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CONTRIBUTIONS OF ORGANIC AMENDMENTS TO EXCHANGEABLE POTASSIUM PERCENT AND SOIL NITRATE CONCENTRATION IN AN ULTISOL AND THEIR EFFECT ON MAIZE (*ZEA MAYS* L) GRAIN YIELD

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ABSTRACT
The effect of organic wastes on soil exchangeable potassium percent (EPP), Nitrate (NO_3^-) concentration and maize yield was evaluated in an ultisol during the 1999, 2000 and 2001 cropping seasons. The experiment was a split plot in randomized complete block design (RCBD). The wastes comprising poultry droppings (PD), cow dung (CD), swine waste (SW) and sewage sludge (SS) were applied concurrently (at the rates of 0, 12 and 24 kg/Plot), equivalent to 0, 10 and 20 t ha^{-1}) for two years and the residual effect tested in the third year. Results of the study show that soil EPP values ranged between 2.4 and 4.3% (first season), 1.8-3% (second season) and 1.2 – 2.7% (third season) in waste amended plots. Similarly wastes significantly ($P \leq 0.05$) increased soil NO_3^- concentration with percentage increase of 8 to 30% (first season) 25 to 39% (second season) and 43% to 143% (third season) relative to the control. Grain yield significantly ($p \leq 0.05$) increased in waste amended plots relative to the control. Results of the study also showed that grain yield correlated positively with EPP and NO_3^- concentration in the first and second seasons, indicating that both elements contributed to the final grain yield. However, non-significant correlation was observed between grain yield and the studied parameters (EPP and NO_3^-) in the third season, indicating that the amendments contributed less to grain yield in the residual trial. The results of the study showed that the amendments increased soil EPP and NO_3^- concentration to non-toxic level and are therefore, safe for agricultural use at the rates studied.

Keywords: Exchangeable potassium percent, organic wastes, soil nitrate concentration, grain yield

INTRODUCTION
Crop production in the tropics is largely dependent on the use of inorganic fertilizers that are scarce and expensive. The soils are known to be low in organic matter and deficient in N and available P in most cases. According to Food and Agricultural Organization (FAO, 1975), low crop yield in most tropical soils is traceable to the abandonment of the culture of building soil organic matter (SOM) through nutrient restoration, bush fallow or shifting cultivation. The use of inorganic fertilizer to marginally increase yield, particularly after the Second World War, has resulted in long-term deterioration of soil physical properties. Physical deterioration of soil is associated with the depletion of SOM, a situation that can worsen inorganic fertilizer application. Studies have shown that productivity of many tropical soils cannot be maintained by the use of inorganic fertilizer alone (Nambiar, 1995, Beets 1990), thus leading to increasing studies on organic wastes as alternative fertilizers (Agbim 1981, Mbagwu and Piccolo, 1990b). The organic wastes provide a continuous decomposition substrate and consequent gradual input of SOM, thereby improving the soil physically. While the positive influence of organic wastes has been affirmed (Anikwe 2000, Nyamangara 2001, Mbagwu *et al.*, 1994) on ultisols, information on the levels (rates) and intensity of soil application of these wastes to avoid excessive build up of certain elements or compounds that could constitute potential hazards to crops and human beings are limited or scarce. Mbah *et al* (2005) observed that soil application of sewage sludge and swine waste at 20 t ha^{-1} could lead to toxic levels of soil sulphate. Similarly, Smith (1996) reported ground water pollution due to high doses of waste application. Again, Johnson

and Wolf (1995) observed that in well aerated soil high doses of agricultural wastes resulted in the formation of large amounts of nitrate which according to Adams *et al.* (1994) is not fixed in appreciable quantities by soil and thus could be leached to the ground water. The objective of this study was to find out the effect of soil application of three rates of animal wastes (sewage sludge, cow dung, swine waste and poultry droppings) on soil exchangeable potassium percent (EPP), nitrate concentration and maize (*Zea may* L) yield in an ultisol in Southeastern Nigeria.

MATERIALS AND METHODS

This study took place at the Teaching and Research Farm of Ebonyi State University, Abakaliki, during the 1999, 2000 and 2001 cropping seasons. Abakaliki (06^0 4^1N, 08^0 65^1E) has a mean annual rainfall of 1700 mm, distributed between April and November. The soil is an ultisol, classified as Paleudult (FDALR 1985).

Treatments and Experimental Design

The treatments consisted of cow dung (CD), swine waste (SW) poultry droppings (PD) - all collected from the animal science section of Ebonyi State University Abakaliki and sewage sludge (SS, collected from sewage disposal site in University of Nigeria, Nsukka) applied at three (3) rates viz 0, 12 and 24 kg/plot equivalent to 0, 10 and 20 t ha^{-1}. The wastes were dried at room temperature, crushed to fine particles, sieved with 2 mm sieve and analyzed for its nutrient content (Table 1) before application to the soil.

The experiment was laid out as a split-plot in randomized compete block design (RCBD) with the animal wastes as the main plot treatment and the rates as the subplot treatment. A total land area of 0.0595ha, comprising of 3 blocks and 12 experimental units each (3x4m) with plot alley of 0.5m was used for the study. The area was manually cleared and the trashes removed at the inception of the experiment in 1999. The amendments were evenly spread on the appropriate plots and worked into the soil during tillage. The applied amendments were allowed to decompose 7 days before planting the test crop (Zea mays L, Oba super 11 variety). Two grains of maize were planted per hole and thinned down to one per stand two weeks after germination . At maturity the test crop was harvested, dried, threshed, weighed and yield data adjusted to 14% moisture content. The experiment was repeated in the second and third cropping seasons, using the same procedure as in the first cropping season, however, without application of wastes in the 3rd cropping season. This season was used to test the residual effect of the wastes. Composite soil samples were collected from 6 observation points at the depth of 0 – 20 cm before the start of the experiment. Similarly, at the end of the study soil samples were collected from the plots at depth of 0 – 20 cm and composited. The soil samples were air dried at room temperature (about 26^0C) and passed through a 2 mm sieve. The result of the analysis of the initial soil sample shows the following chemical properties, viz- Exchangeable Ca, 2.1 cmol (+) kg^{-1}, K, 0.3 cmol (+) kg^{-1}, Mg,1.1 cmol (+) kg^{-1}, Na, 0.17 cmol (+) kg^{-1}, pH (H_2O), 5.9. Available P, 3.2 $mgkg^{-1}$ and OM, 1.03 cmol (+) kg^{-1}. Soil samples were analyzed for Ca and Mg using the complexiometric titration method of Chapman (1982) whereas Na and K content were determined from 1.0 N ammonium acetate solution/extract using flame photometer. Exchangeable potassium percent (EPP) was calculated thus

$$EPP = \frac{K^+}{CEC} \times \frac{100}{1} \quad .... 1$$

The soil nitrate content was determined using the phenoldisuphonic acid method thus;

1. Shake 20.0 g of soil in 250 ml conical flask for 10 minutes with 100 ml, 0.25% $CuSO_4$, using water to dissolve it. Add 1g of a mixture of $Ca(0H)_2$ and $MgC0_3$. Shake for 10 minutes.
2. Decant into whatman No. 1 filter paper. Collect the filterate for determination.

Data collected from the study were analyzed using analysis of variance based on split plot in randomized complete block design.

RESULTS AND DISCUSSIONS

Table 1 shows that Ca, Na and K concentrations in wastes were highest in PD, while CD gave the highest concentration of Mg.

Table 1: Nutrient Content of the Wastes

Parameters	Unit	PD	SS	SW	CD
Ca	%	6.4	3.0	5.3	4.6
K	%	3.2	0.43	0.63	0.45
Mg	%	1.96	1.20	2.16	2.04
Na	%	0.72	0.36	0.44	0.36

On the average, the order of nutrient concentration was PD > SW > CD > SS, reflecting the feed and food quality of the animals and human being producing the waste.

Table 2: Effect of Wastes on Exchangeable Potassium Percent (EPP)

Treatment		First Season	Second Season	Third Season
C	Unit	1.9	1.8	1.1
SS_{10}	%	2.4	3.1	1.2
SS_{20}	%	4.3	2.9	1.3
SW_{10}	%	3.0	2.1	1.7
SW_{20}	%	3.2	2.0	2.7
CD_{10}	%	2.8	1.9	1.6
CD_{20}	%	3.2	2.0	1.7
PD_{10}	%	2.9	1.8	1.9
PD_{20}	%	3.5	1.8	2.2

Acceptable level: MAFF (1967), C = Control, SW = swine waste, CD = cow dung, SS = Sewage sludge and PD = poultry dropping. (Acceptable Level ≤25%)

Table 2 shows that waste application in the first season increased exchangeable potassium percent (EPP). The EPP values in the waste amended plots ranged between 2.4 – 4.3%, corresponding to 26 – 126% increase relative to the control. The highest value of 4.3% occurred in 20 t ha^{-1} SS amended plots. Observed % increase in EPP in the second seasons ranged between 11 and 61% with PD having a zero increase. Residual values of EPP varied between 1.2 and 207%.

These values where 9 – 145% higher than the control. Exchangeable K is the portion of the soil K that is electro statically bound as an outer – sphere complex to the surface of clay minerals and humic substance. This portion of K is readily exchanged with other cations and also readily available to the plants. Exchangeable potassium percent (EPP) above 25% has been reported (MAFF, 1967) to have adverse effect on soil permeability and structure. Increases observed in EPP due to waste application in this study are within the acceptable level.

Effect of Amendment on Soil Nitrate Concentration

Waste application significantly ($P < 0.05$) increased soil nitrate concentration in all the seasons (Table 3).

Table 3: Effect of Amendment on Soil Nitrate Concentration

Treatment	Unit	First Season	Second Season	Third Season
SS_{10}	Mgl^{-1}	10.8	10.8	14.0
SS_{20}	,,	16.6	10.0	20.0
SW_{10}	,,	19.0	11.1	10.0
SW_{20}	,,	17.0	11.0	14.0
CD_{10}	,,	14.0	10.0	11.0
CD_{20}	,,	14.0	10.0	17.0
PD_{10}	,,	13.0	11.0	11.0
PD_{20}	,,	14.0	10.1	12.0
C	,,	10.0	8.0	7.0
$LSD_{0.05}$(A		0.515	0.467	0.057
®		0.427	0.312	0.221
(A X R)		0.810	0.639	0.467

Acceptable Level: Long (1967), C=Control, SW= swine waste, SS sewage, Sludge, CD cow dung, PG= poultry droppingscc (Acceptable Level ≤ 45 Mgl^{-1})

The highest value of 19 mg L^{-1}, corresponding to 90% increase relative to the control was obtained in 10 t ha^{-1} SW- amended plots in the first season. Soil nitrate values ranging from 10 – 11.1 mg L^{-1} were obtained in the second cropping season. The Table showed that soil nitrate concentration was higher in the first than in the second cropping season. For instance at 10 t ha^{-1}, SW increased soil nitrate by 90% and 39% in the first and second cropping seasons, respectively. Residual % increase in soil NO_3^- following waste application could be attributed to increased output of organic or NH^+_{4-N} in line with the observations of Adriano et al (1973). Similarly, bioxidation of OM, such as that occurring during decomposition, affects the available forms of nitrogen (Miguel et al, 1996). At the onset of decomposition compounds such as amino acids, proteins, etc are mineralized to give NH_4^+. As a result their contents decreased through volatilization or subsequent oxidation to NO_3^- (Garcia, 1990) which may have accounted for higher levels observed in waste amended plots. Soil NO_3^- is the major form of nitrogen available as nutrients to plants. Nitrate in excess may accumulate in plant tissues in response to high N levels in waste amended soils and ruminants are quite susceptible to NO_3^- poisoning. Similarly, soils receiving high levels of wastes release NO_3^- rapidly enough to pollute shallow aquifers, especially on sandy soils (Smith, 1996). Longe (1967) reported that soil NO_3^- concentration above 45 Mgl^{-1} constitutes potential problems in drinking water. Results obtained from the study showed that soil NO_3^- levels due to waste application at the studied rates were within acceptable level in soils.

Effect of wastes on maize grain yield (t ha^{-1})

Maize grain yields in the three seasons were significantly ($P < 0.05$) increased in the waste amended plots relative to the control (Table 4).

Table 4: Effect of wastes on maize grain yield (t ha^{-1})

Amendments	First Season	Second Season	Third Season
C	1.26	1.22	0.38
SS_{10}	2.46	3.25	2.06
SS_{20}	2.70	3.80	2.27
SW_{10}	2.62	3.20	2.10
SW_{20}	3.08	4.02	2.22
CD_{10}	2.41	3.78	2.22
CD_{20}	2.68	3.78	2.23
PD_{10}	**2.64**	**3.66**	**2.19**
PD_{20}	**3.10**	**4.16**	**2.15**
LSD $_{0.05}$			
Amendment (A)	**0.097**	**0.171**	**0.062**
Rates (R)	**0.103**	**0.099**	**0.268**
A x R	**0.105**	**0.216**	**0.121**

C= Control, SW = swing waste, SS = sewage sludge CD = cow dung, PD = poultry droppings.

The highest grain yields of 3.10 and 4.16 Mg ha^{-1}, corresponding to 146 and 241% increase relative to the control, were obtained in 20 t ha^{-1} PD amended plots in the first and second seasons, respectively. Similarly, amendments increased grain yield relative to the control in the third season with highest value of 2.23-Mg h^{-1} observed in CD amended plot. This value corresponds to 487% increase relative to the control. The highest value obtained in CD – amended plots in the third season may be attributed to its slow decomposition and release of nutrients as observed by Mbah and Mbagwu (2003). Addition of wastes may have decreased soil bulk density and increased soil porosity, thereby increasing root penetration, water transmission and cumulative feeding area of crops, all of which translated to better yield, in line with the studies of Nnabude and Mbagwu (1998). Relationship between grain yields (Y) and Exchangeable K/total Nitrogen of the soil The relationship between exchangeable K, total N and grain yield is presented in Table 5.

Table 5: Relationship between grain yields (Y) and Exchangeable K/total (Z) Nitrogen of the soil

Season	Dependent Parameter	Regression equation	Coefficient of determinant r^2
First Season	Ex. K Cmol (+) Kg^{-1}	Y = 0.99 + 8.0(k)	0.49^{**}
	Total N Cmol (+) Kg^{-1}	Y = - 1.68 + 3.9(TN)	0.692^{**}
Second Season	Ex. K Cmol (+) Kg^{-1}	Y = -0.983 + 30.0(k)	0.70^{**}
	Total N Cmol (+) Kg^{-1}	Y = -3.412+65.02(TN)	0.663^{**}
Third Season	Ex. K Cmol (+) Kg^{-1}	Y = 0.901+10.37(k)	0.289^{NS}
	Total N Cmol (+) Kg^{-1}	Y = 0.908 + 1.013 (TN)	0.028^{NS}

** significant at P=0.01, Ns not significant

The results indicated that soil exchangeable K and total N correlated positively with grain yield in the first and second cropping seasons. This shows that both soil exchangeable K and total N contributed highly to the final grain yield. However, the relation between soil exchangeable K and total N was not significant in the third cropping season, indicating that after two years of application, the effects of the organic wastes were not significant

In conclusion the agronomic values of organic material should be assessed through the physical observation of crop response and performance in soil due to the amendment material. Crop yield response to organic material is highly variable and dependent upon many factors, including the type of organic material used. Similarly the organic material to be used as bio-fertilizer should not have any deleterious effect on the soil, crops and animals/human that use them. Results from the study showed that the organic material, at the applied rates increased crop yield and does not constitute potential EPP and NO_3^- problems. Thus, these wastes (CD, PD, SW, and SD) are recommended for use at the rates studied, as bio-fertilizers for sustained agriculture and increased crop production.

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