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AMELIORATIVE EFFECTS OF POULTRY MANURE ON CADMIUM TOXICITY TO MAIZE (*Zea mays*)

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ABSTRACT

Plant uptake is one of the major pathways by which cadmium (Cd) in the soil enters the human food chain. This study was conducted to investigate the effects of poultry manure on cadmium uptake by maize. A pot experiment was conducted for nine weeks using soil samples amended with constant quantity of poultry manure (5 tons per hectare) and cadmium was applied at 0, 10, 20, 50 and 100 mg Cd kg^{-1}. Each rate was applied to the soils with and without poultry manure amendment. Results showed that the addition of poultry manure (PM) to the Cd polluted soil increased the height of maize particularly at 8 and 9 weeks after planting. The increment in maize shoot dry weight due PM addition were by 59 %, 19.25 % and 11.92 % at 50 mg Cd kg^{-1}, 20 mg Cd kg^{-1} and 10 mg Cd kg^{-1} respectively. The study also showed that maize grown in soil polluted with 100 mg Cd kg^{-1}, 50 mg Cd kg^{-1} and 20 mg Cd kg^{-1}, but amended with PM at 5 t ha^{-1} resulted in 10.43 %, 32.72 % and 125.94 % reduction in Cd uptake. There was also positive and significant correlation between maize Cd uptake and K uptake ($r = 0.48$ $p < 0.01$) and residual Cd in soil ($r = 0.42$ $p < 0.01$).

Keywords: Cadmium toxicity; poultry manure

INTRODUCTION

The potential toxicity of heavy metals in the environment either initially present or added as pollutant depends on their concentration in the soil, soil solution and exchangeable sites. The contamination of our environment with these heavy metals due to anthropogenic activities is a major environmental and human problem. Cadmium is a non-essential element and rates as one of the most hazardous heavy metal. It poses a significant indication of danger on food safety due to its mobility in the soil- plant system.

Cadmium partitioning in the soil is greatly affected by soil properties like soil pH, organic matter content (Mc Grath *et al.*, 2001), and soil solution ionic strength. The influences of soil pH and organic matter content are the most important in affecting the metal uptake by plant.

Application of organic materials such as poultry litter is known to affect the soil pH and therefore this material may through its effect on solubility or dissociation kinetics of heavy metal change the soil or liquid phase equilibrium. Heavy metal contained in the organic material may also affect the cadmium concentration in the soil. Hence, the increasing use of organic waste and animal manure (e.g., poultry manure) as fertilizer on large arable farms and in horticulture poses some risks from heavy contaminant.

Plants and soil organisms are highly active in the processes controlling solubility, mobility and uptake of elements from the soil solution. The plants' metal uptake is controlled not only by the soil types and soil conditions but also by plant species. One of the indirect ways of applying Cd to agricultural soils is the use of phosphate rocks (PRs). However, the addition of organic materials is a popular way of increasing the agronomic efficiency of PR. Thus, this increased efficiency could either have positive or negative effects on the dissolution and availability of cadmium. Hence, there is the need to document the effect of poultry manure on Cd uptake by plants. Therefore, the objective of this study was to determine the effect of poultry manure on the uptake of cadmium by maize.

MATERIALS AND METHODS

Soil sampling and analysis

Soil sample used for the experiment was collected from the University of Agriculture, Abeokuta cashew plantation at the depth of 0 – 15 cm (07 º 13.522[1] N, 003 º 26.121[1]E, Altitude 143m). The soil sample was fairly dried at collection, hence, air-dried for 24 hours and screened with 2 mm sieve. Analysis of the soil sample was carried out as follows: the pH was determined in 1:2 soil: water suspension by using glass electrode pH meter, and the organic matter was determined by the wet digestion (Walkley and Black, 1934) rapid titration method. Exchangeable bases were extracted with 1 M ammonium acetate; Na and K were analyzed by using flame photometry while Atomic absorption spectrophotometer was used to analyze Ca and Mg in the extracts. Available P was extracted with Bray-1-extractant and determined using a spectrophotometer. Total N was determined by the Kjedahl digestion method (Bremner, 1996). Available Cadmium was determined by atomic absorption spectrophotometer after the soil was extracted with 1M ammonium acetate solution (Kim et al., 2003). The particle size was determined by the pipette method (Gee and Bauder, 1986).

Poultry Manure Analysis

Cured poultry manure was collected, air-dried and screened through 2 mm sieve to remove unwanted materials. Nitrogen in the manure was analyzed by Kjedahl digestion method. The manure was digested with HNO_3 and sulphuric acid to analyze K and Na by using flame photometry, P by the vanado-molybdate method using spectrophotometer, Mg, Ca and Cd were analyzed by atomic absorption spectrophotometer.

Treatments Allocation

After all the analyses, 5 kg of air-dried soil sample was weighed into each plastic pot of 5-litres capacity. Cadmium was added to the soil sample in the pot at 5 rates, viz; 0, 10, 20, 50 and 100 mg kg^{-1} as $CdCl_2$. Poultry manure was applied to the soil samples at the rate of 5 tons/ha in each pot. Each pot with the soil sample amended with poultry manure and cadmium chloride salt as the treatments was mixed thoroughly which were watered for a week for interaction between the soil and applied materials (treatments). Two maize (*Zea mays*) seeds were then planted into each pot and later thinned to one per pot. Prior to the start of the experiment, the field capacity of the soil was estimated by adding a known amount of excess water to the soil, the amount of water that drained out of the soil was subtracted from the initial amount added to estimate the field capacity of the soil. All the pots were adequately watered with constant volume of water to maintain the field capacity of the soil sample. The experimental design was completely randomized with four replications.

Data Collection and Analysis

During the growing period, data on plant height were taken. Maize root and shoot weights were also taken at 12 weeks after planting (WAP).

Plant Sample Analysis

All the plant parts were separately oven-dried and later ground to take a representative sample for analysis. These plant samples were dry-ashed at 405^0 C and digested with HNO_3 and H_2SO_4. Total N content was determined by Kjedahl method, P by vanado-molybdate method using spectrophotometer and K was analyzed by using flame photometry. Cadmium content of the plant parts was then analyzed by atomic absorption spectrophotometer. Finally, the residual soil Cd content of pot was determined using AAS after ammonium acetate extraction. The data generated were subjected to analysis of variance (ANOVA) and correlation analysis; significant means were separated by Duncan Multiple Range Test.

RESULTS AND DISCUSSION

Table 1 shows both the chemical and physical characteristics of the experimental soil. The soil total nitrogen was 0.80 % and available phosphorus 1.55 mg kg^{-1}. The exchangeable Na was low, 0.08 cmol (+) kg^{-1} and Ca, was 3.98 cmol (+) kg^{-1}. Exchangeable Mg and K are 0.5 cmol (+) kg^{-1} and 0.43 cmol (+) kg^{-1}, respectively.

Table 2 shows the chemical characteristics of the poultry manure that was used. Nitrogen content of the poultry manure was 1.09 % while the phosphorus content was 14.75 mg kg^{-1}. The quantity of cadmium was 0.4 mg kg^{-1}.

Table 3 shows the effects of cadmium and poultry manure on maize plant height. At 4 WAP, the least maize height was observed in the treatment that had 100 mg kg^{-1} and 5 tons of poultry manure while the highest maize was observed in the pot that had 10 mg Cd kg^{-1} only. The difference between the two treatments was significant. Generally, the addition of poultry manure to the Cd polluted soil decreased the plant height, particularly at 4 and 6 WAP. However, there were significant reductions in maize plant height with poultry manure application in the treatments with 10 and 100 mg Cd kg^{-1}. The increment in plant height were 13.35 % and 10.81 % for 20 and 50mg Cd kg^{-1} rates and 43.58 % and 25.92 % reduction for 10 and 100mg Cd kg^{-1} application, respectively. The least plant height was also found at 6WAP in the treatment with 100 mg Cd kg^{-1} and 5 tons of poultry manure while the highest was recorded in the treatment with 10 mg Cd kg

$^{-1}$ only and both were significantly different. In general, the addition of poultry manure to the Cd polluted soil increased the maize plant height at 8 and 9 weeks after planting. Also, at 8 weeks after planting, the highest and lowest plant height were recorded in the treatments that had 20 mg Cd kg^{-1} and 5 tons of poultry manure and 50 mg Cd kg^{-1} only, there was a significant difference between the treatments. In overall, the addition of poultry manure to the soil that had been polluted with Cd increased the maize plant height. More so, there were significant reductions in maize height due to poultry manure inclusion in treatments with 100mg Cd kg^{-1}. The increases in plant height were 4.15 %, 42 %, 33 % and 19.82 % for 10, 20 and 50 mg Cd kg^{-1} rates and 1.13 % reduction for 100 mg Cd kg^{-1} application rate. At 9WAP, the highest and lowest plant height were both recorded at 20 mg Cd kg^{-1} only, the difference between the treatments was significant. Generally, the addition of poultry manure to the Cd polluted soil increased the maize plant height. However, there were no significant reductions in maize plant height due to poultry manure being included in the treatment. The increases in maize height were 0.49 %, 52.27 %, 13.34 % and 10.28 % for 10, 20, 50 and 100 mg Cd kg^{-1} rates. Therefore poultry manure increased the height of the maize at all rates of cadmium.

The effect of cadmium and poultry manure application on root and shoot dry weight is shown in Table 4. The highest root weight was observed in the treatment that had 5 tons poultry manure only while the highest weight of the root recorded at 50 mg Cd kg^{-1} only rate and both were significantly different. Generally, the addition of poultry manure to Cd polluted soil had inconsistent effect on the root dry weight. However, there were significant reductions in root dry weight due to poultry manure inclusion in the treatment that had 20 mg Cd kg^{-1} and 10 mg Cd kg^{-1}, the increase in root dry weight were 31.40 %.

Table 1: Chemical and physical characteristics of the experimental soil

N	P	Cd	pH	Organic matter	Available cations				Particle size distribution			Textural Class
					Na	K	Ca	Mg	Sand	Silt	Clay	
(%)	(mg kg^{-1})			%	(cmol(+) kg^{-1})				%			
0.80	1.55	ND	6.53	1.9	0.08	0.43	3.98	0.55	74	13.6	11.6	Loamy sand

ND = Not detected

Table 2: Composition of the poultry manure

Parameter	Unit	Value
N	%	1.09
K	%	0.38
Mg	%	0.24
Ca	%	2.09
Na	%	1.03
P	mg kg-1	14.75
Cd	mg kg-1	0.40

Table 3: Effects of cadmium and poultry manure on maize height

Treatment	Weeks after planting 4	6	8	9
Control	38.50^{a}	65.13^{abc}	81.55^{b}	100.68^{b}
5 tons PM only	34.05^{ab}	62.58^{ab}	98.13^{ab}	131.48^{ab}
10 mg Cd kg^{-1} only	39.59^{a}	67.20^{a}	101.15^{ab}	120.13^{ab}
10 mg Cd kg^{-1} + 5 tons PM	26.18^{bc}	48.23^{c}	105.35^{ab}	120.69^{ab}
20 mg Cd kg^{-1} only	28.83^{bc}	52.00^{bc}	84.59^{b}	98.61^{b}
20 mg Cd kg^{-1} + 5 tons PM	32.68^{abc}	52.45^{bc}	120.40^{a}	150.15^{a}
50 mg Cd kg^{-1} only	30.98^{abc}	47.70^{c}	79.85^{b}	103.13^{b}
50 mg Cd kg^{-1} + 5tons PM	34.33^{ab}	56.70^{abc}	95.68^{ab}	122.05^{ab}
100 mg Cd kg^{-1} only	30.60^{abc}	49.55^{bc}	83.18^{b}	101.65^{b}
100 mg Cd kg^{-1} + 5tons PM	24.30^{c}	47.98^{c}	82.25^{b}	112.10^{b}

Means with the same superscript in the same column are not significantly different ($p>0.05$)
PM = poultry manure

Table 4: Effects of cadmium and poultry manure on maize root and shoot dry weight

Treatment	Root ← (g)	Shoot →
Control	4.98^{ab}	14.85^{abc}
5 tons PM only	5.23^{a}	17.34^{ab}
10 mg Cd kg^{-1} only	2.85^{bc}	13.09^{ab}
10 mg Cd kg^{-1} + 5 tons PM	2.55^{c}	14.65^{ab}
20 mg Cd kg^{-1} only	4.19^{abc}	18.29^{ab}
20 mg Cd kg^{-1} + 5 tons PM	3.09^{abc}	21.81^{a}
50 mg Cd kg^{-1} only	2.44^{c}	9.65^{b}
50 mg Cd kg^{-1} + 5tons PM	2.90^{bc}	15.34^{b}
100 mg Cd kg^{-1} only	3.09^{abc}	13.26^{ab}
100 mg Cd kg^{-1} + 5tons PM	4.06^{abc}	10.31^{b}

Means with the same superscript in the same column are not significantly different ($p>0.05$)
PM = poultry manure

and 18.85 % for 100 and 50 mg Cd kg^{-1} rates and 35.60 % and 11.37 % reduction for 20 and 10 mg Cd kg^{-1} application, respectively. On the shoot dry weight, the highest value was recorded in the treatment with 20 mg Cd mg^{-1} only while the least was at 50 mg Cd kg^{-1} only, which was significantly different. Generally, addition of poultry manure to the soil that had been polluted by Cd increased the shoot dry weight. However, there were significant reductions in the maize shoot dry matter weight due to poultry manure added to the soil in treatment with 100 mg Cd kg^{-1} the percent increase in the shoot weight were 59 %, 19.25 % and 11.92 % for 50, 20 and 10 mg Cd kg^{-1} rates and 28.62 % reduction for 100 mg Cd kg^{-1} application rater, respectively.

Table 5 shows the effects of poultry manure and cadmium on N, P, K and Cd uptake by maize plants and the residual soil Cd. The uptake of quantity of N, P & K showed no significant difference in the treatments. However, poultry manure added to Cd polluted soil generally increased the amount of nitrogen uptake. The percent increases in nitrogen uptake was 27.83 %, 11.8 % and 5.22 % for 100, 50 and 100 mg Cd kg^{-1} rates and 17.83 % reduction for 20 mg Cd kg^{-1} application rates, respectively. Also, highest amount of phosphorus was taken by maize plant in pot where only poultry manure and cadmium was applied while the lowest uptake was found where 50 mg Cd kg^{-1} and 5 tones of poultry manure was applied, the difference was not significant. The increase in phosphorus uptake

Table 5: Effects of cadmium and poultry manure on N, P, K and Cd uptake by maize plants and residual soil Cd

Treatment	← Plant tissue concentration			→	Cd in Soil
	N	P	K	Cd	
	%	(mg kg-1)			
Control	1.08^{a}	773.13^{a}	2.32^{a}	0.25^{e}	0.41^{c}
5 tons PM only	1.31^{a}	799.38^{a}	2.01^{a}	0.55^{e}	0.00^{c}
10 mg Cd kg^{-1} only	1.34^{a}	758.13^{a}	1.86^{a}	2.46d^{e}	10.9^{c}
10 mg Cd kg^{-1} + 5 tons PM	1.41^{a}	768.75^{a}	2.43^{a}	4.40^{cd}	15.34^{c}
20 mg Cd kg^{-1} only	1.52^{a}	761.75^{a}	2.34^{a}	5.40^{cd}	20.64^{c}
20 mg Cd kg^{-1} + 5 tons PM	1.29^{a}	796.25^{a}	2.10^{a}	2.39^{de}	39.03^{bc}
50 mg Cd kg^{-1} only	1.27^{a}	788.13^{a}	2.43^{a}	9.41^{ab}	30.93^{bc}
50 mg Cd kg^{-1} + 5tons PM	1.42^{a}	576.25^{a}	2.00^{a}	7.09^{bc}	36.03^{bc}
100 mg Cd kg^{-1} only	1.15^{a}	769.38^{a}	2.21^{a}	12.49^{a}	75.64^{ab}
100 mg Cd kg^{-1} + 5tons PM	1.47^{a}	768.75^{a}	2.38^{a}	11.31^{a}	118.89^{a}

Mean with the same superscript in the same column are not significantly different ($p>0.05$)
PM = poultry manure

was 4.53 %, 1.40 % for 20 mg Cd kg^{-1}, 10 mg Cd kg^{-1} and 0.082% and 36.77 % for 100 and 50 mg Cd kg^{-1} application, respectively. Generally, poultry manure addition to the Cd polluted soil had inconsistent effect on the amount of phosphorus uptake. The percent increase in potassium up taken were 7.70 % and 30.64 % for 100 and 10 mg Cd kg^{-1} and 21.5 % and 11.43 % reductions for 50 and 20 mg Cd kg^{-1}. Generally, adding poultry manure to the Cd polluted soil had inconsistent effect on potassium uptake. Expectedly, the uptake of Cd showed that least amount was observed in control pot while the highest amount was observed at the rate of 100 mg Cd kg^{-1} only. The difference between the two treatments was significant. The increase in Cd uptake with increasing rates of application is consistent with the findings of Salim *et al.* (1993). However, there was significant increase in Cd uptake by maize due to poultry manure inclusion in the treatment with 10 mg Cd kg^{-1}. The percent reductions in Cd uptake by maize were 10.43 %, 32.72 % and 125.94 % for 100, 50 and 20 mg Cd kg^{-1} rates and 78.86 % increase for 10 mg Cd kg^{-1} application rates, respectively. Generally, the addition of poultry manure to the Cd polluted soil decreased the amount of Cd taken up. The residual Cd in the soil shows that pot with 5 tons poultry manure only had no soil cadmium. The highest amount was detected in pot with 100 mg Cd kg^{-1} and 5 tons poultry manure. The difference is significant between the two treatments. In general, the addition of poultry manure to the Cd polluted soil increased the residual Cd. The increase in Cd residual in soil were 57.18 %, 16.50 %, 89.10 % and 49.08 % for 100 mg Cd kg^{-1}, 50 mg Cd kg^{-1} and 10mg Cd kg application rates respectively. This might be connected with the ability of the poultry manure to form complexes with the applied Cd, hence, making the Cd available for subsequent crops or being leached to pollute ground water bodies. Similar results were reported by Hettiarachchi *et al*. (2003). However, the release of the poultry manure bound Cd may be over time (McBride, 1995).

Table 6 shows a positive and significant correlation between the uptake of P and N by maize plant. However, the negative correlation between the uptake of phosphorus and cadmium might indicate an antagonistic relationship between the uptakes of the two elements.

Table 6: Correlation coefficient between maize nutrients uptake and soil residual Cd

	N	P	K	Cd in Plant	Cd in Soil
N					
P	0.43**				
K	0.10 NS	-0.14 NS			
Cd in plant	0.18 NS	-0.08 NS	-0.10 NS		
Cd in Soil	-0.09 NS	-0.10 NS	-0.10 NS	0.42*	_

NS = Not significant
** = Significant at 1%

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CONCLUSION AND RECOMMENDATION

It is inferred from the experimental results that poultry manure increased maize height at later part of the growth stage despite the cadmium pollution. Shoot dry weight was also found to be increased by poultry manure in cadmium polluted soil. Moreover, ability of maize plant to absorb cadmium was also reduced by poultry manure, thus it is recommended that large quantity of poultry manure should be tried and applied on agricultural land polluted with cadmium. There was also positive and significant correlation between maize Cd uptake and K uptake ($r = 0.48$ $p < 0.01$) and residual Cd in soil ($r = 0.42$ $p < 0.01$).

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