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Influence of the concentrated pig slurry on soil and corn fodder yield and chemical composition in presence of N top dressing

E. Vasconcelos & F. Cabral
Department of Agricultural Chemistry, Instituto Superior de Agronomia, Tapada da Ajuda, 1399 Lisboa Codex, Portugal

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Abstract

A pot experiment was carried out using corn plants (*Zea mays* L.), in order to define the possible utilization of the concentrated pig slurry as an organic fertilizer, avoiding soil pollution caused by its chemical composition. Results obtained showed that on a slightly loamy coarse sand soil an amount of 40 t ha^{-1} on fresh weight basis of concentrated pig slurry can eventually substitute mineral nitrogen and phosphate fertilization at planting. The effects of increasing amounts of this organic fertilizer on soil characteristics and corn fodder composition were also investigated.

Introduction

Organic matter amendments to soils show particular interest, not only because of their effects on soil physical, chemical and biological fertility, but also because their buffering effect reducing soil pollution caused by an excessive or unbalanced use of mineral fertilizers (Rauhe, 1987). As a matter of fact, pollution caused by an inaccurate use of mineral fertilizers may lead in a near future to one of the following situations:

- Reduction in the amounts of mineral fertilizers applied, with the respective consequences on yield;
- Increase of the nutrient utilization efficiency, amended trough fertilizers, using for instance slow release fertilizers;
- Simultaneous use of products showing fertilizing value as well as mineral fertilizers, to provide a slower release of nutrients, decreasing pollution risks.

Concerning soils that are poor in organic matter, erosion and desertification processes are accelerated. Therefore, the recycling of plant and animal residues from agricultural related activities is of increasing interest within the present economical and environmental policies. However, if the amounts, methods and times of application of these organic wastes are not properly monitored, pollution of atmosphere, soil and water may occur Amberger, 1990; Cabral et al., 1991; Tunney et al., 1980; Vasconcelos & Cabral, 1993).

In the majority of the countries, the output of pig slurry has been steadily increasing. In situations where pig farms without land are abundant, those wastes, because of their amounts and pollutant characteristics, constitute one of the main sources of diffuse pollution with a significant environmental impact. To overcome those problems, a treatment of pig slurry with a new technology that combines two different steps is proposed. It consists in reducing the liquid phase of the fresh pig slurry by a separator (a centrifuge with horizontal axis - 3000 r.p.m.) and concentration of the liquid phase coming out of the separator by means of evaporation panels before it is reinjected in the fresh pig slurry (Almeida-Duarte & Neto, 1994). The concentrated pig slurry so obtained can be used directly or after composting. Because composting is a costly process, the direct use appears to be more interesting.

The following work aims to provide an evaluation of the value of the concentrated pig slurry, under present economical and ecological points of view, and studies the effects of its application on soil and on corn fodder yield.

Table 1. Soil physical and chemical characteristics

Coarse sand (%)	69.50
Fine sand (%)	16.90
Silt (%)	9.40
Clay (%)	2.40
Field capacity (%)	8.00
Organic matter (%C × 1.724)	0.70
pH (H_2O)	5.70
P(Egner-Riehm) $\mu g\ g^{-1}$	10.90
K(Egner-Riehm) $\mu g\ g^{-1}$	45.60
Cu(Lakanen & Ervio) $\mu g\ g^{-1}$	1.10
Fe(Lakanen & Ervio) $\mu g\ g^{-1}$	38.80
Mn(Lakanen & Ervio) $\mu g\ g^{-1}$	7.20
Zn(Lakanen & Ervio) $\mu g\ g^{-1}$	2.20
Exchangeable cations	
Ca (cmol(+)kg^{-1})	0.92
Mg (cmol(+)kg^{-1})	0.15
Na (cmol(+)kg^{-1})	0.11
(K cmol(+)kg^{-1})	0.13

Material and methods

Experimental details

An experiment, with a completely randomized design was carried out in a greenhouse of the Agricultural Chemistry Department, using PVC pots (0.038 m^2 in surface area and 0.25 m in depth), filled with 12 kg of the epipedon (fraction< 2mm) of a Cambic Arenosol - FAO classification (Table 1).

Treatments were replicated three times and consisted of: A - NPK+N′ ; B, C, D and E = A plus respectively 10–20–30 and 40 t ha^{-1} (38 to 152 g per pot) of concentrated pig slurry on a fresh weight basis; F - N' + 40 t ha^{-1} of concentrated pig slurry. NPK basic dressing consisted of 131 N, 58 P and 326 K kg ha^{-1} (respectively 0.50; 0.22 and 1.24 g per pot). A nitrogen top-dressing fertilization (N′) was carried out in every treatment and consisted of 262 kg N ha^{-1} (1.0 g per pot).

The amount of concentrated pig slurry to the soil in the pots was calculated taking into consideration the available area of each pot. Basic dressing fertilization as well as the concentrated pig slurry were thoroughly incorporated into the soil in each pot. Table 2 shows the moisture content and chemical composition of the concentrated pig slurry used in this experiment.

Six corn seeds (cv. Px 74) were sown per pot (18^{th} June). A week after emergence, a selection was made in order to leave the three most uniform plants in the pots. At the beginning of the experiment, pots were watered up to 70% of the soil field capacity with demineralized water. After the initial wetting, soil water content was controlled by weighing pots twice a week.

At the end of the experiment (7^{th} August) plants were harvested, weighed and a chemical analysis was performed. At the same time soil samples were taken from each pot and analyzed.

Analytical methods

Organic carbon in soil was measured by dry combustion at 1200°C, followed by measurement of the CO_2 evolved in a Ströhlein (Ströhlein & Co., Dusseldorf, Germany) apparatus. Based on the assumption that soil organic matter is 58% carbon, organic matter content was calculated by multiplication of the percentage of organic carbon by the factor 1.724.

Organic matter in the solid fraction was determined by weight loss in a furnace at 350-400 °C during 7–8 h.

Exchangeable cations in the soil, were determined by atomic absorption spectrophotometry, after extraction by the Mehlich method, using a barium chloride - triethanolamine solution of pH 8.1 (Mehlich, 1953).

Soil field capacity was determined with pressure membrane at 1/3 atmosphere. Available phosphorus and potassium in the soil were respectively determined by colorimetric and flame emission photometric methods, after extraction using an ammonium lactate - acetic acid solution of pH 3.5 (Egner-Riehm method). Copper, iron, manganese and zinc in soil were determined by atomic absorption spectrophotometry, after extraction using an ammonium acetate-acetic acid - EDTA solution of pH 4.65 (Lakanen & Ervio, 1971). Nitrogen in the concentrated pig slurry and plant tissues was determined by the Kjeldhal method (Jackson, 1958) in a Tecator equipment (Herdon, VA, USA).

All the other mineral elements were determined by atomic absorption spectrophotometry in a Pye Unicam SP-9 apparatus (Cambridge, UK) after a hydrochloric mineralization of the ash (Martí & Muñoz, 1957), with the exception of phosphorus which was determined by the vanadomolybdophosphoric yellow colour method in a Hitachi U-2000 spectrophotometer.

Table 2. Moisture content of fresh and chemical composition of dried (105 °C) concentrated pig slurry

Moisture (%)	73 .60	N -NH_4^+(%)	1.55
N-Kjeldhal (%)	2.77	Zn(μg g^{-1})	1131.00
P total (%)	3.23	Cu (μg g^{-1})	635 .00
P water soluble(%)	0.43	Fe (μg g^{-1})	4769.00
K total(%)	0.53	Mn(μg g^{-1})	558.00
K water soluble(%)	0.22	Organic matter (%)	62.30
Ca(%)	3.34	pH dil. 1:5	6.26
Mg (%)	2.79	EC_5(1:5) dS m^{-1}	5.20

Table 3. Yields at the end of the experiment (g pot^{-1}DM)

Treatments	A	B	C	D	E	F
	167.4a	191.8a	192.0a	181.7a	200.9a	183.8a

*Different letters in the same row means that treatments differ significantly (p<0.05).

Table 4. Some chemical characteristics of the soil at the end of the experiment

Treatments	A	B	C	D	E	F
Org. matter (%)	0.77a	0.79a	0.90a	0.84a	0.87a	0.83a
pH(H_2O)	5.37c	5.40c	5.47c	5.70b	5.87b	6.17a
P (μg g^{-1})	8.15e	14.85d	29.11c	42.21b	53.86a	42.35b
K (μg g^{-1})	15.49ab	16.32ab	19.64a	18.53ab	17.98ab	13.00b
Cu (μg g^{-1})	1.70a	1.23a	1.77a	1.43a	2.27a	2.50a
Fe (μg g^{-1})	40.53a	39.40a	40.50a	41.13a	41.50a	38.40a
Mn (μg g^{-1})	7.80a	7.30a	8.30a	8.80a	8.40a	8.20a
Zn (μg g^{-1})	1.67a	2.43a	2.40a	2.80a	2.87a	2.77a
Exchangeable cations						
Ca (cmol(+)kg^{-1})	1.40a	1.35a	1.48a	1.56a	1.51a	1.48a
Mg (cmol(+)kg-1)	0.24a	0.25ab	0.27ab	0.35ab	0.38b	0.33ab
Na (cmol(+)kg^{-1})	0.28a	0.30a	0.23a	0.22a	0.27a	0.21a
K (cmol(+)kg^{-1})	0.04a	0.04a	0.05a	0.04a	0.04a	0.03a

*Different letters in the same row means that treatments differ significantly (p<0.05).

Table 5. Plant analysis at the end of the experiment (DM)

Treatment	N	P	K	Ca	Mg	Na	Cu	Fe	Zn	Mn
	(%)						(mg/100g)			
A	0.84ab*	0.17d	0.90a	0.29b	0.08e	0.007a	2.30a	17.92a	1.56b	7.35a
B	0.82b	0.23c	0.88a	0.29b	0.13de	0.008a	0.82a	20.86a	1.92ab	6.90a
C	0.91a	0.33b	0.79a	0.34b	0.17cd	0.008a	0.57a	19.15a	2.33ab	7.42a
D	0.92a	0.35b	0.81a	0.35b	0.20bc	0.007a	0.72a	17.38a	2.61a	7.27a
E	0.89ab	0.36b	0.72a	0.34b	0.23b	0.008a	0.57a	18.50a	2.64a	7.52a
F	0.89ab	0.45a	0.30b	0.48a	0.40a	0.008a	0.71a	19.39a	2.74a	8.18a

*Different letters in the same column means that treatments differ significantly (p<0.05).

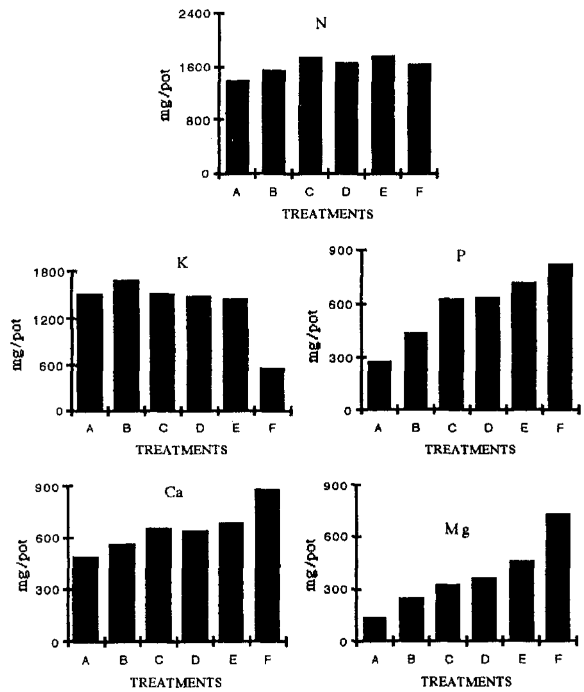

Figure 1. Uptake of nitrogen, potassium, phosphorus, calcium and magnesium by corn plants.

Statistical analysis

Results from the study were subjected to a one-way ANOVA, followed by Scheffe's test at $p = 0.05$ (Danzart, 1986).

Results and discussion

Corn plant yields at the end of the experiment are shown in Table 3. From this table it is possible to observe that yields increased with increasing amounts of concentrated pig slurry applied, though differences between treatments are not statistically significant. On the other hand, the yield obtained in treatment F (without NPK basic dressing) is almost the same as that obtained from other treatments. This fact allows the hypothesis that at least for the studied soil and crop, mineral fertilization at planting can be completely substituted by an amount of concentrated pig slurry correspondent to an application of 40 t ha^{-1}. However, the observation of Tables 4 and 5 as well as Figure 1 lead us to conclude that the elimination of mineral fertilization at planting is not the most convenient solution, specially in what concerns potassium fertilization. The addition of the concentrated pig slurry in the absence of mineral basic dressing, even when 40 t ha^{-1} of concentrated pig slurry are applied, led to a decrease of the content of this nutrient in soil and plant tissues as well as to a decrease of its uptake by corn plants. This result is probably due to the lower content in potassium shown by concentrated pig slurry when compared with that of the fresh pig slurry. Generally the addition of large amounts of fresh slurry, results in the application of excessive amounts of potassium (K) with deleterious effects on crop quality and animal health (Gasser, 1987).

Table 4 shows the results obtained from soil analysis at the end of the experiment. Concerning soil characteristics some particular aspects should be emphasized, when compared with those of Table1:

- Concentrated pig slurry shows a significant liming capacity;
- Available phosphorus increases significantly with increasing amounts of concentrated pig slurry even in the absence of phosphate fertilization;
- There appears to be an increase of exchangeable magnesium with increasing amounts of concentrated pig slurry applied;
- Concentrated pig slurry amendments particularly concerning treatments E and F, appear to lead to an enrichment of the soil in copper, zinc and manganese. Concerning plant analysis (Table 5) as well as nutrient uptake by corn plants (Figure 1) some particular aspects should be emphasized:
- The use of concentrated pig slurry leads to an enrichment of corn fodder in phosphorus, calcium and magnesium. This fact is particularly evident in the treatment where NPK basic dressing was not carried out (treatment F). Their high content in the plants may be explained taking into account the chemical composition of the concentrated pig slurry. Potassium content of the fodder show a pronounced decrease in treatment F, that is in accordance with the percentage of this nutrient shown by concentrated pig slurry (Table 2).
- In what concerns nitrogen, increasing amounts of the concentrated pig slurry seem to lead to an increase of this nutrient in the fodder, though differences between treatments are not significant. Even in treatment F, where mineral nitrogen at planting was not applied, nitrogen content in the fodder is higher than in treatment A. This fact lead us to the conclusion that an amount of 40 t ha^{-1}of concentrated pig slurry fulfills crops nitrogen needs.
- Considering the micronutrients analyzed, a significant increase in the fodder is observed for zinc,

when amounts >30 t ha^{-1} of concentrated pig slurry are applied.

Conclusions

Results obtained show that amounts of 40 t ha^{-1} of concentrated pig slurry to this particular soil and crop, can eventually substitute mineral nitrogen and phosphate fertilization at planting.

The results also indicate that potassium must be incorporated in the usual fertilization scheme to prevent nutritive unbalances of the fodder as well as a decrease in soil fertility. On the other hand the concentrated pig slurry shows a significant liming capacity and seems also to be an excellent source of calcium and magnesium, while increasing amounts of concentrated pig slurry led to a significant increase of these nutrients in the fodder. Although, copper, zinc and manganese content in the soil didn't show significant differences, a light soil enrichment in those nutrients is observed. Because of this particular aspect some long-term experiments are already running for studing it.

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