Effects of the Application of Sewage Sludge and Fowl Manure on Soils of Paraná State in Maize Plants (*Zea mays* L.) as a Macro-nutrients Source

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ABSTRACT

*The potential of two organic residues as sources of macro-nutrients in three types of soils of the third plateau of Paraná state was studied. Treatment consisted of a dose (38 t.ha^{-1}) of fowl manure and sewage sludge neutralized by a 3:1 (CaO+MgO) mixture. Fowl manure was kept in natura. Maize (*Zea mays L.*) was reference plant. After 30 days of seeding, the aerial parts of the plants were cut. They were dried at 70 ^{0}C till constant weight was obtained, then weighted and ground. Analyses were undertaken after nitric-perchloric digestion of the samples. Macro-nutrient levels in soils and in plants were determined by atomic absorption spectrometry, flame technique. Results showed that production of dry matter was higher when fowl manure was used. Levels of macro-nutrients in Terra Roxa - TR were higher than those of Latossolo Vermelho Escuro – LE (Deep Red Latisol) and Podzólico Vermelho – PV (Red Podzolic), soils respectively. In aerial parts of maize plants collected in the soils treated with organic residues the concentrations of K, Ca, Mg, S and P were higher than those without treatment. The sewage sludge caused highest relation in Ca:Mg.*

Key words: sewage sludge, macro-nutrients, maize culture, soil fertility

INTRODUCTION

Concern with the great quantity of urban and industrial residues produced by humans is constantly on the increase in modern society (IPT, 1995; Lima, 1985). Home sewage is a refuse frequently disposed of in water courses without any treatment, causing pollution of water sources and endangering the environment (Przybysz & Guidi, 1997). When treated it produces sewage sludge. Sufficient studies, however, have not been undertaken about its use (Manahan, 1994). Sewage sludge applied to agriculture has now become a common practice (Favaretto et al., 1997; McBride, 1995). Depending on the origin and composition of material, its agricultural use may represent a source of nutrients for plants, bettering of soil conditions due to high level of its organic matter, minimizing storage problem of so much residue (De Deus, 1992). The possibility of employing sewage sludge in agriculture in soils appropriate for culture not directly destined for food is very promising. However, due to the great diversity of this waste and chiefly because of pathogenic germs and other non-soluble materials, it is necessary to know its chemical composition and biological analysis so that its effects may be quantified (Bertoncini, 1997; Andreoli & Fernandes, 1997).

The availability of metallic ions in soil solutions depends on a series of factors, such as pH, Cations Exchange Capacity (CEC), level and type of organic matter, texture, composition of soil clay, competition of other cations by exchange systems, absorption, chelation, temperature (Smith, 1994; Zhu & Alva, 1993; Sposito, 1989; Oates & Coldwel, 1985; Pavan et al., 1984; Jardim, 1983). Among other factors, temperature, humidity, aeration and nutrient levels control the microbiological activity responsible for degradation process of residue (mineralization) and consequent solubility and availability of metallic ions in the soil (Ladonin & Margolina, 1997; Cavallaro et al., 1993; Sarkis, 1987; Zibilske, 1987; Bull, 1986; Lindsay, 1979).

Absorption of metallic ions by plants depends on their availability in soil solution and on the characteristics of each species in its different

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stages of development (Farina et al., 1980; Epstein, 1975).

It has been observed in applications of sewage sludge that the production of the plant's upper part is associated to the relation Ca : Mg and C : N of soil (EMBRAPA, 1983; Farina et al., 1980; Silva, 1980). Maize (Ros et al., 1990; Silva, 1980); rice and tomatoes (Hosono et al., 1979) and lettuce (Hernandez et al., 1992) are some species tested in soils treated with sewage sludge.

Because of possible environmental impacts in the application of sewage sludge in soils and with the aim of establishing some criteria, studies have been undertaken on an international (McBride, 1995), national (Matiazzo-Prezotto, 1994) and local (Paraná state) (Andreoli et al., 1997) levels. Since there are variations in sludge composition, the subject matter is worth attention and new experiments should be conducted for better technical and scientific clarifications.

Present analysis intended to evaluate the effects of sewage sludge, neutralized with CaO+MgO (3:1) applied to Terra Roxa - TR, Latossolo Vermelho Escuro – LE (Deep Red Latisol - DRL) and Podzólico Vermelho – PV (Red Podzolic - RP), collected in the north of Paraná state and compared to effects of in natura fowl manure applied to the same soils.

MATERIALS AND METHODS

Characterization of soils, sludge and fowl manure: Soils employed in experiment were collected in the third plateau of Paraná state, Maringá region, horizon A, at depth 0 – 20 cm and belonged to different texture classes. They were classified as Terra Roxa – TR a clayey soil; Latossolo Vermelho escuro – LE (Deep Red Latisol - DRL) a medium texture soil and Podzólico Vermelho – PV (Red Podzolic - RP) a sandy soil. Samples were dried in a clean and ventilated ambient, and sifted in a 2-mm sieve. The percentage of base saturation of the soils was elevated to 70% with calcite limestone.

Sewage sludge employed in the experiment was obtained from the Sanitation and Sewage Treatment Station of Curitiba PR Brazil. Sludge was neutralized with 60% (dry weight) of a mixture of CaO+MgO in the proportion 3 : 1 respectively, to avoid bad smell and germ proliferation, especially pathogenic ones. For incorporation to soils it was then dried, ground and homogenized.

The chemical characteristics of sewage sludge and of fowl manure were undertaken. Ca, Mg, K were determined by atomic absorption spectrometry, flame technique, after decomposition of samples with digesting nitric-perchloric solution (Griepink, 1984). Elemental C and N were dosed by classical methods of gravimetry and Kjeldahl respectively (Horwitz, 1980). P and S were dosed by colorimetric and turbidimetric methods respectively (Horwitz, 1980).

Experiment assembly and collection of samples: Soils collected amounting to 2 liters per vase received dose of fowl manure and sewage sludge equivalent to 38 $t.ha^{-1}$ (47.50 g per vase) respectively. Three-liter polyethylene vases were used and experiment was conducted in a green house with three replications. Each vase received amount of water equivalent to 70% of its capacity.

Systems (soil+sludge and soil+fowl manure) in triplicates were left to incubate for 15 days. Five hybrid maize seeds, cultivar BR 300, were sown. After germination, plants were pruned and three were left in each vase. After 30 days of seeding, harvest of upper aerial part of the maize plant was done. Samples were dried and level of dry matter (mass) was calculated. Samples were then ground, dried once more and stored for further analysis. After harvest of aerial part, the contents of vases with rhizome (lower part + maize roots) and soil were spread on a plastic sheet and stalk removed. After being dried in aerated place and cleaned, soil from each vase was sifted in a 2 mm sieve and stored for further analysis.

Analysis of dry matter of the upper part of maize plant: Exact portions (0.2000 g) were weighed in triplicates of each sample of the upper part. The sample digestion was made by the nitric perchloric mixture (Horwitz, 1980). Concentrations of elements Ca, Mg, K and S (indirectly with Ba) were read by technique of atomic absorption spectrometry, using VARIAN atomic absorption spectrometer, Spectr AA 10 PLUS model (Welz, 1985). Reference and standards for each element were submitted to same digestion process of their respective samples. Nitrogen level was determined by Kjeldhal classical method (Horwitz, 1980).

Analysis of residual soil: Analysis of samples of residual soil followed the same techniques employed in the chemical characterization of virgin soils. K^+ was extracted by Mehlich extractor; for CEC calculation, Ca^{2+} and Mg^{2+} were moved from active sites with HCl 1.0 mol.L^{-1} solution. Concentration of all these ions was determined by atomic absorption technique. Nitrogen was dosed by Kjeldhal method. Carbon level was determined by gravimetric method of mass loss towards deep red. Sulfur was extracted and level calculated by turbidimetric method. Colorimetric method was used to determine phosphorus level extracted by Mehlich's method (Horwitz, 1980). Potential acidity {$[H^+]+[Al^{3+}]$} in $cmol_c.kg^{-1}$ was determined by calcium acetate solution method.

Statistic analysis: Experimental data were submitted to variance analysis employing Tukey's test to interpret differences at 5% level of significance (SANEST).

RESULTS AND DISCUSSION

Soils and treatments: In soils of each vase 3,468 and 2,327 Ca; 314 and 931 N; 181 and 238 Mg; 4,513 and 14,298 C; 323 and 1520 P; 48 and 903 K; 489 and 143 S respectively (in $mg.vase^{-1}$) were added to 47.50 g of sewage sludge and fowl manure (Table 2).

Table 1. Chemical characteristics of soils employed in experiment.*

Soil	P	S	N	C	K_T	Ca	Mg	K	H^++PA^{3+}	CEC	BS	Ca:CEC	Ca:Mg
	←(mg.dm^{-3})→		←---(g.kg^{-1})---→			←------------($cmol_c.kg^{-1}$)----------------→					←---(%)---→		relation
TR	3.0	1.3	1.3	12	0.46	3.0	1.1	0.38	2.3	6.8	66	44	3:1
LE (DRL)	2.0	10	0.60	10	0.36	2.1	0.68	0.30	1.3	4.4	70	49	3:1
PV (RP)	1.1	8.0	0.60	8.0	0.26	1.6	0.79	0.26	1.0	3.7	72	42	2:1

TR – Terra Roxa; LE – Latossolo Vermelho Escuro (DRL – Deep Red Latisol); PV – Podzólico Vermelho (RP – Red Podzolic); K_T - Total Potassium; $[H^++PA^{3+}]$ – potential acidity; CEC – Cations Exchange Capacity; BS – Percentage of Bases Saturation; * - Values are averages of analyses results in triplicates.

Table 2. Chemical characteristics of sludge sewage and fowl manure employed in experiment.

Residues	N	P	K	Ca	Mg	S	C	Ca:Mg	C:N
	←------------------------------- g.kg^{-1}						--------------------------------→	←-- relation	--→
Sewage Sludge Curitiba 60%	6.6	6.8	1.0	73	3.8	10.3	95.0	19:1	14:1
Fowl Manure	19.0	32.0	19	49	5.0	3.0	301	10:1	16:1

Values are averages of analyses results in triplicates; relation Ca:Mg and C:N were approximated.

The highly varied chemical composition of residues and the lack of equilibrium of nutrients made impossible their employment for general use in soil fertilization. From Table 2 one may notice that relation Ca:Mg of part applied was around 19:1 for sewage sludge and 10:1 for fowl manure, indicating problems of salinization of soils fertilized with sewage sludge neutralized with 60% CaO+MgO in the proportion 3:1 (Gobbi, 1998).

Table 5 shows results of chemical analyses of soils with and without treatment after 45 days. In soils treated with fowl manure and neutralized sewage sludge, there was a significant increase in level of macro-nutrients Ca, K, P, S, C and N compared to that of reference. Nutrient Ca was more available with sewage sludge and it inhibited availability of Mg that was lower than that of reference. Increase in level of bases Ca^{2+} and K^+ reflected an increase in CEC, % BS and relations Ca:CEC and Ca:Mg.

Table 3. Production of dry matter, in g.vase^{-1}, in maize plants cultivated in three soils with and without treatment of sewage sludge and fowl manure after 30 days of germination*.

Treatments	Soil TR	Soil LE (DRL)	Soil PV (RP)
Soil + sludge	4.82^{b}	4.71^{b}	4.43^{b}
Soil + fowl manure	10.9^{a}	6.86^{a}	5.65^{a}
Reference	3.94^{c}	2.59^{c}	1.92^{c}

*- Values correspond to averages of plants in three vases respectively. Averages followed by same letter (a,b, ...) do not differ among themselves at 5% level of significance by Tukey's test; TR – Terra Roxa; LE – Latossolo Vermelho Escuro (DRL – Deep Red Latisol); PV – Podzólico Vermelho (RP – Red Podzolic).

Table 4. Accumulated quantity of N, K, Ca, Mg, in g.kg^{-1}, in aerial part of maize plants in three soils with and without treatment.*

Elements	Soils with sewage sludge			Soils with fowl manure			Soils without treatment		
	TR	LE (DRL)	PV (RP)	TR	LE (DRL)	PV (RP)	RL	LE (DRL)	PV (RP)
N	39	37	36	40	40	38	30	28	26
P	5.9	5.3	5.9	4.6	5.1	6.0	4.0	3.0	3.7
K	22	20	18	24	25	21	20	15	11
Ca	9.0	8.9	6.8	6.2	7.6	8.2	4.4	3.9	3.8
Mg	2.4	2.3	2.1	2.9	4.9	3.2	2.8	2.1	1.7
S	2.0	1.9	1.8	3.2	2.6	1.9	1.8	1.5	1.2

TR – Terra Roxa; LE – Latossolo Vermelho Escuro (DRL – Deep Red Latisol); PV – Podzólico Vermelho (RP – Red Podzolic); *- Values correspond to analyses averages in triplicates.

Table 5. Chemical characteristics of soils after harvest of maize plants and after 45 days of incubation with and without treatment with sewage sludge and fowl manure.*

Soil	P	S	N	C	Ca	Mg	K	[H^{+}+PA^{3+}]	CEC	BS	Ca:CEC	Ca:Mg
	←mg.kg^{-1}→		←g.kg^{-1}→		←--------------- cmol$_c$.kg^{-1} -----------------→					←----- % -----→		
TR + SS	4.1	15	1.3	17	8.6	0.28	0.40	1.4	11	84	78	31:1
LE (DRL)+SS	5.0	12	0.90	12	5.8	0.25	0.39	1.1	7.5	86	77	23:1
PV (RP) + S	3.2	9.0	0.80	12	3.2	0.22	0.36	1.1	4.9	77	65	15:1
TR + FM	6.0	15	1.7	12	4.7	0.84	0.55	2.4	8.5	72	55	6:1
LE (DRL)+FM	6.1	12	0.80	11	3.6	0.60	0.37	1.6	6.2	74	58	6:1
RP + FM	2.0	14	1.1	12	3.2	0.60	0.33	1.4	5.5	75	58	5:1
TR	3.1	12	0.90	9.0	2.3	0.85	0.35	1.9	5.4	65	43	3:1
LE (DRL)	3.0	9.0	0.60	9.3	2.0	0.50	0.18	1.3	4.0	67	50	4:1
PV (RP)	1.1	7.0	0.60	8.0	1.3	0.70	0.21	1.1	3.3	67	39	2:1

TR – Terra Roxa; LE – Latossolo Vermelho Escuro (DRL – Deep Red Latisol); PV – Podzólico Vermelho (RP – Red Podzolic); SS – neutralized sewage sludge; FM – fowl manure; [H^{+}+PA^{3+}] – potential acidity; BS – Base saturation; *- Values correspond to averages of analyses results in triplicate.

An approximate balance of mass for N and C employing data from Table 1 and 2 for different soils and a comparison with what was left of same after 45 days of incubation and maize seeding, Table 5, verify that during this period mineralization of organic matter associated to N and C occurred only for soils treated with fowl manure; no mineralization occurred in soils treated with sewage sludge. If it occurred, it was insignificant. In some cases, there was a slight increase in C which may be due to possible remains of small roots during the process of freeing the lower stalk from earth.

According to Table 1 relation Ca:Mg for soils TR, LE (DRL) and PV (RP) was 3:1, 3:1 and 2:1 respectively, after incubation of sludge, fowl manure and cultivation of plants. Ratio of Ca : Mg increased for soils treated with sewage sludge 31:1; 23:1 and 15:1 and for soils treated with fowl manure, 6:1, 6:1 and 5:1, respectively (Table 5). These values were completely different from those considered normal 3:1 to 5:1 for maize culture (EMBRAPA, 1983), at least in soils treated with neutralized sewage sludge. Ca:CEC had a considerable increase, reaching 78% of CEC of soil TR + SS, Table 5.

Ratio of Ca:Mg and %SB (Table 5) showed that a break in nutritional balance occurred in soils treated with neutralized sewage sludge. Before sludge incorporation, soils presented a satisfactory Ca:Mg relation in nutritional terms. Ideal relation Ca:CEC for majority of plants is approximately 60–70%. This did not occur when same parameters were analyzed in soils treated with fowl manure. These had satisfactory relations in nutritional terms.

With regard to cationic participation in CEC, exchange complex must be between 60 and 70% Ca, between 15 and 20% Mg and between 3 and 5% K (Lopes, 1984) so that soil might have best ion balance conditions. However, this was not observed in experiment (Table 5). In Table 5 average values of 72% Ca, 7.3% Mg and 3.7% K were calculated and showed excess of Ca and deficiency of Mg in soils treated with neutralized sewage sludge. Such data have not been observed in soils treated with fowl manure which have parameters compatible to those in literature.

Maize plants: Harvest of maize plants was done on the 30^{th} day of seeding since plants with neutralized sewage sludge treatment showed senescence problems, such as yellowing and dried tips of leaves. Probably this was caused by excess of salinity by the addition of sewage sludge neutralized by a high quantity of CaO. Salinity consisting of presence of salts on soil surface which was visually observed. Salinity might have hindered water absorption by maize plants due to the consequent increase of osmotic pressure of soil solution. This did not occur in vases treated with fowl manure and with reference. Another explanation for the yellowing of leaves migth be the nitrogen deficiency caused by excess of calcium via neutralized sludge, hindering availability of potassium, inhibiting nitrification and the transport of nitrogen to plants. Data such as the reduction in sorghum production in calcite soil treated with sewage sludge due to salinity (Cripps & Matocha, 1991) and growth of roots of the cotton shrub affected by high Ca concentrations (Cramer et al., 1987) have been reported in literature.

Results of weight of dry matter (aerial part) of maize plants with and without treatment with sewage sludge and fowl manure are shown in Table 3. In all soils, production of dry matter was greater in those treated with fowl manure, followed by those treated with neutralized sewage sludge, differing between them and reference treatment at 5% level of significance by Tukey's test. For both soils with and without treatment, production of dry matter was in the order TR > LE (DRL) > PV (RP).

Total production of dry matter (Table 3) was influenced by relations Ca:Mg of soils (Table 5), even though by Tukey's test there was no significant difference. When relation Ca:Mg of soils increased, a decrease in plants' dry matter production was noted. Such depressive effect in yield seemed to be linked to nutritional disturbances in plant induced by unfavourable cationic relations in soil. Absorption of nutrients by plants depended on ion activity in the solution and in exchange sites (Rosolem et al., 1984). Research has shown decrease in production of dry matter in plants with increments in relation Ca:Mg and % Ca:CEC in maize. Arantes (1983) has shown that relations Ca:Mg higher than 5:1 established by fertilizers in which base saturation reached 70% caused reduction of dry matter in plants.

With regard to absorption of nutrients K and N by leaves of maize (Table 4), there was a level increase of same nutrients in dry matter collected in treated soils. However, this didn't occur with Mg, which showed a slight decrease for soils with sludge treatment.

When studying effect of sewage sludge application to maize, Ros et al. (1990) observed that it increased dry matter and an increase of N and K in millet. The need of mineral supplements became evident when sewage sludge is applied to soils with deficiency in the two elements.

CONCLUSIONS

From above results the following conclusions were reached:

1. There was an imbalance in nutritional equilibrium available in the solution of soils treated with neutralized sewage sludge; relation Ca:Mg for soils TR, LE (DRL) and PV (RP) without treatment before planting was 3:1, 3:1 and 2:1; after harvesting relation was 31:1, 23:1 and 15:1, respectively.
2. Level of macro-nutrients Ca, Mg and K available in soils solution without treatment, before and after incubation and respective sampling collection, remained practically the same.
3. Plants in soils treated with sludge presented signs of senescence but they still had a greater production in dry matter than those in soils without treatment.
4. Reduction in production of dry matter is inversely proportional to relation Ca : Mg of solution of the respective soils.
5. Plants cultivated in soils with treatment assimilated more nutrients (N, P, S, Ca and K) than those cultivated in soils without treatment. With regard to Mg, a contrary behavior occurred.
6. Taking into consideration type of soil TR > LE (DRL) > PV (RP), decreasing order of production of dry matter was the same for all soils with or without treatment.
7. In soils treated with fowl manure there was an equilibrium in nutritional balance in soils solution.
8. When treatments are compared, fowl manure treatment produced the best yield, followed by neutralized sewage sludge and reference treatment.

RESUMO

Em casa de vegetação avaliou-se a potencialidade de dois resíduos orgânicos como fonte de macronutrientes em três solos do terceiro Planalto do Estado do Paraná. Os tratamentos consistiram numa dose (38 $t.ha.^{-1}$) de esterco de ave e de lodo de esgoto neutralizado, permanecendo o esterco de ave *in natura*. O milho safrinha (*Zea mays* L.) foi utilizado como planta teste. Após 30 dias da semeadura, cortou-se a parte aérea das plantas. Estas, foram secadas a peso constante, moídas e analisadas após digestão nitro-perclórica. Os teores de macronutrientes nos solos e nas plantas foram determinados por espectrometria de absorção atômica. Os resultados mostraram que a produção de material seco foi superior com a cama de ave. Os teores de macronutrientes no solo TR (Terra Roxa) foram superiores aos dos solos LE (Latossolo Vermelho Escuro) e PV (Podzólico Vermelho), respectivamente. Na parte aérea das plantas de milho apenas as concentrações dos elementos K, Ca, Mg, S, P foram estatisticamente diferentes. O lodo de esgoto 60% foi responsável pela maior relação Ca:Mg.

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