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Effects of poultry manure, corn straw and sawdust on plant growth and soil chemical properties.

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Abstract

Portions of poultry manure corresponding to 3% (30g/kg) rate of addition (dwb) were mixed with corn *(Zea mays* L.) sraw and sawdust from *Canarium schweinfurthii Engl.* in the ratios of 4:1, 2:1 and 1:1 respectively. The poultry manure and its admixtures with the plant residues were mixed with airdried, seived (2mm) soil samples and allowed to incubate for 2 weeks. The treated soil was cropped with tomato *(Lycopersicon esculentum* L.) for 2 successive 8-week periods, in the greenhouse.

Except for tissue Mg, results indicate that the organic amendments significantly increased plant height, dry matter yield, organic C, soil pH, soil and tissue contents, and plant uptake of N, P, K, Ca and Mg compared to the control. Plant height, dry matter yield, organic C, and uptake of N, K, Ca and Mg were enhanced by the use of admixtures of poultry manure with corn straw and sawdust respectively compared to the use of poultry manure alone. Corn straw was, however, superior to sawdust in increasing plant nutrient uptake. The addition of plant residues to poultry manure led to significant reductions in soil NO_3-N. Available P was increased by sawdust-containing treatment over the poultry manure while corn straw reduced P availability though insignificantly.

Introduction

Wastes generated from domestic, agricultural and industrial activities continue to pose problems of disposal to the society. Application of wastes on agricultural land is a popular means of their disposal. Since organic wastes could enhance the levels of both major and minor elements in the soil (McCalla, 1974), these could be explored as an alternative to the costly commercial fertilizers to boost crop production. The beneficial effects of wastes on the soils' physical conditions have also been stressed (Darra *et al.*, 1968; May *et al.*, 1973; Aina and Egolum, 1980).

Unplanned waste disposal can promote several undesirable effects. For example, poultry manure because of its low C:N ratio, tends to decompose fast and release nutrients above the plant's uptake rate (Miller, 1974). Besides luxury consumption of NO_3-N by the plant (Wilkinson *et al.*, 1971; Macmillan *et al.*, 1972), underground water might be polluted (Marriot and Bartlett, 1972). Conversely, carbonaceous residues like corn straw and sawdust degrade slowly in soil and might cause N immobilization and depressed plant growth (Rennie and Heimo, 1984; Olayinka and Adebayo, 1985). In order to ameliorate this problem, the high C:N ratios of carbonaceous residues could be reduced through amendment with either inorganic (Azevedo and Stout, 1974; Sabey *et al.*, 1975) or organic nutrients (Olayinka and Adebayo, 1985).

In Nigeria, the present practice of waste disposal involves dumping or burning of most solid wastes. In an environment where soil organic matter degrades fast because of high temperature regimes (Jenkinson and Ayanaba, 1977), burning of organic wastes constitutes a loss of potential sources of organic matter. Applying poultry manure, straw and sawdust separately might produce detrimental effects on plant growth and environmental quality. However, when poultry manure is mixed with either straw or sawdust, the decomposition of the carbonaceous plant residues is enhanced thereby releasing essential nutrients for plant uptake. The aim of this investigation was to assess the effects of application of poultry manure and its mixtures with corn straw and sawdust on growth and nutrient uptake of tomato *(Lycopersicon esculentum* (L.) var. Ife Plum) and soil chemical properties.

Materials and Methods

A bulk soil sample was obtained from the plough-layer (0-15 cm) of Iwo series (Oxic Paleustalf) at the Obafemi Awolowo University Research Farm, Ile-Ife, Nigeria. The sample which was airdried and passed through a 2mm screen, was used for the greenhouse experiment. Particle size analysis by the hydrometer method (Bouyoucos, 1962) showed that the soil, a sandy loam, contained 75% sand, 12% clay and 13% silt. Chemical analysis of the soil is as follows: pH (0.01M $CaCl_2$) 5.9; Organic carbon 0.60%; Total N 0.08%; NO_3-N 8.7 ppm; Available P (Bray-1) 6.1 ppm; Exch. Ca, K, Mg, Na and CEC 1.94, 0.38, 1.78, 0.15 and 4.27 meq/100 g respectively.

Poultry manure was obtained from the Obafemi Awolowo University Commercial Farm. Dry corn *(Zea mays* L.) straw from unfertilized plots at the Soil Science Section of Obafemi Awolowo University Research Farm, was milled before use. Sawdust from *Canarium schweinfurthii* (Engl.) was obtained from a local sawmill in Ile-Ife. The chemical compositions of the organic wastes are as shown in Table 1.

TABLE 1: CHEMICAL COMPOSITIONS (% DWB) OF POULTRY MANURE CORN *(ZEA MAYS* L.) STRAW AND SAWDUST FROM *CANARIUM SCHWEINFURTHII* ENGL.

Organic waste	*Organic carbon*	*Total N*	*P Ratio*	*K*	*Ca*	*Mg*	*Na*	*C:N*
Poultry manure	12.7	2.10	0.71	1.06	1.42	0.58	0.33	6
Corn straw	35.7	0.84	0.33	0.12	0.09	0.04	0.02	43
Sawdust	65.1	0.55	0.21	0.06	0.08	0.03	0.01	118

Portions of poultry manure corresponding to 30 g/kg of addition to soil (dry weight basis) were weighed and were thoroughly mixed by hand with appropriate masses of corn straw and sawdust in the ratios of 4:1, 2:1 and 1:1 respectively. The admixtures were then thoroughly mixed with 5kg portions of airdried soil and transferred into 10-litre plastic pots perforated and plugged at the bottom to allow free exchange of air. The pots were watered to FMC and allowed to incubate for 2 weeks in the greenhouse. The treatments, replicated thrice and arranged according to Randomised complete block design included the following:

01:	Control									
02:	Soil	+	Poultry manure (PM)							
03:	Soil	+	poultry	manure	and	corn	straw	mixed	4:1	($PMST_1$)
04:	Soil	+	,,	,,	,,	- ,,	,,	,,	2:1	($PMST_2$)
05:	Soil	+	,,	,,	,,	,,	,,	,,	1:1	($PMST_3$)
06:	Soil	+	,,	,,	,,	sawdust	,,	,,	4:1	($PMSD_1$)
07:	Soil	+	,,,	,,,	,,,	,,,	,,,	,,,	2:1	($PMSD_2$)
08:	Soil	+	,,	,,	,,	,,	,,	,,	1:1	($PMSD_3$)

Three week-old tomato *(Lycopersicon esculentum* (L.) var. Ife Plum) seedlings of uniform height were transplanted one per pot. The seedlings were allowed to grow up to flowering stage (8 weeks) in the first instance. Plant heights were measured, shoots harvested and the roots were sieved out. The shoots and roots were later oven-dried at 70°C and ground in a Wiley Microhammer stainless steel mill prior to chemical analyses. The soil in each pot was thoroughly mixed and 50 g subsample was taken and airdried for chemical analyses. Nitrate nitrogen was determined in moist soil samples and reported on dry weight basis. A second planting was made using the previously cropped soil in each pot and the crop was allowed to grow for the same period of 8 weeks. Harvesting of tissues, soil sampling and treatments prior tc analyses were as earlier stated.

The organic C was determined using chromic acid digestion procedure of Walkley-Black (1934). Soil pH was read potentiometrically in a soil solution ratio of 1:2 in 0.01M $CaCl_2$. Total N was determined using steam distillation technique (Bremner and Keeney, 1966) after digestion of samples with conc. H_2SO_4 in the presence of Kjeldahl catalyst. Nitrate nitrogen was extracted in a mixture of 1N $CuSO_4$ and 0.6% Ag_2SO_4 solution and determined colorimetrically using the phenol-disulfonic acid method (Jackson, 1958). Available P was by Bray and Kurtz (1945) extraction method. Exchangeable cations were extracted using 1N NH_4OA_c solution (Chapman, 1965). Potassium and Na were read using flame photometry while Ca and Mg were determined on atomic absorption spectrophotometer. The organic wastes and tissue samples were digested with conc. H_2SO_4-H_2O_2 before the cations and phosphorus contents were determined.

Results and Discussions

Plant heights and dry matter yields:

The organic amendments significantly increased (P = 0.05) both the plant heights and dry matter yields of tomato (Table 2). This is expected since poultry manure is a rich source of major plant nutrients as earlier indicated in Table 1. The mixtures of corn straw or sawdust with poultry manure led to significant increases in plant height compared to poultry manure treatment alone. Since corn straw and sawdust have relatively high C:N ratios, immobilization of nutrients and depressed plant performance were expected (Rennie and Heimo, 1984; Olayinka and Adebayo, 1985). Apart from lowering the C:N ratios of the organic amendments in the presence of poultry manure, the decomposition of the carbonaceous residues might have con-

TABLE 2: PLANT HEIGHTS AND DRY MATTER YIELDS OF TOMATO (*LYCOPERSICON ESCULENTUM* L.) AT THE END OF TWO 8-WEEK PLANTINGS IN THE GREENHOUSE

Treatments	Plant heights (cm)			Dry matter (g/pot)		
	*1**	*2*	*Mean*	*1*	*2*	*Mean*
Control	37.3	36.7	37.0a**	1.65	1.14	1.40a
PM	53.3	46.0	49.7b	3.02	2.23	2.63b
$PMST_1$	65.0	52.3	58.7cd	4.59	3.37	3.98e
$PMST_2$	66.7	50.0	58.4cd	5.02	3.35	5.19e
$PMST_3$	68.0	54.3	61.2d	7.16	4.30	5.73f
$PMSD_1$	58.0	53.3	55.7c	3.29	2.46	2.88bc
$PMSD_2$	59.3	52.3	55.8c	3.67	2.87	3.27cd
$PMSD_3$	62.3	57.7	60.0cd	4.21	3.35	3.78de

* Each value is the mean of 3 replicates at the end of two successive 8-week plantings.

** Means followed by different letters are significantly different (Duncan's Multiple Range Test, P = 0.05).

tributed additional nutrients that led to increase in plant height.

With the exception of $PMSD_3$, all treatments containing corn straw gave a significantly (P = 0.05) higher dry matter yield than all other treatments. The treatment that received poultry manure alone produced yields significantly lower than those of $PMSD_2$ and $PMSD_3$ but not significantly different from that of $PMSD_1$. As earlier stated, these trends might be attributable to the release of additional nutrients from corn straw and sawdust.

Soil pH and organic carbon:

The organic amendments significantly increased (P = 0.05) both soil pH and organic C contents over the control (Table 3). Organic manures have been found to be capable of increasing soil pH because they contain exchangeable Ca, Mg and K (Agbim, 1977; Olayinka and Adebayo, 1983). Except for the treatment $PMSD_3$, the mixtures of poultry manure with corn straw or sawdust did not significantly increase (P = 0.05) soil pH when compared to soil treated with poultry manure alone. The organic C contents increased significantly with increases in the ratios of straw or sawdust in their mixtures with poultry manure. These carbonaceous plant residues contain more recalcitrant forms of C than poultry manure which has a low C:N ratio. No significant differences in organic C contents were found in treatments containing corresponding ratios of straw and sawdust.

Soil NO_3-N, tissue N contents and N uptake:

Soil NO_3-N contents were significantly increased (P = 0.05) by the addition of poultry manure and its mixtures with straw and sawdust to the soil (Table 3). The

TABLE 3: SOIL CHEMICAL PROPERTIES, TISSUE CONTENTS AND UPTAKE OF N AND P AT THE END OF TWO SUCCESSIVE 8-WEEK PLANTINGS OF TOMATO *(LYCOPERSICON ESCULENTUM* L.)

Treatments		*Soil*			*Plant*			
	pH	*O.C (%)*	*NO_3-N (ppm)*	*Bray-P (ppm)*	*Tissue (%) N*	*Tissue (%) P*	*Uptake (mg/pot) N*	*Uptake (mg/pot) P*
Control	5.57a*	0.54a**	4.45a	5.5a	2.35d	1.29a	32.90a	17.84a
PM	5.70b	0.66b	41.6b	17.7de	2.75a	2.08b	72.33b	54.72b
$PMST_1$	5.65b	0.73c	31.0d	19.0d	2.64abc	1.82c	105.07de	72.40c
$PMST_2$	5.68b	0.80d	27.05e	17.2e	2.67ab	1.77c	111.87e	74.37c
$PMST_3$	5.75b	0.92e	19.25f	16.4e	2.61abc	1.67c	149.55f	96.67d
$PMSD_1$	5.73	0.77c	37.95c	24.4b	2.57bc	1.89c	74.02b	54.15b
$PMSD_2$	5.73b	0.83d	35.45c	22.9c	2.54bc	1.90c	83.06bc	61.47bc
$PMSD_3$	5.85c	0.95e	29.05de	21.6c	2.47cd	1.86c	93.37cd	69.96bc

* Each value is the mean of two successive 8-week plantings.
** Means followed by different letters are significantly different (Duncan's Multiple Range Test, P = 0.05).

NO_3-N contents were, however, significantly lower in pots that had mixtures of poultry manure and straw or sawdust than that obtained in soil treatment with poultry manure alone. The reductions generally increased with increasing ratios of carbonaceous plant residues probably because of increased C:N ratios. The fact that poultry manure is a richer source of plant nutrients (Table 1) could further explain the above observation. Despite fostering superior plant height and dry matter yield (Table 2), the lowest content of soil NO_3-N, was produced in $PMST_3$. Readily oxidizable C sources decompose fast and cause more rapid nutrient immobilization than the more resistant materials like sawdust (Ahmad *et al.*, 1969; Ghoshal, 1974). The increased plant height and dry matter accumulations in the presence of corn straw and sawdust might, therefore, be due to additional nutrient supply.

With the exception of $PMSD_3$, tissue N contents were significantly increased over the control by the organic amendments. While tissue N contents obtained with the sawdust-containing treatments were not significantly different from the poultry manure treatment, those of the straw-containing treatments were significantly lower. This trend might be due to enhanced N immobilization in the presence of corn straw.

The uptake of N was significantly lower in the control, than the other treatments. Nitrogen uptake in the poultry manure treatment was not significantly different from those of $PMSD_1$ and $PMSD_2$ but was lower than those of the remaining treatments, except the control. The highest N uptake was found in pots that received $PMST_3$. As results indicate significant reductions in NO_3-N contents in the presence of straw and sawdust, the enhanced N uptake observed might be due to the release of nitrogen as a result of the mineralization of the carbonaceous residues.

Available and tissue P contents, and P uptake:

Available and tissue P contents, and P uptake were significantly enhanced

(P = 0.05) over the control by the organic amendments (Table 3). While the available P contents in pots that received mixtures of poultry manure and sawdust were significantly higher, those of treatments containing straw were not significantly different from that of poultry manure alone. Phosphorus immobilization was probably higher in the presence of the more easily decomposable corn straw. Poultry manure added to the soil alone produced tissue P content significantly higher than those of the remaining treatments. This would be due to the absence of straw and sawdust that could tie up phosphorus in the soil. There was no significant difference in tissue P contents between the various straw and sawdust-containing treatments. this might be due to the mineralization of P in the residues and the fact that available P content in the soil appeared non-limiting.

The mixtures of poultry manure with corn straw in the ratio of 1:1 ($PMST_3$) led to a significant increased in P uptake compared to the other treatments. This is probably related to the significant enhancement of dry matter accumulation by straw-containing amendments. There was no significant difference in P uptake between the poultry manure treatment and its mixtures with sawdust.

Exchangeable K, tissue K contents, and K uptake:

The organic amendments significantly increased (P = 0.05) exchangeable and tissue K contents over the control (Table 4). Organic wastes are known to enhance the content of exchangeable cations in soil (Bache and Heathcote, 1969; Olayinka and Adebayo, 1983). There was no significant difference in tissue K contents between the poultry manure treatment and its mixtures with sawdust.

As with the uptake of N and P, while organic amendments significantly increased (P = 0.05) K uptake over the control, $PMST_3$ significantly enhanced K uptake more than the remaining treatments. Except $PMSD_1$, all treatments containing mixtures of poultry manure and sawdust or straw significantly increased (P = 0.05) K uptake over poultry manure alone. This could be due to additional contributions of K from the plant residues.

Exchangeable and tissue Ca contents, and Ca uptake were significantly increased (P = 0.05) by the organic amendments (Table 4). The exchangeable Ca content in the poultry manure treatment was not significantly different from that of $PMST_3$ which in turn was not significantly different from $PMSD_3$. Tissue Ca contents in treatments containing mixtures of poultry manure and straw or sawdust were not significantly different. There was also no significant difference between PM, $PMSD_1$, $PMSD_3$ and $PMST_3$. Considering the significantly higher Ca uptake in $PMST_3$ and $PMSD_3$ compared to poultry manure addition alone, the straw and sawdust amendments probably supplied additional Ca to the soil. However, while there was no significant difference between PM, $PMSD_1$ and $PMSD_2$, Ca uptake from the straw-containing treatments were significantly higher than in the poultry manure treatment. Apart from being richer in nutrients (Table 1), corn straw probably released more nutrients for plant uptake because its lower C:N ratio made it more easily decomposable.

Exchangeable Mg, tissue Mg contents, and Mg uptake:

Both exchangeable Mg contents and uptake were significantly lower (P = 0.05) in

TABLE 4: EXCHANGEABLE, TISSUE CONTENTS AND UPTAKE OF K, Ca AND Mg AT THE END OF TWO SUCCESSIVE 8-WEEK PLANTINGS OF TOMATO *(LYCOPERSICON ESCULENTUM* L.)

Treat-ments	Exch. cations (meq/100g)			Tissue contents (%)			Nutrient uptake (mg/pot)		
	K	Ca	Mg	K	Ca	Mg	K	Ca	Mg
Control	0.30a*	1.44a**	1.34a	1.94a	0.64a	0.29a	27.51a	9.10a	4.07a
PM	0.38b	2.32b	1.88cd	2.57b	1.17b	0.34a	67.79e	30.51d	9.03d
$PMST_1$	0.38b	1.89f	1.86d	2.36cd	1.07c	0.32a	94.27bc	42.14b	12.75bc
$PMST_2$	0.37b	2.08de	1.95bc	2.24d	1.05c	0.32a	94.98bc	43.87b	13.42b
$PMST_3$	0.37b	2.28bc	1.88cd	2.06a	1.08bc	0.33a	121.04f	60.01e	18.44e
$PMSD_1$	0.38b	1.97ef	1.96bc	2.50bc	1.14bc	0.32a	70.74de	32.22d	9.12d
$PMSD_2$	0.41b	1.92def	1.99b	2.50bc	1.05c	0.30a	82.01cd	34.05cd	9.68d
$PMSD_3$	0.41b	2.13cd	1.90cd	2.57b	1.08bc	0.31a	96.61b	40.48bc	11.45c

* Each value is the mean of two successive 8-week plantings.

** Means followed by different letters are significantly different (Duncan's Multiple Range Test, P = 0.05).

the control than in the remaining treatments (Table 4). No significant differences (P = 0.05) in tissue Mg contents was, however, found between all the treatments. Except $PMSD_2$, all the organic amendments did not produce any significant differences in exchangeable Mg contents. However, Mg uptake in the straw-containing amendments and $PMSD_3$ were significantly higher than those of PM, $PMSD_1$ and $PMSD_2$ which were not significantly different from each other. This trend, as earlier stated, could be due to the release of additional nutrients by the carbonaceous plant residues.

Conclusion

Findings in this study show the efficacy of poultry manure and its mixtures at various ratios with corn straw and sawdust in enhancing plant growth, dry matter yield, soil reaction (pH), organic C, soil and tissue contents, and uptake of N, P, K, Ca and Mg, on addition to soil. Poultry manure presumably enhanced the decomposition and release of nutrients from the carbonaceous plant residues as can be seen from the significant increase in plant height, dry matter yield, organic C, uptake of N, K, Ca and Mg in the straw and sawdust-containing treatments. However, soil NO_3-N content was significantly depressed by the presence of corn straw and sawdust. Considering the improved plant growth and dry matter yield, uptake of nutrients and reduced soil NO_3-N (apparent index of reduced chances of underground water pollution), mixing poultry manure with straw and sawdust prior to soil application would be a beneficial agronomic practice.

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