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Influence of Slurry-Fertigation of Maize (*Zea Mays*) Production on Nutrient-Depleted Sand-Loam Soil

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Abstract: Attempt to improve the standard of living and maintain a natural environment with crop production for a healthy man living, the use of different soil amendments to upgrade agricultural soils are of great concern in this millennium. The use of animal wastes for crop production and to reduce the menace of these wastes in man's environment must also be considered. Hence, a field experiment was carried out at Lagos State University of Education, Michael Otedola Campus, Teaching and Research Farm, Epe Lagos using pig and poultry wastes; prepared into a slurry and applied at different rates for maize production under field conditions. The experimental design was randomized complete block design (RCBD) with six treatments; which are: NFE-Control, Pig dung (0.6, 1.2 and 1.8 kg/ 3.6 m2) and Poultry dung (0.6, 1.2 and 1.8 kg/ 3.6 m2) and replicated three times. From this study, animal waste slurry for maize production increased both the vegetative growth and maize grain yield. Maize Plant Height (PH, cm), at 4 weeks after sowing ranged from 19.8±8.8 – 33.1±8.8 under NFE and Poultry dung (0.6kg) applications, and 50.8±18.9 – 93.4±18.9 under NFE and Pig manure (1.8kg) application at 6 weeks after sowing. Both Poultry and Pig dung slurry at 0.6kg - 1.8kg/3.6 m2 on nutrient-depleted soil gave grains yield ranging from 1.1 to 2.0 t/ha. As a result, the application of these dungs increased the growth and yield of maize and is thus recommended for maize production.

Keywords: Depleted, Maize, Production, Slurry-fertigation

1. Introduction

Maize (Zea mays) is an arable grain crop of the Graminae family and is a widely grown staple food crop in sub-tropical and tropical regions (Gao et al., 2020). Maize is regarded as a staple cereals crop in Nigeria and across the world. It plays a significant role in Nigeria's food safety and as raw material for industrial use. It provides a significant amount of daily calorie and other nutrient benefits such as macro and micronutrients when ingested by the world's populace, especially for the residents of sub-Saharan Africa where access to animal products is scarce. It is also used extensively for direct animal feed and human consumption (Adejumo et al., 2007). Nigeria, the most populated country in Africa (known as the Giant of Africa) is the second major producer of maize behind South Africa. Demand for maize in Nigeria has been on the rise due to higher incomes, urbanization, and increased animal protein consumption. The estimated amount of maize used in Nigeria for feed increased exponentially by 600% from 300,000 to 1.8 million tons (Liverpool-Tasie et al., 2019). Despite the impact of maize on the Nigeria and world economy at large, significant economic losses continue to affect production due to natural enemy events, bringing about a 6-19% grain decrease from insects and other herbivores and an additional 10% due to pathogens attack such as fungi (Block et al., 2018). Besides these factors facing maize production in Africa, especially Nigeria, the lack of adequate supply to the plant during production affects maize productivity.

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Several factors such as low soil fertility, disturbed soil properties, nutrient imbalance, and weed infestation are major problems limiting the yield of maize crops (Mahmood et al., 2017). In Nigeria, traditionally, shifting cultivation has been used for a long period to replenish lost nutrients after production. However, this method is no longer feasible due to reduced arable land as well as the ever-increasing world population, hence, reducing the fallow period (Toungos, 2019). Generally, maize production needs a high dosage of fertilizer application as well as a significant amount of nutrients, particularly in relation to nitrogen and potassium is needed (Abubakar & Ali, 2018). Maize takes up nitrogen, phosphorus, and potassium from the soil as the main nutrients needed for growth and development. Though, the exact dosage needed depends on the history of the soil fertility, past crop history and the time required for the growth of the crop. However, it is advised for different ecosystems for maize production in Nigeria to apply a balanced amount of 60–120 kg N, 40–60 kg P2O5, and 40 kg K2Oha-1 (Toungos, 2019). However, the recommended nutrient requirement is not readily available in the soil, especially sandy soil so therefore, amendment of the soil with fertilizer (such as organic and inorganic) is required to enhance both the soil fertility and crop productivity.

Using inorganic fertilizer or organic manure for soil development is a crucial component of crop production because improving soil fertility is essential for sustainable agriculture (Olatunji et al., 2020). They are designed to directly meet plant needs as opposed to indirectly doing so by altering the pH and texture of the soil. When the right amounts are supplied at the right stages of plant growth, both the quality and quantity of crops are greatly improved (Abubakar & Ali, 2018). The frequent analysis of plant tissue provides the basis for future determinations as to how to manage nutrients best Salisu et al., (2013). Both chemical/inorganic fertilizers and organic manure have been reported to improve plant growth, development, and productivity. However, the use of chemical/inorganic fertilizers in agriculture has a detrimental impact on human health, animal health and environmental issues have sparked up interest in organic farming recently. Organic farming embraces human and environmental health (Olatunji et al., 2020).

Organic fertilizers are those made from plant, animal, or human waste, such as compost or manure (Sekumade, 2017). Using organic fertilizers will ensure the production of crops free of heavy metal contamination. The use of bokashi fertilizer formulation incorporated horse bedding waste increased the crop germination index Gashua et al., (2022). It has been suggested that organic amendments be added to soil to control the current trend of soil deterioration on a physical, chemical, and biological level. Organic fertilizer can be utilized to enhance soil properties and provide abundant crop harvests (Toungos, 2019). Furthermore, a 92% increase in maize grain was reported due to the application of manure compared to the control (Sekumade, 2017). The judicious use of organic fertilizer increases crop growth and yield (Mahmood et al., 2017) with little or no effect on the ecosystem. Additionally, it is important to lower fertilizer costs by determining appropriate rates or incorporating organic fertilizer into crops Adekunle (2014). To reduce the havoc of mineral fertilizers, several studies have shown that the use of organic fertilizers can help to promote sound ecological and human safety as well as reduction of soil degradation. Hence, this work aimed at assessing the growth and yield performance of maize using poultry waste (liquid form; slurry) as a liquid form of organic fertilizer on nutrient-depleted soil.

2. Materials and Method

2.1 Description of the Experimental Site

The field trial was conducted at the Teaching and Research Farm, Lagos State University of Education, Michael Otedola Campus, Epe. Noforija; coordinate of 6.6°N and 4.0°E; along Ijebu-Ode Road. The trial was carried out on sand-loam soil which has been under continuous cultivation for several years, and the soil properties depicted low nutrient status.

2.2 Material Used

The material used for the experiment include: Maize seeds (Oba super), pig and poultry dung

2.3 Slurry preparation

Pig and Poultry manures were sourced from the School of Vocational and Entrepreneurship, Department of Agricultural Science Education farm. The dungs were air-dry and milled. The slurry was prepared using 1 litre of water to 100g of manure (1000 cl: 100g) for each and kept for one week before application. After one week, the slurry was diluted with water before use. The maize seed was sourced from the School of Vocational and Entrepreneurship, Department of Agricultural Education, Noforija Epe, Lagos State. The maize was sown at 75 cm by 90 cm at two seeds per stand and was thinned to a seedling per stand two weeks after sowing.

2.3 Experimental design

Randomized Complete Block Design (RCBD) was used with six treatments and replicated thrice to give (18) eighteen micro-plots with 6 stands of maize per plot giving a total of 108 stands of maize plants. The experimental plot was manually cleared and the layout was done in three (3) blocks, each micro-plot was 4.0 m^2 with a plant population of six (6) stands of maize per micro plot.

2.4 Treatments rates and Application

The treatments are as follows:

a. NFE- No fertigation (control)
b. Pig manure, 0.6, 1.2 and 1.8 kg/ 3.6 m^2, = (L_1, L_2 & L_3, respectively)
c. Poultry manure, 0.6, 1.2 and 1.8 kg / 3.6 m^2 = (L_1, L_2 & L_3, respectively)

The slurry was applied to the seedlings two weeks after sowing. Regular manual irrigation was carried out except on rainy days. Hand weeding was carried out on each plot regularly and all insect pests seen were handpicked. Growth parameters such as plant height, number of leaves per plant, stem girth and leaf lengths were collected bi-weekly after sowing. At the harvest, the following data were collected: Fresh cob weight, Dry cob weight, shoot weight, grains weight and chaff weight.

All data collected were analysed using SAS System for Windows 9. A Least Significant Difference (LSD) was used to compare variations among the treatments and mean treatments were subjected to standard error.

3. Results and Discussion

The soil used for the experiment was low in nitrogen with available phosphorus less than 10 (mg kg^{-1}) which was below required level for maize production, while exchangeable cations are moderate; but not adequate for raising crops such as maize for economic profit (Table 1). The physical properties of the soil depicted that it contained a high percentage of sand (71.2%; 712 g/kg) and was very low in silt and clay, hence, it is a sandy-loam soil suitable for maize production (Table 1).

Table 1: Laboratory analysis of the soil used for the experiment

Soil Properties	Soil test values
pH 1:1 (H_2O)	6.5
Soil Organic Carbon (g kg^{-1})	0.4
Total N (g kg^{-1})	0.4
Available P (mg kg^{-1})	5.0
Exchangeable cation (cmolkg^{-1})	
Ca	1.3
Mg	0.5
K	0.1
Effective CEC (cmolkg^{-1})	4.3
Mechanical analysis (g kg^{-1})	
Sand	712
Silt	180
Clay	108
Textural class	Sandy loam

Source: *Laboratory analysis results of soil used (2018)*

The nutrient compositions of both animal manure are adequate especially the nitrogen, calcium and potassium for the supplementary use to improve the fertility of the soil in question for raising maize (Table 2). This indicates that the application or amendment of soil with organic manure is an important source of plant nutrients. Apart from serving as a source of plant nutrients, it also comes along with another beneficial impact on soil such as improvements in the physical, chemical and biological properties of soils consequently bringing about improved plant growth and productivity (Mutlu, 2020**).**

Table 2: Laboratory analysis of the dung slurry used for the experiment

Animal manure	C	N	C: N	P	K	Ca	Mg
	(g kg^{-1})			(mg/kg)		(cmol kg^{-1})	
Pig	2.2	14.2	12.9	4.6	0.2	2.4	0.5
Poultry	2.3	1.5	13.1	1.1	1.1	3.8	0.1

After 4 weeks of sowing, the maximum plant height was observed in poultry manure treatment applied at the rate of 0.6 kg, followed by pig manure applied at the rate of 1.2kg then pig manure and poultry manure applied at the rate of 0.6 and 1.2kg respectively. While the lowest plant height was recorded in poultry manure (1.8kg), NFE and pig manure (1.8kg) with 16.4, 19.8, and 22.1 cm respectively. Furthermore, the highest plant height recorded after six weeks was in pig manure (1.8kg), pig manure (1.2kg), and poultry manure (0.6 kg), with 93.4, 75.2 and 73.2 cm respectively (Table 3).

Table 3: Effects of poultry and pig slurry on maize plant height and leaf at 4 and 6 (WAS) weeks after sowing

Fertigation Rates (*kg*/*litre*) per 3.6 m^2	Plant height(cm) W A S		Leaf length (cm) W A S	
	4	6	4	6
NF	19.8$_b$	50.8$_{cd}$	59.7	76.4
PgmL$_1$ (0.6)	27.5$_a$	63.1$_c$	70.9	82.3
PomL$_1$ (0.6)	33.1$_a$	73.2$_{bc}$	77.5	83.1
PgmL$_2$ (1.2)	28.6$_a$	75.2$_{bc}$	76.4	87.5
PogmL$_2$ (1.2)	27.5$_{ab}$	71.9$_{bc}$	68.7	83.2
PgmL$_3$ (1.8)	22.1$_b$	93.4$_a$	54.1	80.3
PomL$_3$ (1.8)	16.4$_b$	44.2$_d$	40.3	77.5
SE (DF= 20)	±8.8	±18.9	±16.4 ns	±7.1 ns

NFE- No Fertigation (Control), Pig manure = PgmL$_1$, Poultry manure = PomL$_1$,
PgmL$_1$ = 0.6kg, PgmL$_2$ = 1.2kg and PgmL$_3$ =1.8kg/3.6 m^2
PomL$_1$ = 0.6kg, PomL$_2$ = 1.2kg and PomL$_3$ = 1.8 kg/ 3.6 m^2
WAS = Weeks after sowing.

There was a significant difference between the control and the highest plant height recorded for the treatment at both four and six weeks after sowing. Regarding the leaf length, all treatments had increased leaf length than the control after six weeks. A similar result was observed after four weeks except for pig and poultry manure (1.8kg) had lower leaf length compared to the control (Table 3). Increment observed in the plant growth traits may be associated with the amendment of the media with animal manure. This was in accordance with findings by Dlamini et al. (2020) who reported an increase in plant height of amaranth due to fertilizer application. Furthermore, the presence of an adequate supply of nitrogen enhances cell size, leading to rapid elongation of the internodes and consequently, the final plant height (Abubakar and Ali, 2018).

The vegetative growth performance of the maize plant under different fertigation applications of animal manure slurry showed an increase in stem girth and number of leaves per plant at four (4) and six (6) weeks after sowing (WAS). In the fourth week, the stem girth ranged from 3.7 to 6.2 cm under the application rate of (NFE and PomL$_1$; control and PgmL1 = 0.6kg/3.6 m^2). The application rate of poultry manure slurry (PomL$_3$) at 1.8kg/3.6m^2 recorded the least stem girth at 6 weeks and the number of leaves at 4 weeks after sowing (Table 4). In the fourth week, there was no significant difference (±1.6) in the number of leaves produced by the maize plant under all the applications of the two animal manure slurry; the number of leaves at 4 WAS ranged from 8 to 11 per maize plant.

Table 4: Effects of poultry and pig slurry on maize stem girth and number of leaves at 4 and 6 (WAS) weeks after sowing

Fertigation Rates (*kg*/*litre*) per 3.6 m^2	Stem girth (cm) W A S		Number of leaves W A S	
	4	6	4	6
NF	4.3	5.4	9	12
PgmL$_1$ (0.6)	4.7	7.3	11	14
PomL$_1$ (0.6)	6.2	8.0	11	13
PgmL$_2$ (1.2)	5.6	8.5	11	14
PgmL$_2$ (1.2)	5.9	8.1	11	14
PgmL$_3$ (1.8)	4.8	7.7	10	14
PomL$_3$ (1.8)	3.7	7.3	8	13
SE (DF= 20)	±1.4 ns	±0.9	±1.6	±1.4 ns

NFE- No Fertigation (control), Pig manure = PgmL$_1$, Poultry manure = PomL$_1$,
PgmL$_1$ = 0.6kg, PgmL$_2$ = 1.2kg and PgmL$_3$ =1.8kg/3.6 m^2
PomL$_1$ = 0.6kg, PomL$_2$ = 1.2kg and PomL$_3$ = 1.8 kg/ 3.6 m^2
WAS = Weeks after sowing

Similarly, at 6 WAS, the highest number (14) of leaves were observed under the applications of pig manure slurry across all the rates and poultry manure at 0.6kg. The least number of leaves per maize plant was 12 (±1.4) at 6 WAS. However, there was no significant difference in the number of leaves and stem girth growth at the fourth and sixth weeks after sowing (Table 4). This showed that respective of the quantity of the fertigation, the inherent or native fertility of the soil positively influenced the vegetative growth of the maize at the first growth phase. The current result was by a previous report by Dlamini et al. (2020) who observed increment in the stem girth and leaves number may be associated with the amendment of media with organic fertilizers. Furthermore, enhancement in the leaves number among the treatment used compared to the control may be attributed to a high concentration of phosphorus in the amendment media (Rus et al., 2023).

The maize cob yields under poultry and pig slurry fertigation increased at the rate of 1.2 and 0.6 kg pig and poultry manure slurry application. The fresh cob weight ranged from 1.03 to 1.40 kg /3.6 m2 under Poultry manure $PomL_3$; 1.8) application and Pig manure ($PgmL_2$; 1.2) slurry fertigation application (Table 5). It was observed that there is no significant difference between the cob yield performance under the $PgmL_2$ application and $PomL_3$ (1.03±0.02 and 1.02 ±0.02, however, the NFE application was significantly higher than the two rates (Table 4). This was evidence of a high level of one nutrient or the other due to the application of the manures. Similarly, the dry cob weights have the highest yield under the application of poultry manure fertigation (0.84±0.02 kg/3.6 m^2) and the least was (0.50 ±0.02 kg/3.6 m^2) observed under NFE application.

Table 5: Effects of poultry and pig slurry on the fresh and dry maize cobs at harvest

Fertigation Rates (*kg/litre*) per 3.6 m^2	Fresh cob ($kg/3.6m^2$)	Dry cob weight ($kg/3.6m^2$)
NFE- control	1.08_e	0.50_f
$PgmL_1$ (0.6)	1.10_d	0.68_e
$PomL_1$ (0.6)	1.16_c	0.84_a
$PgmL_2$ (1.2)	1.02_f	0.77_c
$PgmL_2$ (1.2)	1.40_a	0.80_b
$PgmL_3$ (1.8)	1.21_b	0.74_d
$PomL_3$ (1.8)	1.03_f	0.68_e
SE (DF= 20)	±0.02	±0.02

NFE- No Fertigation (control), Pig manure = $PgmL_1$, Poultry manure = $PomL_1$, $PgmL_1$ = 0.6kg, $PgmL_2$ = 1.2kg and $PgmL_3$ =1.8kg/3.6 m^2

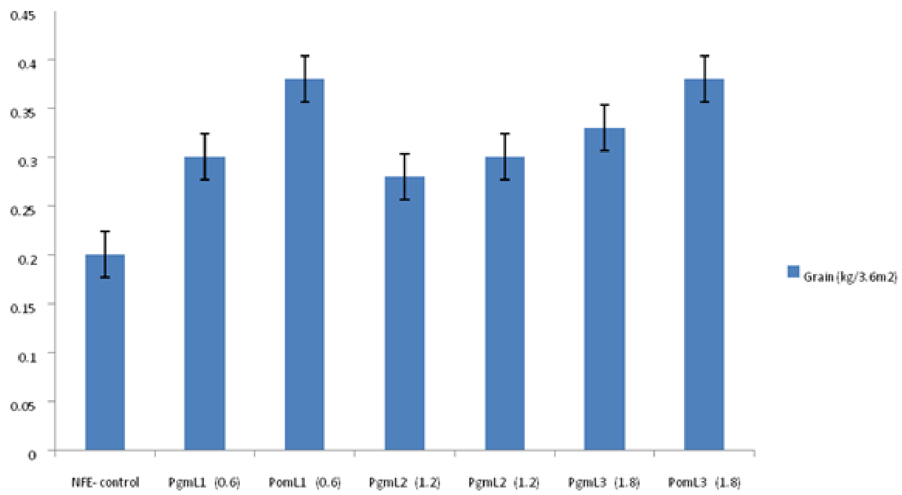

Fig. 1: Maize Grains Yield under Different Rates of Manure Slurry Applications

NFE- No Fertigation (control), Pig manure = $PgmL_1$, Poultry manure = $PomL_1$,
$PgmL_1$ = 0.6kg, $PgmL_2$ = 1.2kg and $PgmL_3$ =1.8kg/3.6 m^2
$PomL_1$ = 0.6kg, $PomL_2$ = 1.2kg and $PomL_3$ = 1.8 kg/ 3.6 m^2
Bars are Error bars with Standard Error (SE)

The grain yields ranged from 0.2kg to 0.42kg under non-fertigation treatment (NFE; control) and poultry manure fertigation ($PomL_3$; 1.8kg/3.6m^2). however, there is a significant difference between the grain yield obtained under the application of $PomL_2$ when compare to grain yields obtained under $PgmL_2$, $PomL_2$ and $PgmL_3$ with grain yields of 0.29kg, 0.27kg and 0.32 kg respectively (Fig. 1). The performance of the two manures in the fertigation application showed that the poultry manure in the liquid form as well as the pig manure in the same quantity released nutrient at variance. This was observed when the grain yields from the three levels of applications of each slurry followed a pattern as; $PgmL_1 \neq$ neither PomL1 nor PomL2 = $PgmL_2$ neither did $PgmL_3$ was the same in maize grain yield with $PomL_3$ applications. It was observed that the highest grain yield was recorded under the application of $PgmL_3$ (0.38 kg/3.6m^2) which is equivalent to 1.1t/ha. This is in line with the report of Olatunji et al. (2020) that organic manure positively affects crop yield which may be attributed adequate supply of phosphorous to the plants.

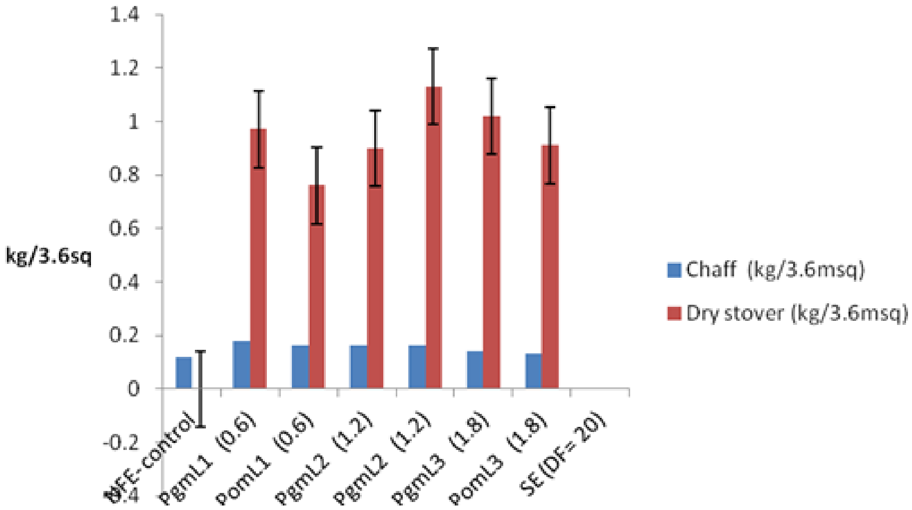

Fig. 2: Chaff and Dry Stover of Maize under Different Levels of Slurry Fertigation

NFE- No Fertigation (control), Pig manure = PgmL, Poultry manure = PomL,
$PgmL_1$ = 0.6kg, $PgmL_2$ = 1.2kg and $PgmL_3$ =1.8kg/3.6 m^2
$PomL_1$ = 0.6kg, $PomL_2$ = 1.2kg and $PomL_3$ = 1.8 kg/ 3.6 m^2
Bars are Error bars with Standard Error (SE).

The dry stover yield was significantly increased under the fertigation rate of 1.8kg/3.6m^2 but not as high as it was observed under the application rate of 1.2kg/3.6m^2. The maize dry stover yield was at variance with the grain yield where the highest yield patterns were observed under 0.6kg and 1.8kg poultry slurry-fertigation with grain yields of 0.29kg and 0.27kg/3.6 m^2, respectively. However, the chaff yield showed no significant difference across all the application rates when compared to the yield obtained under NFE (control) application (Figure 2). This was in line with the vegetative growth performance, where there was no significant difference ($Pr \leq 0.005$). Reduced dry stover yield observed in the control might be attributed to low nutrient supply to the plant, which brings about lesser photosynthates production and subsequently reduced growth (Ahmed et al., 2019).

4. Conclusion

The use of animal wastes in any form aims at improving soil fertility for crop production as well as reducing the menace constituted by animal dung, especially in areas where they are poorly managed in terms of environmental menace. The process of diluting the animal wastes to form a slurry and used for irrigating maize farm increases the release of nutrient and consequently improve the crop yield performance. From this study, it can be deduced that the use of animal waste slurry for maize production goes a long way to improve the soil's physical and chemical properties and increased crop production. It is depicted that the use of animal manure in the slurry form at the rates of 0.6kg - 1.8kg/3.6 m^2 along with irrigation especially on nutrient-depleted soil.

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Conflict of Interest

The authors declare no conflicts of interest.

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