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EFFECTS OF APPLICATION OF COMPOST AND INORGANIC P ON SOIL CHEMICAL PROPERTIES AND MAIZE (*Zea mays* L.) GROWTH IN AN ULTISOL.

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ABSTRACT

The aim of this study was to assess the effects of separate and combined applications of composted poultry droppings and inorganic P on soil chemical properties and maize (*Zea mays* L.) growth in an Ultisol. The study was carried out in the screenhouse at Obafemi Awolowo University, Ile-Ife (latitude $7^0 32^1$ N and $7^0 33^1$ N and longitudes $4^0 32^1$ E and $4^0 40^1$ E). Bulk top soil (0-15 cm) sample was collected from a fallow land at the Teaching and Research Farm (T&RF) of the Institution located within the rain forest zone of Nigeria. The soil sample was air-dried, crushed gently and passed through a 2 mm sieve. There were two consecutive 8-week croppings of maize in the screenhouse. The treatments consisted of the compost mixed with half of the bulk soil or the whole bulk soil. The treatments were replicated thrice and arranged in a Completely Randomized Design (CRD). Maize agronomic parameters (height, dry matter yield, and nutrient uptake) and soil chemical properties (pH, Organic Carbon, total nitrogen, available phosphorus, and exchangeable K, Ca, Mg and Na) were determined at the end of each 8-week growth period. The data generated were subjected to analysis of variance (ANOVA) and the means separated using Duncan's New Multiple Range Test (DNMRT) at 5 % level of probability. Correlation analysis was also carried out using SAS 2000 package. The results showed that increase in the application of compost increased soil pH, plant height, dry matter yield and soil organic matter content.

It was concluded that the application of inorganic P and compost at the rates of 5 and 10 gkg^{-1} with and without half the recommended rate of P, mixed with half bulk soil enhanced plant height, dry matter yield, and organic matter content of the soil.

INTRODUCTION

P is a nutrient required for plant growth as it is intimately involved in a wide range of plant's physiological and biochemical processes. However, large areas of cultivated soils are deficient in plant-available forms of phosphate, thereby limiting agricultural production (Runge - Metzger, 1995). Phosphorus-based fertilizers are, therefore, applied routinely in agricultural systems in order to overcome P deficiency. About 17.5 million tonnes of P is processed annually from reserves of rock phosphates of which approximately 85 % is used in the production of fertilizers (Cordell *et al.,* 2009). However, the reserves are finite with an estimated depletion of quality sources expected to occur within the next 50-80 years (Isherwood, 2000).

The need to use renewable forms of energy and reduce costs of fertilizing crops has revived the use of organic fertilizers worldwide. Organic manures play vital roles in binding together soil particles and providing such plant nutrients as nitrogen (N) and phosphorus (P) (Korsaeth *et al.,* 2002). Compost additions enhanced available plant nutrients, plant growth and soil physical properties (Ahmad *et al.,* 2008; Zafar *et al.,* 2011). Early research on soils from Kenya (Friend and Birch, 1960) and Southern Nigeria (Adepetu and Corey, 1976) showed a strong and direct relationship between total soil organic P and plant available P.

For crops to optimize the benefits of applying organic and inorganic nutrients together, it is necessary to determine the effect of rates and method of application on microbial mineralization of the organic nutrients. While nutrients will be mineralized by microorganisms from the organic component, high microbial activity might be detrimental to plant growth in terms of nutrient immobilization (Olayinka and Ailenubhi, 2000; Olayinka, 2001).

Although, organic manures are bulky and release their nutrient contents slowly, their application improves soil structure, water holding capacity, aeration and drainage (Mc Vickar and Walker, 1978; Cooke, 1980). The objectives of the study were to evaluate the complementary applications of composted poultry droppings and inorganic P on soil chemical properties and maize agronomic parameters.

MATERIALS AND METHODS

The study was carried out in the screenhouse at the Obafemi Awolowo University, (OAU) Ile-Ife, Nigeria (Latitude $7^0 32^1$ N and $7^0 33^1$ N and Longitudes $4^0 32^1$ E and $4^0 40^1$ E). A bulk top soil (0 - 15 cm) sample was collected from a fallow land at the Teaching and Research Farm (T&RF) of OAU located within the rain forest zone of Nigeria. The bulk soil sample was air-dried, crushed gently and sieved using a 2 mm sieve. The study consisted of laboratory incubation and screenhouse experiments. Five hundred grammes (500 g) of air-dried soil (dry weight basis) was weighed into plastic containers. The treatments consisted of the compost mixed with vertical half or the whole soil. The treatments were replicated thrice and arranged in a Completely Randomized Design (CRD). Plant height, dry matter yield, soil pH and soil organic matter were determined. The soil culture experiment was carried out in the screenhouse. The data collected were subjected to analysis of variance and the means separated using Duncan's New Multiple Range Test at 5 % level of probability. Correlation analysis was also carried out using SAS 2000 package.

Screenhouse soil culture experiment

Based on the premise that plants require less of P than N, organomineral fertilizers were formulated by adding half of P recommended for maize (*Zea mays* L.) in Southwestern Nigeria. The treatments were the following :

i Control (C0P0)
ii Soil + P mixed with bulk soil (C0P1b)
iii Soil + P mixed with half bulk soil (C0P1h)
iv Soil + 5 g/kg compost + P mixed with bulk soil (C1P1b)
v Soil + 5 g/kg compost + P mixed with half bulk soil (C1P1h)
vi Soil + 10 g/kg compost added to bulk soil (C2P0b)
vii Soil +10 g/kg compost added to half bulk soil (C2P0h)

viii Soil + 10 g/kg compost added P added to P mixed with the bulk soil (C2P1b)

ix Soil + 10 g/kg compost added to P mixed with half bulk soil (C2P1h)

The inorganic P used was $Na_2HPO_4.12H_2O$. The half recommended rate of P was added to either 5 or 10 g/kg composted poultry droppings and the formulations were either mixed with vertical half or the whole bulk soil.

RESULTS AND DISCUSSION

Chemical properties of soil and composted poultry droppings

The properties of the soil and composted poultry droppings used in the screenhouse soil culture experiments are shown in Tables 1 and 2. The soil organic carbon and available P contents were 2.6gkg^{-1} and 27.45 mgkg^{-1} respectively. Soil pH was 6.1 and the concentrations of exchangeable K, Ca, Mg and Na were 0.49, 0.56, 1.05 and 0.32 cmolkg^{-1}, respectively. The pH of the composted poultry droppings was 6.1, 4.00 % OC, 0.50 % total N and 0.22 % P resulting in low C:N and C:P ratios of 8:1 and 18:1, respectively. Hence, the composted poultry droppings was expected to mineralize readily. The total K, Ca, Mg and Na contents were 0.22 %, 0.36 %, 0.33 % and 0.03 %, respectively.

Effects of composted poultry droppings on plant height and dry matter yield

Table 4 shows that at the end of the first cropping, although the tallest plant was obtained with C0P1h (P added to half the bulk soil), it was not significantly ($P \leq 0.05$) different from

Table 1: Properties of the soil used for the screenhouse soil culture experiments.

Properties	Values
Sand (g kg^{-1})	730
Silt	160
Clay	110
Texture	Sandy loam
pH ($CaCl_2$, 1:2)	6.1
Organic carbon (g kg^{-1})	7.6
Total N (g kg^{-1})	1.8
Available P (mg kg^{-1})	27.50
Exchangeable cations (Cmol kg^{-1}) :	
K	0.49
Ca	0.56
Mg	1.05
Na	0.32

the control, C0P1b and C1P1h. The other treatments were also not significantly different from the control and C0P1b. This trend showed that P was probably immobilized in the presence of the compost. Dry matter yields were significantly ($P \leq 0.05$) affected by the treatments at the end of

Table 2: Properties of the composted poultry droppings used for the laboratory incubation and screenhouse soil culture experiments

Properties	Values
pH ($CaCl_2$)	6.1
Organic carbon (%)	4.00
Total N (%)	0.56
C:N	8.1
Total P (%)	0.22
C:P	18:1
Cations (%)	
K	0.22
Ca	0.36
Mg	0.33
Na	0.33

Table 3: Maize (*Zea mays L.*) Plant height (cm) and total dry matter yields (g) at the end of the first (1) and second (2) 8-week croppings of maize (*Zea mays L.*) in the screenhouse.

Treatments	Plant height (cm)		Total dry matter yield (g)	
	1	2	1	2
C_0P_0	144.67abc	73.33a	18.82i	14.07i
C_0P_1b	137.57abc	97.00a	21.93d	21.47b
C_0P_1h	161.30a	83.83a	24.17a	22.13a
C_1P_1b	150.20ab	92.00a	19.90h	16.30g
C_1P_1h	121.67bc	96.67a	20.87f	18.37f
C_2P_0b	122.33bc	85.67a	21.80e	16.10h
C_2P_0h	112.83c	78.00a	20.67g	20.50d
C_2P_1b	121.67bc	90.33a	22.70c	20.63c
C_2P_1h	126.67bc	77.67a	23.13b	18.80e

*Means followed by different letters within the same column are significantly different (Duncan's New Multiple Range Test, $p < 0.05$) Where C_o= Control; P_o= no addition of P; C_1 = 5 g/kg composted poultry droppings; C_2 = 10 g/kg composted poultry droppings; P_1= 60 Kg P/ha; h= treatments applied to half the bulk soil; b= treatments applied to bulk soil.

Table 4: Soil reaction (Ph), OC (%), tissue N (%) and uptake (mg/pot) at the end of the first (1) and second (2) 8-week croppings of maize (*Zea mays L.*) in the screenhouse.

Treatments	pH		Organic carbon %		Nitrogen %		N (mg/pot)	
	1	2	1	2	1	2	1	2
C_0P_0	5.83NS	5.87ab	0.13a	1.59a	0.40ab	0.29a	56.28i	54.58i
C_0P_1b	6.23NS	6.30a	0.78b	2.16b	0.53b	0.39a	113.79d	85.53c
C_0P_1h	5.90NS	6.37a	0.29a	2.00a	0.50ab	0.38ab	110.65f	91.85b
C_1P_1b	5.80NS	5.67b	2.16c	4.20d	0.46ab	0.31a	74.98g	61.69g
C_1P_1h	5.83NS	5.67b	2.12c	4.36d	0.63b	0.37ab	115.73c	77.33f
C_2P_0b	6.00NS	5.90ab	2.03c	4.29d	0.90c	0.38ab	144.90a	82.84e
C_2P_0h	6.13NS	6.20a	2.30c	4.30d	0.54b	0.29a	110.70e	60.03h
C_2P_1b	6.20NS	6.23a	2.42c	4.46d	0.34a	0.41ab	70.14h	93.07a
C_2P_1h	6.13NS	6.03a	2.02c	3.48c	0.66b	0.37ab	128.08b	85.47d

*Means followed by different letters within the same column are significantly different (Duncan's New Multiple Range Test, $p < 0.05$) Where C_o= Control; P_o= no addition of P; C_1 = 5 g/kg composted poultry droppings; C_2 = 10 g/kg composted poultry droppings; NS = not significant; P_1= (60 Kg P/ha); h= treatments applied to half the bulk soil; b= treatments applied to bulk soil.

Table 5: Exchangeable K, Ca, Mg and Na contents ($cmolkg^{-1}$) at the end of the first (1) and second (2) 8-week croppings of maize (*Zea mays L.*) in .the screenhouse.

Treatments	K		Ca		Mg		Na	
	1	2	1	2	1	2	1	2
C_0P_0	0.57NS	0.10b	21.60NS	7.17NS	0.71NS	4.42NS	0.19NS	0.07b
C_0P_1b	0.80NS	0.24a	15.99NS	11.02NS	0.35NS	4.36NS	0.27NS	0.07b
C_0P_1h	0.69NS	0.12b	28.33NS	7.11NS	0.38NS	4.32NS	0.23NS	0.09b
C_1P_1b	0.70NS	0.19ab	37.15NS	13.52NS	0.46NS	4.48NS	0.24NS	0.09b
C_1P_1h	0.62NS	0.12b	30.48NS	10.12NS	0.47NS	4.08NS	0.21NS	0.08b
C_2P_0b	0.77NS	0.11b	29.98NS	8.11NS	0.54NS	4.26NS	0.26NS	0.08b
C_2P_0h	0.70NS	0.10b	31.15NS	11.63NS	1.01NS	4.43NS	0.24NS	0.14ab
C_2P_1b	0.67NS	0.10b	17.52NS	11.88NS	1.32NS	4.45NS	0.23NS	0.18a
C_2P_1h	0.80NS	0.12b	25.90NS	7.37NS	0.88NS	4.30NS	0.27NS	0.11b

*Means followed by different letters within the same column are significantly different (Duncan's New Multiple Range Test, ($p \leq 0.05$) Where C_o= Control; P_o= no addition of P; C_1 = 5 g/kg composted poultry droppings; C_2 = 10 g/kg composted poultry droppings; NS = not significant; P_1= Recommended rate of P (60 Kg/ha); h= treatments applied to half the bulk soil; b= treatments applied to bulk soil.

both plantings with the yields in the control being significantly lower than in other treatments. At the end of the both croppings, dry matter yields were significantly ($P \leq 0.05$) higher with C0P1h than the remaining treatments. The dry matter yield in C2P1h was significantly higher than with C2P1b which together were also significantly higher than the remaining treatments. Hence, there were increased dry matter yields as the rate of compost increased, a finding similar

Table 6: The uptake of K, Ca, Mg and Na (mg/pot) at the end of the first (1) and second (2) 8-week croppings of maize *(Zea mays L.)* in the screenhouse.

Treatments	K		Ca		Mg		Na	
	(mg/pot)							
	1	2	1	2	1	2	1	2
C_0P_0	5.37NS	1.31c	2.46ab	0.18ab	0.37e	0.64d	0.58c	1.16c
C_0P_1b	9.21NS	3.35a	2.88ab	0.33a	0.63de	1.05a	0.69bc	1.70c
C_0P_1h	7.85NS	2.14b	3.19a	0.23ab	0.67cde	0.97ab	0.97abc	2.16bc
C_1P_1b	7.24NS	2.13b	2.04ab	0.13b	0.72bcde	0.64d	0.75bc	1.75c
C_1P_1h	5.24NS	1.59bc	1.80b	0.27ab	0.81abcd	0.79bcd	0.93bc	1.74c
C_2P_0b	6.57NS	1.50bc	1.69b	0.16b	1.01abc	0.67cd	1.05ab	1.52c
C_2P_0h	6.70NS	1.11c	1.63b	0.23ab	0.82abcd	0.89abc	0.89bc	3.28ab
C_2P_1b	5.49NS	1.18c	1.63b	0.25ab	1.07ab	0.86abcd	0.99ab	4.30a
C_2P_1h	5.39NS	1.11c	2.39ab	0.17ab	1.10a	0.83abcd	1.35a	2.38bc

*Means followed by different letters within the same column are significantly different (Duncan's New Multiple Range Test, ($p \leq 0.05$) Where C_o= Control; P_o= no addition of P; C_1 = 5 g/kg composted poultry droppings; C_2 = 10 g/kg composted poultry droppings; NS = not significant; P_1= Recommended rate of P (60 Kg/ha); h= treatments applied to half the bulk soil; b= treatments applied to bulk soil.

to that of Olayinka (2006). From this result, it appeared that more nutrients were available for plant uptake in C2P1h than C2P1b. At the end of the second cropping, the highest dry matter yield was obtained with C0P1h, followed by C0P1b indicating adequate plant nutrition in the absence of compost. Most of the nutrients in the compost had probably been mineralized and absorbed during the first planting.

Effects of composted poultry droppings and P additions on soil pH

Table 5 shows that C0P0 (Control), C1P1b and C1P1h significantly ($p < 0.05$) had the lowest pH values compared to other treatments at the end of both the first (1) and second (2) plantings. However, there was an increase in the pH values for treatments C0P1b, C0P1h and C2P0h which might have corresponded with the increase in rates of composted poultry droppings. This could be attributed to greater release of exchangeable cations with increase in the rate of composted poultry manure (Atoloye, 2014; Olayinka *et al.,*1996).

Effects of composted poultry droppings and P additions on soil organic carbon contents

Table 5 shows that soil organic carbon contents were significantly ($p < 0.05$) higher in (C1P1b, C1P1h, C2P0b, C2P0h, C2P1b and C2P1h) treatments that received compost whether mixed with half or the whole bulk soil than other treatments at the end of both the first (1) and second (2) plantings, and lowest in the control C0P0. The trend obtained in the control was expected as there was no addition of compost and inorganic P to this treatment.

Effects of the addition of compost on exchangeable K, Ca, Mg and Na on tissue P contents

Table 6 shows the application of inorganic P and or / compost to half and the whole bulk soil generally had no effect on the contents of exchangeable K, Ca, Mg and Na at the end of the 1st and 2nd croppings of maize. The uptake of these cations were generally significantly ($p \leq 0.05$) lower in the control at the end of both croppings. The trend obtained in the control was due to the fact that it had no addition of either organic or inorganic fertilizers. While significantly higher tissue K was obtained with C0P1b at the end of the 2nd cropping, the highest uptake of Ca was obtained with C0P1h at the end of the first cropping

Effects of the addition of compost on uptake of K, Ca, Mg and Na in the soil

Table 7 shows that there was no significant difference among the treatments in terms of the uptake of K, Ca, Mg and Na at the end of the first cropping. However, at the end of the second planting, treatments C0P1b, C1P1b, C2P0b and C2P1b were significantly higher than C0P1b, C1P1h, C2P0b and C2P1h. For Ca at the first planting, treatments C1P1b and C2P0b were significantly higher than their corresponding treatments C1P1h and C2P0h while there were also significant increases in C0P1h and C2P1h. At the end of the second planting, treatments C0P1b, C1P1h, C2P0h and C2P1b were significantly higher than C0P1h, C1P1b, C2P0b and C2P1h respectively. For Mg, the treatments C0P1h, C1P1h, C2P0h and C2P1h were significantly higher than at the end of the first planting. However, at the end of the second planting, C0P1b, C1P1h, C2P0h and C2P1b were significantly higher than other treatments.

However, for Na, the treatments C0P1h, C1P1h, C2P0b and C2P1h were all significantly higher than other treatments at the end of the first planting. At the end of the second planting C2P1h, C2P0h and C1P1b and C0P1h were significantly higher than other treatments. Hence, additions of compost and P enhanced the uptake of Na by the maize plant.

Correlations between soil chemical properties, maize agronomic parameters and nutrient uptake

Tables 8 and 9 show the correlations among the various parameters at the end of the first and second croppings of maize in the screenhouse. At the end of the first cropping, there was significant ($p \leq 0.05$) positive correlation between dry matter yield and Na uptake (r= 0.693**). There were significant ($p \leq 0.05$) correlations between plant height and Mg (r= 0.786*), OC and Mg (r =0.845**) Ca and K (r =0.996*) and Na and P (r = 0.889**).

Furthermore, at the end of the second planting, there were positive significant ($p \leq 0.05$) correlations between the pH and dry matter yield (r=0.803*), Na and K (r = 0.983*), pH and Mg (r = 0.833**), Mg and dry matter yield (r = 0.942**) and P and Ca (r = 0.892**). These trends showed that the nutrients and such soil chemical properties as OC, available P, Ca, Mg and Na were all positively involved in improving the agronomic parameters of maize, namely, height and dry matter yields.

CONCLUSION

The complementary application of both composted poultry droppings and inorganic P, mixed with half of the bulk soil enhanced the soil chemical properties, maize agronomic parameters and nutrient uptake.

Table 7: Correlations between soil chemical properties, maize agronomic parameters and tissue nutrient uptake at the end of the first 8-week cropping in the screenhouse

	OC	K	Ca	Mg	Na	T-N	T-P	T-K	T-Ca	T-Na	T-Mg	pH	Plant height
K	0.22456												
Ca	0.36874	-0.06851											
Mg	0.48477	-0.12618	-0.2867										
Na	0.30181	0.9955**	-0.04553	-0.07488									
N	0.25802	0.51483	0.35079	-0.33143	0.49107								
T-P	-0.04054	-0.06831	0.21011	-0.40611	-0.08532	0.14734							
T-K	-0.37084	0.50128	-0.08866	-0.5686	0.4843	-0.00429	0.21825						
T-Ca	-0.84486**	0.15793	-0.29382	-0.55267	0.08517	-0.19975	0.19346	0.55776					
T-Na	0.48889	0.49551	0.14657	0.31708	0.49433	0.4951	0.18041	-0.34587	-0.17394				
T-Mg	0.78712*	0.51409	0.08157	0.49463	0.55154	0.42333	0.09153	-0.31498	-0.51931	0.8631			
pH	0.24216	0.62059	-0.61769	0.49965	0.64035	0.0055	-0.22007	0.22698	-0.06319	0.31954	0.48621		
Plant height	-0.72287*	-0.14678	0.06676	-0.58254	-0.19559	-0.3554	0.18847	0.44479	0.78635	-0.37623	-0.6119	-0.49938	
Total dry matter yield	0.00743	0.53677	-0.2232	0.05427	0.51103	0.1782	0.52585	0.23147	0.35151	0.68539*	0.54409	0.46198	0.07162

Table 8: Correlations between the soil chemical properties, maize agronomic parameters and tissue nutrient uptake at the end of the second 8-week cropping in the screenhouse.

	OC	K	Ca	Mg	Na	T-N	T-P	T-K	T-Ca	T-Mg	T-Na	pH	Plant height
K	-0.23537												
Ca	0.5522	0.42963											
Mg	-0.13498	0.14238	0.39291										
N	0.09628	0.13398	-0.11458	-0.39203	0.16867								
T-P	0.31623	-0.12555	0.07508	-0.54179	-0.11228	0.11251							
T-K	-0.44063	0.90753**	0.21642	0.01461	-0.51724	0.26081	-0.05347						
T-Ca	-0.19989	0.32343	0.1634	-0.25269	0.0667	0.45065	0.43627	0.48529					
T-Mg	-0.26866	0.32432	0.03954	-0.05353	0.19858	0.47648	-0.01766	0.47429	0.80703				
T-Na	0.46885	-0.33746	0.39414	0.34634	0.98281**	0.26116	-0.0914	-0.39501	0.22193	0.36892			
pH	-0.36383	0.04561	-0.13268	0.29371	0.37854	0.37399	-0.20165	0.23586	0.52307	0.83288*	0.49666		
Plant height	0.29492	0.61718	0.56827	-0.30292	-0.09975	0.53714	0.30368	0.6182	0.50639	0.26663	-0.00999	-0.1208	
Total dry matter yield	-0.02843	0.19354	0.16602	-0.02051	0.40841	0.51414	-0.09604	0.32882	0.68999*	0.94223**	0.56608	0.80282	0.30614

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