 sources of N fertilizer combined with 4 different time of application. An improved open- pollinated maize variety (TZEE-SR-Y) was used for the experiment and data were collected on growth and yield parameters, including grain yield. All data collected were analyzed using the analysis of variance (ANOVA) and significant means were separated with the least significant difference (LSD) method at five percent probability level. Results of the study showed that the application of the inorganic source of N (urea) was superior to all types and forms of the organic sources on all growth, yield components and grain yield, suggesting that the application of sole organic sources of N may not be adequate for optimum grain yield. The best grain yield was obtained with the application of fertilizer at 4 WAP, depending on the source, with most sources producing the best yield with application at 4 WAP, while cow dung showed the best yield with application at the planting of maize. The post crop harvest soil properties (Soil pH, total N and organic matter contents) were better with the application of any type and form of organic N sources, indicating probable long term sustainability of crop production. In conclusion, the sole use of organic sources of N in the evaluated rate may not be adequate for optimum crop yield. Nevertheless the long run sustainability of crop production may be better.

INTRODUCTION

The increasing demand for grains to feed the growing human population and the ever expanding livestock industries in Nigeria has created the need for the expansion of maize production. Guin-

ea savanna agro-ecological zone has been reported to have the greatest potential for maize cultivation in Nigeria (Kassam and Kowal, 1973). However, nitrogen is known to be the most important constraint to optimum maize production in the ecological zone (Singh *et al.*, 2001). Even though the use of chemical fertilizer is appreciated by farmers, its high cost and poor distribution have made the commodity not always available to resource poor farmers. Ironically, large amounts of organic wastes abound that can be turned into fertilizers for crop production at little cost. The use of organic manures as a means of maintaining and improving soil fertility has been advocated by many workers (Alasiri and Ogunkeye, 1999., Smil, 2000). Nutrients contained in manures are reported to be released more slowly and are stored for a longer time in the soil, ensuring longer residual effects, improved root development and higher crop yields (Abou EL Magd *et al.,* 2005). The application of manures sustains cropping system through better nutrient recycling (El – Shakweer *et al.,* 1998). Manures serve as sources of all necessary macro and micro nutrients in available forms, thereby improving the chemical, physical and biological properties of the soil (Abou El Magd *et al.,* 2006).

Mineralization and N recycling begin as soon as the manure is incorporated into the soil and as such. The timing of application is a crucial component to maximizing N use efficiency. Manure and other organic fertilizers are affected by the handling during storage and application as well as the timing of incorporation and distribution (Thomsen, 2005). A study by Maroko *et al.* (1998) showed a linear relationship between soil nitrate availability at the time of planting and maize yields. Early applications have been shown to increase N loss through the soil system, in comparison with later applications that led to increased crop utilization of N (Thomsen, 2005). However, Mallory and Griffin (2007) found that in the other hand inorganic N applied became available more quickly than N applications from organic manure.

The need to increase food production and at the same time improve the quality and sustainability of our soil conditions and its environment has prompted the search for cheaper and readily available sources of fertilizer for cereal crops. This study was therefore conducted to evaluate the performance of maize in response to different types and forms of manure and urea fertilizer as sources of N in a typical southern Guinea Savanna agro ecological zone of Nigeria, with the specific objectives to:

i) Evaluate the responses of maize growth and grain yield to organic sources of N applied at different periods of crop growth; and

ii) Determine the effect of the organic manures and urea fertilizer on post harvest soil chemical properties. .

MATERIALS AND METHODS

Field experiments were conducted at the Research Farm of the National Centre for Agricultural Mechanization, Idofian via Ilorin, located on Latitude 8^0 26^1 North and Longitude 4^0 30^1 East at an elevation of 310 m above sea level, during the 2009 and 2010 cropping seasons. The soil of the study site is classified as Typic Haplustalf of Eruwa, and Odo – Owa (Kwara State) series, loamy sand in texture in the first 50 cm soil depth.

The two field experiments in 2009 and 2010 l were designed as 7 x 4 factorial involving seven fertilizer levels (Control, wet poultry manure, dry poultry manure, dry cow manure, compost of cow manure, compost of poultry manure and Urea fertilizer) and four different times of fertilizer application (0. 2, 4 and 6 WAP) in a Randomized Complete Block arrangement with three replications. Following land

preparation and before planting in each year of the study, soil samples were collected at the top soil (0 – 15), which were taken from each experimental plot using soil auger. The samples were air dried and later analyzed for physical and chemical characteristics. Thereafter, field layout was done to mark out the appropriate number of treatment plot. A plot size of 3 m x 5 m with 0.5 m alley between plots was used.

Improved open pollinated maize (TZEE-SR-Y) variety was planted at a spacing of 75 cm by 25 cm. Two seeds were planted per hole and were later thinned to one plant per stand two weeks later. Weeds were controlled by spraying with a pre-emergence herbicide Atrazine [2 – Chloro – 4 – (Ethylamino) - 6 – (isopropylamino) s-triazine] on the following day after planting of seed. The herbicide was sprayed uniformly on the field at the recommended rate of 2.5 kg a.i./ha which was supplemented with one hoe weeding at 6 weeks after planting (WAP).The fertilizer treatments were all applied at the rate of 100 kg N/ha.

Data were collected on plant growth parameter (plant height), yield components (500 seeds weight, cob length and dry biomass yield) and grain yield. All data collected were analysed using the analysis of variance (ANOVA) with Genstat Discovery 4 statistical package. Significant means were separated using the least significant difference (LSD) method at 5 percent probability level.

RESULTS

Effects on Soil Physico-chemical Properties.

The results of the pre-treatment soil characteristics and the chemical composition of the organic manures utilized in the study are shown on Table 1.The results showed that the soil of the study site was inherently low in organic matter content (1.9 %), total N content (1.22 g/kg) with slightly acidic soil pH value (6.6). The soil physical characteristics indicated a loamy sand texture.The results of the chemical properties of the applied manures on the same table show that dry poultry manure (dPM) has the highest N value (2.68 g/kg), followed by dry cow dung (dCD) (2.04g/kg), wet poultry manure (wPM)(1.96 g/kg), compost of cow dung (cCD) (1.92 g/kg) and compost of poultry manure (cPM)(1.83 g/kg) in that order.

The results of the post-harvest soil analyses presented on Table 2 show the changes in the chemical properties of the soil after harvesting of maize. The total N content of soil in the control plots (no fertilizer application) decreased to 0.7 g/kg from the pre planting soil value of 1.22 g/kg. However, the post-harvest soil total N variably increased due to the application of the various types and forms of the N fertilizer, including urea, with the cPM showing the highest total N value of 2.82 g/kg. Similarly, the results on Table 2 showed that while the none application of any form of fertilizer and the application of the inorganic fertilizer resulted in post-harvest decreases in soil organic matter, the application of any type and form of organic manure resulted in post-harvest increases in the organic matter of the soil. In similar manners, none application of fertilizer and the application of urea resulted in post-harvest lower soil pH, while the application of organic manures increased soil pH values.

Effects on Plant growth Parameter

The results of the plant growth parameter measured as the plant height at 9 WAP presented on Table 3 show that there were no significant differences in plant height due to treatments application in 2009. However, in 2010 there were significant variations in plant heights among plants given the different fertilizer treatments. In both years of the study, plant height was highest with the application of urea fertilizer and shortest with none application of any form of fertilizer. Among the organic fertilizer sources, plant height was highest with the application of dPM, which was closely followed by

the values obtained with the application of dCD.

Effects on Yield Components of maize

The results of the maize yield components presented on Table 4 show that the cob length varied significantly due to the application of different type and forms of N fertilizer sources, with the non application of any form of fertilizer resulting in significantly smaller cobs than those with the application of inorganic or organic sources of N fertilizer in both years of the study. Among the fertilizer sources, the application of urea resulted in significantly longer cobs than in any form of the organic sources.. However, time of application did not significantly affect the maize cob length in the two years of the study. The results on the same table show that there were no significant variations in the 500 seeds weight among the different sources of N fertilizer and time of their application. Nevertheless, the highest 500 seed weights were obtained with the application of dPM and urea in 2009 and 2010, respectively and lowest weights were obtained with none application of any form of fertilizer in the two years.

The total dry biological weight on the other hand varied significantly due to the application of different sources of N fertilizer, with the highest values obtained with the application of the inorganic (urea) source in both 2009 and 2010, while the lowest weights were obtained with none application of any form of fertilizer (Table 5). The application of any organic source of N fertilizer resulted in significantly higher dry biological weight than the control. The results further show that while the time of fertilizer application had no appreciable effects on dry biological weight in 2009, the application at 4 WAP resulted in significantly higher weight in 2010. The results of the significant source of N fertilizer X time of application on the dry biological weight (Table 6) revealed that while dry biological yield increased with time of application to a peak at 4 WAP with three sources of N fertilizer (urea, dPM and wPM), the component decreased with the time of application with dCD.

Effects on maize grain yield

The results of the different sources and time of application of N fertilizer on maize grain yield for the two years of the study are presented on Table 5. The results showed similar trends of responses of grain yield to the sources and time of application of N fertilizer as in the total dry biological weights, with the parameter been significantly influenced by both the sources and time of application of N fertilizer. The application of the inorganic (urea) source resulted in significantly superior grain yields than with the application of any type and forms of organic sources, the application of which however, resulted in significantly higher grain yields than the control. The application of fertilizer at 4 WAP resulted in significantly higher grain yields than the application at the other periods in both years of the study.

The results of the interactive effects of source and time of application of N fertilizer on grain yield are presented on Table 7. The results revealed that out of the seven treatments, four fertilizer sources (urea fertilizer, wet poultry manure, dry poultry manure and compost of cow manure) gave their highest grain yields with applications at 4 weeks after planting (WAP), while dry cow manure treatment produced its highest grain yield at planting time and compost of poultry manure gave the highest grain yield when it was applied at 6 WAP.

DISCUSSION

The results of the pre-treatments soil analyses revealed that the soil of the experimental site is loamy sand, low in N (1.22 gkg^{-1}) and organic matter and slightly acidic (pH 6.6). These were in agreement with the reports of Abayomi *et*

al.(2008) and showed that the values were below the critical levels (Aune and Lal, 1995). The low nutrient status of the experimental site can be attributed to the nature of most Nigerian soils which have been characterized as highly leached ferruginuos ultisols, low in organic matter, N and P, but high in K content (Klinkiberg and Higgins, 1968). The results also corroborate the report of Aduayi *et al* (2002) that most Nigerian soils are deficient in N, P and K. It has been reported that the sustainable method of improving these soils is the application of fertilizer (organic/inorganic) (Abdulmalik, 2013). The results of the analyses of the various forms of organic fertilizer used for the study showed that the highest nutrients were obtained with the dPM, even though the organic matter content was highest with dCDM. These results were in consonance with the reports of earlier workers (Bunke and Lavkulich, 1975; Shegel, 1992) which showed that poultry manure had highest effects on soil available levels of N and P compared to other animal manures, thereby in agreement with the reports that the nutrients of the organic manure from animal sources depend on many factors including the type of feeds the animals eat (Abdulmalik, 2013).The superiority of PM over the other soil

Table 1: Pre-planting soil characteristics and chemical properties of organic manures

Chemical Properties	Soil	Wet Poultry Manure	Dry Poultry Manure	Dry Cow Manure	Compost of Poultry manure	Compost of Cow Manure
Ph	6.6	4.9	5.8	5.9	6.2	6.2
Organic matter (%)	1.90	4.8	3.9	5.0	6.7	6.8
Organic Carbon (%)	1.10	2.1	1.9	2.8	2.3	2.5
Total N %	1.22	1.96	2.68	2.04	1.83	1.92
Available P.	22.54	41.0	59.0	45.0	28.0	33.0
Exchangeable K	122.22	183.0	198.0	155.0	30.0	42.0
Physical Proprieties	Loamy sand					

Table 2:Post maize harvest soil chemical properties in 2010

Source of N fertilizer	Total N (g/kg)	Available P (mg/kg)	Exchangeable K(mg/kg)	Organic Matter (g/kg)	pH 1:1in H_2O
Pre-planting soil value	1.22	2.25	1.22	1.90	6.6
Control	0.7	2.03	0.86	1.37	5.8
Wet Poultry Manure	2.10	2.26	1.16	2.40	6.1
Dry Poultry Manure	2.71	2.03	2.02	2.72	6.4
Dry Cow Manure	2.65	3.52	1.19	2.87	6.5
Compost of Poultry Manure	2.82	3.94	1.29	2.50	6.8
Compost of Cow Manure	2.74	3.12	1.39	2.65	6.8
Urea Fertilizer	1.62	2.19	1.02	1.66	5.3

Table 3: Effects of sources and time of application of N fertilizer on plant height at 9 WAP

	Plant height(cm) 2009	2010
Source of N fertilizer		
Control	140.9	157.7
Wet Poultry Manure	154.4	162.1
Dry Poultry Manure	174.2	185.9
Dry Cow Dung	165.4	173.7
Compost of Poultry Manure	162.5	161.5
Compost of Cow Dung	163.1	172.7
Urea Fertilizer	205.5	194.2
LSD(0.05)	ns	13.6
Time of Application (WAP)		
0	170.5	172.6
2	162.0	174.5
4	162.2	176.6
6	171.5	166.4
LSD	ns	ns
Interaction		
Source X Time	ns	ns

ns = Not significant

Table 4:Effects of source and time of application of N fertilizer on maize yield components.

	Weight of 500seeds (g)		Cob Length (cm)	
Treattments	**2009**	**2010**	**2009**	**2010**
Source of N Fertilizer				
Control	95.3	100.0	7.17	7.67
Wet Poultry Manure	108.4	110.7	8.32	7.96
Dry Poultry Manure	114.9	114.4	9.12	9.29
Dry Cow Manure	105.3	111.8	9.77	7.69
Compost of Poultry Manure	113.0	103.2	8.84	8.26
Compost of Cow Manure	114.0	104.8	8.37	8.26
Urea Fertilizer	106.6	120.9	12.06	11.78
LSD(0.05)	ns	ns	0.98	0.87
Time of Application (WAP)				
0	109.0	92.9	8.80	8.65
2	107.5	83.2	8.56	8.34
4	104.4	88.2	9.45	9.00
6	111.9	84.9	9.56	8.80
LSD	ns	ns	0.74	ns
Interaction				
Source X Time	ns	ns	ns	ns

ns = Not significant

amendments can be attributed to its rich source of plant nutrients, especially N and P among other animal based manures. The results of the post maize-harvest soil analyses showed that the application of any form and type of organic sources of N fertilizer resulted in improved soil properties, suggesting probable appreciable residual effects of the organic sources of fertilizer on subsequent crop growth. This was amply demonstrated by the results on plant height on Table 3 which showed that while there were no appreciable differences in the plant height due to different N sources in the first year of the study in 2009, the residual effects of the treatments became apparent in the follow-

Table 5: Effects of source and time of application of N fertilizers on dry biomass and grain yield of maize.

	Dry biomass (t/ha)		Grain yield (t/ha)	
Treatments	**2009**	**2010**	**2009**	**2010**
Source of N Fertilizer				
Control	1.91	2.39	0.62	0.56
Wet Poultry Manure	2.38	3.02	0.91	1.05
DryPoultry Manure	2.65	4.21	1.23	1.73
Dry Cow Manure	2.51	3.80	1.37	1.45
Compost of Poultry Manure	1.99	2.65	0.86	0.82
Compost of Cow Manure	2.05	3.00	0.97	0.93
Urea Fertilizer	4.32	6.00	2.12	2.40
LSD(0.05)	0.56	0.51	0.22	0.25
Time of Application (WAP)				
0	2.21	3.51	1.07	1.22
2	2.78	3.54	1.14	1.19
4	2.57	3.97	1.19	1.45
6	2.62	3.36	1.22	1.25
LSD(0.05)	ns	0.38	ns	0.20
Interaction				
Source X Time	ns	*	ns	*

ns = Not significant * = significant at 5%

Table 6: Interactive effects of source and time of application on N fertilizer ondry biomassyield (t/ha) of maize in 2010

	Time of application (WAP)			
Source of Fertilizer	**0**	**2**	**4**	**6**
Control	2.52	1.39	3.26	2.39
Wet Poultry Manure	2.76	3.08	3.26	2.99
Dry Poultry Manure	3.76	4.03	5.22	4.24
Dry Cow Manure	4.12	3.97	3.41	3.70
Compost of Poultry Manure	2.55	2.82	2.49	2.76
Compost of Cow Manure	3.49	2.64	3.23	2.64
Urea	5.39	6.88	6.94	4.80
SED			0.504	
LSD(0.05)			1.011	

Table 7: Interactive effects of source and time of application of N fertilizer ongrain yield (t/ha) of maize in 2010

	Time of application (WAP)			
Source of Fertilizer	**0**	**2**	**4**	**6**
Control	0.87	0.25	0.55	0.56
Wet Poultry Manure	0.96	0.83	1.26	1.16
Dry Poultry Manure	1.44	1.63	2.15	1.70
Dry Cow Manure	1.85	1.37	1.27	1.32
Compost of Poultry Manure	0.78	0.86	0.75	0.89
Compost of Cow Manure	0.67	0.75	1.39	0.91
Urea	1.95	2.64	2.81	2.20
SED		0.262		
LSD(0.05)		0.526		

ing year 2010 with significant differences in maize plant heights possibly due to the residual effects of the previous year's treatments application.

The capability of the applied sources of N fertilizer to improve plant growth was demonstrated in the results of the plant height measured at 9 WAP, which was improved by the application of any form of N fertilizer sources (organic/inorganic) compared to the none application control in both years of the study, even though significant differences were obtained only in the second year of the study. This was in agreement with the reports of earlier workers which showed that the application of N fertilizer significantly increased the plant height of maize genotypes and at different time of planting (Abayomi and Adedoyin, 2004; Shafshak and El-Debaby, 1981; Lucas, 1986; El-Kholy, 1987). Significant increase in plant heights with nitrogenous fertilizers had also been reported in sorghum by Ayube *et al.*, (1999). Furthermore, Azraf-ul- haq *et al.* (2007) also reported that mineral fertilizer treatment gave the highest plants height in sorghum.

The importance of plant height on grain yields of cereal crops had been demonstrated by earlier workers who showed significant positive relationship between plant height and grain yield (Abayomi, 2004). Consequently, it has been suggested that variations in plant height may become one of the causes of yield variations in crops (Hadjichristoudoulou, 1987). It has also been reported that plant height is one of the plant growth parameters directly linked with the potential productivity of plants. This was emphasized by Singh *et al* (2001) who reported that an optimum plant height is positively connected with maize productivity.

The main effects of different sources of N fertilizer application were significant for yield components (cob length and dry biomass yield) and grain yield of maize. The application of inorganic source (urea) of N fertilizer resulted in significantly superior values of yield components and grain yield than with the application of organic sources of N fertilizer. These results were in consonance with the reports of Mohammed *et al.* (2001) who had earlier reported that inorganic fertilizer was superior to sole organic manure in dry matter production, cob length and grain yield of maize. Similarly, Makinde *et al.* (2001) reported that maize grain yields with the application of the inorganic fertilizer and a mixture of inorganic with organic manure were similar and higher than with the application of sole organic manure. Omisore (2014) suggested that the superiority of the inorganic fertilizer in grain yield over the organic manure was probably due to the fact that urea made its N availalable for plant

use quickly and more readily than the organic manure which required time for mineralization before the N could be released for plant use. This was in line with the observation of Mallory and Griffin (2007) that the applied inorganic N fertilizer became more quickly available for plant growth and development than N application from the organic sources.

Nevertheless, the application of N fertilizer from the organic sources resulted in significantly higher values of yield components and grain yield than in the none application of any form of fertilizer, suggesting that the application of any source of N fertilizer to savanna soils result in improvement in grain yield of maize. This may be due to the improvement in the physiological components such as radiation use efficiency and dry matter partitioning to the reproductive organ occasioned by N availability (Uhart and Andrade, 1995). Despite this fact, the lower grain yields due to the application of organic sources of N fertilizer compared to the inorganic fertilizer can be related to the fact that the nutrients from the sole organic sources may not be adequate for optimum grain yield in maize, thereby corroborating the observation of Titiloye (1982) that sole organic manure could not be depended upon as the sole source of nutrient for maize production. However, it has been observed that the immediate short term effects of the applied fertilizers are often emphasized to the neglect of the residual effects. It has been reported that when farming is continued for several years on the same site, residual effects of the fertilizer treatments may considerably affect the chemical properties and consequently the crop yield (Gauo, 1982., Enwezor *et al*., 1989). Results of the present study showed that the first year fertilizer application resulted in improved soil properties in the second year with higher grain yields. This is in line with the observation that the residual effects of organic materials can contribute to the improvement in soil quality for several years after the application ceases (Guitang *et al.,* 2003).

Furthermore, application timing is a critical component of maximizing N use efficiency. The management of organic manure fertilizers is much more difficult than that of mineral fertilizers primarily because manure and other forms of organic fertilizers are affected by the timing of incorporation and distribution (Thomsen, 2005). However, results of the present study showed no appreciable effects due to time of fertilizer application. Nevertheless, significant time X source effects revealed that the application of cow dung manure was best at planting of maize, while other sources including the inorganic fertilizer were best with the application at 2 - 4 WAP. The importance of the time of application had been related to N loss, known to be affected by soil type, soil temperature and moisture regimes (Van Es *et al.,* 2006). Loria *et al* (2007) reported that the differences between maize yields among different site locations were attributable to N loss potential from a late fall application as opposed to spring applications at the other sites.

In conclusion, the application of any source of N fertilizer improved maize growth and grain yield, with the inorganic source showing the best results. Nevertheless, organic N sources showed better potential residual effects that can result in improved soil properties and crop yield in subsequent cropping. Moreover, while time of fertilizer application did not produce appreciable effects on maize yield, significant time x source effect revealed that the application of cow dung manure was best at maize planting, while the other sources were best applied at 2-4 WAP.

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