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Effects of Poultry Manure and Spent Mushroom Substrate on Soil, Weed and Maize Performance in an Ultisol

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ABSTRACT

Field experiment was carried out at the Teaching and Research Farm of the University of Port Harcourt, Rivers State to determine effects of poultry manure and spent mushroom substrate on soil, weed and maize performance in an Ultisol. The experiment consisted of five treatments namely: control (0 tons/ha), 5 tons / ha of poultry manure (PM_5), 10 tons / ha of poultry manure (PM_{10}), 2.5 tons / ha of poultry manure + 2.5 tons / ha of spent mushroom substrate ($PM_{2.5}$ + $SWS_{2.5}$) and 5 tons / ha of poultry manure + 5 tons / ha of spent mushroom substrate (PM_5 + SWS_5). The treatments were laid out in randomized complete design (RCBD) and replicated four times. Result showed that Bulk density ranged from 1.18 g cm^{-3} for PM_5 to 1.35 g cm^{-3} for the control, total porosity ranged from 21.22% for the control to 34.62% for PM_5, saturated hydraulic conductivity ranged from 12.96 cm/hr for the control to 23.13 cm/hr for PM_{10}. Aggregates stability ranged from 0.587 mm for the control to 0.784 mm for PM_{10}. Poultry manure and spent mushroom substrate significantly ($P < 0.05$) increased soil organic carbon, pH and total N compared with the control. At 12 weeks after sowing (WAS) plots that received 5 tons/ha tends to have better weed suppression than other treatments. Plots that received 10 tons/ha of poultry manure produced the tallest plants while plots that received 5tons/ha of poultry manure had the highest leaf area index and grain yield when compared to other treatments. Since the application of poultry manure at 5 tons/ha can greatly improve soil physico-chemical properties, suppressed weed growth which led to higher grain yield of maize, it is thus recommended to farmers in the area of study.

1 INTRODUCTION

Poultry manure and spent mushroom substrate (SMS) contain nutrient elements that can support plant growth by enhancing the chemical and physical properties of the soil. The degradation of soil physical properties and the increase in the risk of erosion in the tropics are strongly related to long term agricultural intensification that causes a gradual deterioration of soil properties (Mbagwu *et al.,* 2004). Addition of organic manure to the soil has been reported to improve the physical, chemical and biological properties of the soil and plays a critical role in sustaining soil quality and productivity (Andrew *et al.,* 2004).

Soil organic matter enhances soil aggregate stability and soil strength by increasing friction between particles. Poultry manure contains the essential plant nutrients that are used by plant nutrients that are used by plants. Thus, poultry manure alone or in combination with spent mushroom substrate can support crop production and enhance the physical and chemical properties of soil. Application of poultry manure alone have been reported to enhance soil properties, such as, plant nutrient availability, organic matter content, cation exchange capacity, water holding capacity and soil tilth (Dekissa *et al.,* 2008). Addition of poultry manure to soil not only helps to overcome the disposal problems but also enhances the physical, chemical and biological fertility of soils (Mc Grath *et al.,* 2009). In arable crop production under continuous cultivation, deterioration in soil structure often results in reduced crop yield. Addition of poultry manure has been reported to improve fertility of such cultivated soils by increasing the organic matter content, water holding capacity, oxygen diffusion rate and the aggregate stability of the soil (Adeli, *et al.,* 2009).

Spent mushroom substrates provide slow-release of basic nutrients that are useful to crop upon application. It also contains a number of micronutrients that are usually not present in standard N,P, K fertilizers. When used as soil amendment, it improves agricultural soils by increasing the soil organic matter (OM) content. Spent mushroom substrate is ideal organic manure, in that it has low heavy metal content with substantial amount of plant nutrients, such as phosphorus and potassium and high organic matter (Maher and Magette, 1997). Maize is the third most important cereal after wheat and rice (Jones 1997). Maize is an important crop in food security and in alleviating poverty. The maize plant requires adequate supply in nutrients particularly nitrogen, phosphorus and potassium for optimum growth and yield. Therefore, sustaining soil condition for its production is important.

Although enhancement of soil productivity can be achieved by the use of inorganic and organic fertilizers; there has been increased use of chemical fertilizers, with high cost. The result is often higher input and low yield and does not commensurate with the purchased price. The use of acid forming ammonia nitrate can increase soil acidity and reduce both crop yield and soil conditions. According to Nottidge *et al., (*2005), the use of inorganic fertilizers has not been able to sustain high productivity due to increase in soil acidity, leaching and degradation of soil organic matter and soil physical conditions. The role of organic manure in maintaining organic matter and raising the growth and yield of cereal crops had long been recognized in most agro-ecological zones (Ano, 1991). Organic manure such as poultry manure and Spent Mushroom Substrate are readily available as cheap source of nitrogen for sustainable crop production. Although organic manure can be used as a source of nutrient to improve soil fertility (Baitilwake et al., 2011) some can promote weed growth which reduced crop yield while some can be effective in reducing weed growth and increased crop yield. For instance Lado et al (2010) reported that farm yard manure as a measure of improving soil fertility result in high weed growth due to weed seeds from animal dung and non-decaying pasture. The authors also noted that poultry manure (poultry droppings) as a measure of improving soil fertility will be advantageous because aside from resulting in high cure bulb yield it also increased the competitive ability of onion against the weeds by reducing weed population (weed density) and weed biomass. Glauninger and Holzner (1982) noted that nutrient poor environments frequently increased weed species diversity. O'Donovan et al (1997) also noted that application of manure alters soil fertility that affects not only the growth of crop, but also the growth of associated weeds and their floral composition. Hence the objective of the study was to evaluate the effect of poultry manure alone or in combination with spent mushroom substrate on soil, weeds and maize performance.

2 MATERIALS AND METHODS

2.1 Description of the Study Site

The study was conducted at the Faculty of Agriculture, Teaching and Research Farm of the University of Port Harcourt, Rivers State. The site is located on latitude 4^0 15'N and longitude $6^0$15'E. The rainfall distribution range from 2000 mm to 4000 mm annually with peaks in June and September, the mean monthly temperature range from 22 ^{0}C to 25 ^{0}C, the relative humidity varies between 35% to 90% depending on the particular period of the year (FORMECU, 1998).

2.2 Maize used

Variety DMESR-Y (Downy Mildew Early Streak Resistant – Yellow) was used for the study. The variety was purchased from the International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria. It is a cross pollinated maize with yellow kernel and early maturity.

2.3 Field Layout and Treatment Application

The experiment was laid out in a Randomized Complete Block Design (RCBD) consisting of five treatments in four replications given a total of 20 plots of 4 m x 3 m each. The total land area used for the study was 17 m x 19 m (0.0323 ha). The treatments consisted of:

- Control – 0 tons /ha
- PM_5 – 5 tons / ha of poultry manure
- PM_{10} – 10 tons / ha of poultry manure
- $PM_{2.5}$ + $SMS_{2.5}$ (2.5 tons / ha poultry manure + 2.5 tons / ha of Spent Mushroom Substrate).
- PM_5 + SMS_5 (5 tons / ha of poultry manure + 5 tons / ha of Spent Mushroom Substrate).

The treatments were applied as a single dose during land preparation and allowed for incubation before sowing maize. Three seeds were planted per hole at spacing of 25 cm x 75 cm and the seedlings were thinned to one stand per hole at 2 weeks after sowing (WAS). All the plots were hoe weeded twice at 3 and 7 WAS.

2.4 Soil Sample Collection

Core and disturbed soil samples were collected at 0 – 15 cm depth for the determination of some physical and chemical properties. The soil samples were collected before and after experiment.

2.5 Laboratory Studies

2.5.1 Measurement of Aggregate Stability

Aggregates stability was determined by the wet-sieving techniques described in details by Kemper and Rosenau (1986). In this procedure, 50 g of the 4.75 mm aggregates were placed on the topmost of a nest of sieves of diameters 2, 1, 0.5 and 0.25 mm and presoaked in distilled water for 10 minutes before oscillating vertically in water 20 times at the rate of 1 oscillation per second. The resistant aggregate on each sieve were dried at 50 ^{0}C for 24 hours, and weighed. The mass of < 0.25 mm aggregate fraction was obtained by difference between the initial sample weight and the sum of samples weights collected on the 2, 1, 0.5 and 0.25 mm sieve nest. The percentage of resistant aggregate on each sieve, representing the Water-Stable Aggregates (WSA) was calculated as:

$$\% \, WSA = \frac{MR}{MT} \, x \, \frac{100}{1}$$

Where, MR is the mass of resistant aggregate (g), and MT is the total mass of wet sieve soil (g). The mean weight diameter of water-stable aggregates was calculated as:

$$MWD = \sum^{n} xiwi$$

Where MWD = Mean weight diameter (mm), xi = the mean diameter of each size fraction (mm) and wi = proportion of the total aggregates in each sieve.

2.5.2 Determination of Hydraulic conductivity, Bulk Density, Particle Size Distribution and Total Porosity.

Saturated hydraulic conductivity (Ksat) was determined by the constant-head permeameter technique (Klute and Dirksen, 1986). Leachate volume was measured over a time period until flow was constant at which time, the final rate was determined from the equation: $Ksat = \frac{Q}{AT} \, x \, \frac{L}{\Delta H}$ where Q is the volume of water collected (cm^3), A is the area of the core (cm^2), T is time elapse(s), L is length of core (cm), and ∆H is hydraulic height.

Bulk density was determined by the method described by Black and Hartge (1986).

$$Bulk \; density \; (gcm^{-3}) = \frac{Mass \; of \; oven \; dry \; soil \; (g)}{Volume \; of \; bulk \; soil \; (cm^3)}$$

Particle size was determined by hydrometer method using sodium hexametaphosphate (Calgon) as the dispersing agent, as described in details by Gee and Bauder (1986).

Total porosity was measured with the undisturbed soil core samples, and calculated using the method of Flint and Flint (2002).

2.5.3 Determination of pH, Total Organic Carbon and Total Nitrogen

Soil pH was measured with a glass electrode in a 1:2.5 soil/water aqueous solution (McLean, 1982) Total organic carbon (TOC) was determined by the Walkey and Black wet dichromate oxidation method (Nelson and Sommers, 1982). Total nitrogen was measured by the Macro Kjeldahl digestion procedure as described by Bremner and Mulvaney (1982).

2.6 Data collection

2.6.1 Weed

Weed species present in the experimental site before sowing and after treatments application at 12 weeks after sowing (WAS) were identified with a Hand book of West African Weeds (Akobundu *et al*., 2016) . At 12WAS, weed density was determined by diagonally placing 50 cm x 50 cm quadrats twice per plot. The weeds were clipped at soil surface with the use of secateurs. The weeds were counted and expressed in no/m^2. The weed samples were dried to a constant weight at 80°C for 48 hours in an oven, weighed using electronic weighing balance and the values were expressed in g/m^2

2.6.2 Maize

Measurement on plant height, and leaf area index were done at 12 WAS. Plant height was determined by randomly selecting five tagged plants from the net plot and measured with a ruler from the base of the plant to point of emergence of the tassel. Leaf area Index (LAI) was calculated as the total leaf area divided by land space as described by Shih and Gastro (1980). Grain yield was determined by harvesting cobs from the net plot. The harvested cobs were shelled and winnowed; the grains were weighed per plot and expressed in kilograms per hectare.

2.7 Statistical Analysis

The data collected were subjected to analysis of variance (ANOVA) using Genstat Version 8.1, 2005 statistical package. Treatment means were separated using the least significant difference (LSD) at 5 % level of probability.

3 RESULTS AND DISCUSSION

3.1 Some properties of the soil, poultry manure and spent mushroom substrate before planting

The soil properties before planting (Table 1) showed that the soil was sandy loam. The pH was slightly acidic. The total nitrogen and organic matter of the soil were low when compared with their critical levels of soil in southeastern Nigeria established by Ibedu *et al.* (1988). The total nitrogen content of poultry manure was higher compared with that of the spent mushroom substrate (Table 2). The available phosphorus content of spent mushroom substrate was higher compared with poultry manure (Table 2).

Table 1: Some properties of the soil before planting

Soil properties	Unit	Value
Sand	g/kg	880
Silt	g/kg	68
Clay	g/kg	52
Texture	-	Sandy loam
Total Nitrogen	g/kg	1.28
Organic matter	g/kg	14.4
pH (1:2.5 H2O)	–	4.6
Bulk density	g/cm^3	1.35
Hydraulic conductivity	cm/hr	14.80
Total porosity	%	21.14
Aggregate Stability (MWD)	Mm	0.532

Table 2: Some properties of poultry manure and spent mushroom substrate before planting

Properties	Unit	Poultry manure	Spent mushroom substrate
Total Nitrogen	g/ kg	4.08	1.60
Available phosphorus	g/ kg	7.2	14.5
Organic matter	g/kg	22.2	51.1
pH (H2O)		7.51	6.5

3.2 Physical properties of the soil after poultry manure and spent mushroom substrate application

3.2.1 Particle-Size, Bulk Density, Total Porosity and Saturated Hydraulic Conductivity

The particle size analysis of soil showed higher sand contents ranging from 854 g kg^{-1} to 873 g kg^{-1} (Table 3). The variations in particle sizes fractions did not alter the soil textual class. Bulk density ranged from 1.18 gcm^{-3} for PM_5 to 1.35 gcm^{-3} for the control, this implied that application of poultry manure reduced the soil bulk density when compared with the control (Table 3). This is in agreement with some studies conducted by Mbagwu (1992) that reduction in bulk density was achieved by the application of organic wastes to the soil. Total porosity ranged from 21.22% for the control to 34.62% for $PM_{5.}$ Total porosity showed significant increase compared to the control plot, this implied that application of poultry manure improved soil porosity; confirming the study of Mbagwu (1992). Saturated hydraulic conductivity ranged from 12.96 cm/hr for the control to 23.13 cm/hr for $PM_{10.}$

Table 3: Effect of poultry manure and spent mushroom substrate on Particle-Size, Bulk Density, Total Porosity and Saturated Hydraulic Conductivity

	Particle Size (g/kg)			Bulk density	Total porosity	Hydraulic conductivity	Permeability Class
Treatment	Sand	Silt	Clay	(g/cm^3)	(%)	(cm/hr)	
Control	871	35	94	1.35	21.22	12.96	Very slow
PM_5	855	41	104	1.18	34.62	18.54	Slow
PM_{10}	854	40	106	1.24	26.70	23.13	Slow
$PM_{2.5}$ + $SMS_{2.5}$	873	39	88	1.25	24.86	15.15	Very slow
PM_5 + SMS_5	865	55	80	1.27	22.60	20.22	Slow
LSD (P = 0.05)	8.26	4.62	8.69	0.06	6.81	2.06	

3.2.2 Aggregate Stability

Aggregate stability measured by percent water stable aggregate and mean weight diameter (MWD) of water stable aggregate (Table 4) showed that water stable aggregates were improved with the treated plots when compared with the control plots. The highest value was in PM_{10}. This is in agreement with the assertions of Lee *et al.* (2004) that organic wastes enhanced soil aggregate stability.

Table 4: Effect of poultry manure and spent mushroom substrate on Aggregate Stability

Treatment	Aggregate Sizes (mm)					MWD (mm)
	4.75 - 2	2 – 1	1 – 0.5	0.5 – 0.25	<0.5	
Control	5.7	6.4	16.0	35.60	36.3	0.587
PM_5	6.0	7.0	16.4	32.1	38.5	0.599
PM_{10}	8.7	9.2	25.7	35.6	20.8	0.784
$PM_{2.5}$ + $SMS_{2.5}$	8.1	9.8	18.3	33.6	30.2	0.721
PM_5 + SMS_5	8.2	10.6	20.1	38.0	23.1	0.758
Mean	7.34	8.60	19.30	34.98	29.78	0.690

3.3 Chemical properties of the soil after poultry manure and spent mushroom substrate application

3.3.1 pH, Organic Matter and Total Nitrogen

The pH, Organic Matter and total Nitrogen of the soil are shown in Table 5. pH ranged from 4.1 for PM_{10} to 4.7 for PM_5 . The highest pH was recorded for PM_5 . The soil was generally slightly acidic. Organic matter ranged from 13.60 g kg^{-1} for control to 27.08 g kg^{-1} for PM_{10} . The organic matter content showed significant increase in treatment plots compared with the control plot indicating different rates of poultry manure alone or in combination with spent mushroom substrate which significantly increased the soil organic matter. Adeli *et al.* (2009) noted that addition of poultry manure to the soil increase organic matter content.

Total Nitrogen ranged from 1.29 g kg^{-1} for control to 1.94g/kg for PM_5 + SMS_5. The total nitrogen showed significant increase in treatments plot compared with the control plot. The highest was recorded for treatment combination of spent mushroom substrate (PM_5 + SMS_5) followed by the highest rate of 10 tons/ha of poultry manure (PM_{10}) This implied that poultry manure supplied nitrogen more; confirming the study by Bitzer and Sims, (1988).

Table 5: Some chemical properties of the soil as influenced by poultry manure and spent mushroom substrate

Treatment	pH (H2O)	Organic matter (g/kg)	Total nitrogen (g/kg)
Control	4.5	13.60	1.29
PM_5	4.7	20.47	1.78
PM_{10}	4.1	27.08	1.91
$PM_{2.5}$ + $SMS_{2.5}$	4.3	20.43	1.48
PM_5 + SMS_5	4.2	25.60	1.94
LSD (P = 0.05)	0.14	0.50	0.31

3.4 Weed growth characteristics

3.4.1 Weed species composition

Table 6 shows the effect of poultry manure and spent mushroom substrate on weed species composition before planting and after treatment application at harvest. A total of 15 dominant weed species belonging to 9 families were found at the experimental site before planting. Ten (10) broad leaf weeds were identified, grasses (3) and sedges (2). After treatment application at harvest, the same weed species identified before planting were also present before planting or treatment application, which implied that no new weed species were found. After treatment application, the control plot had 73.3 % weed species, which was slightly higher than plots treated with poultry manure and spent mushroom substrate probably as a result of ineffective weed control. The reduced weed species observed in the control plots could also be attributed to senesce of some weed species such as *Celosia isertii, Ageratum conyzoides, Euphorbia heterphylla, Setaria barbata* either as a result of old age or shading effect of the leaves which intercepted solar radiation that could had induced their growth.

Table 6: Effect of poultry manure and spent mushroom substrate on weed species composition (%) before planting and after treatment application at harvest

Weed species	Plant family	GF	Bf	After treatments application at harvest				
				0	PM_5	PM_{10}	$PM_{2.5}$ + $SMS_{2.5}$	PM_5 + SMS_5
Broad Leaves								
Alternanthera pungens	Amaranthaceae	PBL	+	+	+	+	+	+
Celosia isertii	Amaranthaceae	ABL	+	X	X	X	X	X
Ageratum conyzoides	Asteraceae	ABL	+	X	X	X	X	X
Euphorbia heterphylla	Asteraceae	ABL	+	X	X	X	X	X
Platostoma africanum	Lamiaceae	ABL	+	+	X	X	X	+
Peperomia pellucida	Piperaceae	ABL	+	+	+	+	+	+
Portulaca quadrifida	Portulaceae	ABL	+	+	+	+	+	+
Mitracapus villosus	Rubiaceae	ABL	+	+	+	+	+	+
Oldenlandia corymbosa	Rubiaceae	ABL	+	+	+	+	+	+
Pouzolzia guineensis	Urticaceae	ABL	+	+	X	X	X	X
Grasses								
Acroceras zizanioides	Poacea	PG	+	+	+	+	+	+
Digitaria horizontalis	Poaceae	AG	+	+	X	+	+	+
Setaria barbata	Poaceae	AG	+	X	X	X	X	X
Sedges								
Cyperus esculentus	Cyperaceae	PS	+	+	+	+	+	+
Cyperus rotundus .	Cyperaceae	PS	+	+	+	+	+	+
% Total composition			100	73.3	53.3	60	60	66.7

Key: GF = Growth form, Bf = before planting, ABL=Annual broadleaf, PBL= Perennial broadleaf, PS= Perennial sedge, PG=Perennial grass, AG= Annual grass. X= absent, + = present.

3.4.2 Weed density and dry weight

Table 7 shows the effect of poultry manure and spent mushroom substrate on weed density and dry weight. There were no significant differences among the treatments on weed density and dry weight. This implied that none of the treatments had advantage over one another in terms of suppression of weeds. Although there were no significant differences among the treatments plot treated with 5 tonnes of poultry manure tended to have lower weed density and dry weight. The probable reason for this could be attributed to better canopy formation resulting from high leaf area index which intercepted solar radiation that could had stimulated weed growth. Weed suppressive effect of crops due to greater leaf area index had been reported by several researchers (Binang *et al.* 2016; Anorvey *et al.* 2018) Crotser and Witt (2000) noted that plants with greater leaf area index area are more competitive against weed growth as a result of being able to capture higher Photosynthetic Active Radiation (PAR) .

Table 7: Effect of poultry manure and spent mushroom substrate on weed density and weed dry at harvest

Treatment	Weed density (no/m^2)	Weed dry weight(g/m^2)
Control	929.2	102.50
PM_5	926.2	100.00
PM_{10}	927.2	100.50
$PM_{2.5}$ + $SMS_{2.5}$	927.5	100.75
PM_5 + SMS_5	928.8	101.25
LSD (P = 0.05)	10.08NS	927.5NS

NS = Not significant at 5% level of probability

3.5 Maize performance

Table 8 shows the effect of poultry manure and spent mushroom substrates on growth attributes and grain yield of maize. The plant height differed significantly among the treatments. Plot treated with $PM_{2.5}$ + $SMS_{2.5}$ produced the tallest plants while the control plots produced the shortest plants. Plot treated with $PM_{2.5}$ + $SMS_{2.5}$ produced the tallest plants probably as a result of proper synergic which enable them to have better nutrients supply particularly nitrogen and phosphorus required for plant growth. The leaf area index ranged from 5.0 for PM_5 to 4.0 for control. The treated plots showed significant improvement compared with the control. The high leaf area index recorded in 5 tons of poultry manure could be attributed to the ability of the rate to supply optimum nutrients particularly nitrogen to plant for leaf expansion. This finding is agreement with that of Zhao *et al*. (2003) who noted that nutrients especially N, increase leaf area index in maize plots treated with N source and decrease leaf area index of plants in plots without application of N source as a result of nutrient deficiency particularly nitrogen.

There was significant (P < 0.05) increase in grain yield over the control; this implied that although the yield in grains from combination of different rates of poultry manure with spent mushroom substrate is lesser than those obtained from the application of poultry manure alone, it was far greater than the yields obtained from control plots (Table 8). Hussain *et al.* (2002) noted that lack of application of fertilizer in poor soils result to sweet corn zero yield. The highest grain yield was recorded for PM_5 probably because 5 tons/ha could be the optimum rate that was compatible to maize in the area of study. The low value of grain yield in plot treated with 10 tons/ha of poultry manure when compared with the high yield obtained in plots treated with 5 tons /ha might be attributed to excess supply of nutrients to the soil which favors more increase in vegetative growth which was detrimental to grain yield. Agba *et al* (2012) observed similar finding in maize where there was a decrease in yield beyond optimum level of poultry manure.

Table 8: Effect of poultry manure and spent mushroom substrates on growth attributes and grain yield of maize

Treatment	Plant height (cm)	Leaf area index	Grain Yield (kg/ha)
Control	159.0	4.0	1780
PM_5	177.4	5.0	4020
PM_{10}	213.8	4.2	3688
$PM_{2.5}$ + $SMS_{2.5}$	246.9	4.6	3604
PM_5 + SMS_5	197.3	4.8	2500
LSD (P = 0.05)	1.99	0.35	299.74

4 CONCLUSION

It can be seen that the application of organic manures improve the physical and chemical properties of the soil and plays a critical role in sustaining soil quality, strength and productivity. Application of 5 tons / ha poultry manure (PM_5) and 10 tons / ha of poultry manure (PM_5) improves soil physico-chemical properties and sustain productivity than when poultry manure was combined with spent mushroom substrate as $PM_{2.5}$ + $MW_{2.5}$ and PM_5 MW_5. Weed suppressive effect tends to be better in plots that received 5 tons/ha of poultry manure when compared to other treatments. In the same vein, plots that received 5 tons/ha of poultry manure had the highest grain yield when compared to other treatments. Since the application of poultry manure at 5 tons/ha can greatly improve soil physico-chemical properties, suppressed weed growth which led to higher grain yield of maize it is thus recommended to farmers in the area of study.

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