Effects of solid phase from pig slurry on soil and wheat micronutrient's content.

Influence de l'addition de la fraction solide du lisier de porc, sur la teneur en micro-éléments dans le sol et le blé.

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Abstract

A two years lysimeter experiment was conducted using wheat plants on two texturally contrasting soils (soil A and soil B). The main objective of this study was to evaluate the influence of increasing doses (5, 10, 15, 20 and 25 t.ha^{-1}) of solid phase from pig slurry (SP) on soil extractable copper (Cu), zinc (Zn), iron (Fe) and manganese (Mn) content, as well as on wheat micronutrient's composition and uptake. As the control, a basic dressing of NPK fertiliser was applied. Results showed that increasing additions of SP significantly enhanced extractable Cu, Zn, Fe and Mn content on the topsoil for both soils tested. Similar results were obtained only for subsoil A. A significant increase in the content of Fe, Mn and Zn in the plants as well as its uptake was observed from increasing doses of SP. On the contrary, Cu content in the plants was not significantly affected. Finally, a strong pH effect was exerted in the Mn and Zn uptake by the plants.

Key words : wheat, solid phase from pig slurry, micronutrients

Résumé

Un essai en lisimètres a été conduit pendant deux années, avec deux sols à textures différenciées (sol A et sol B), utilisant du blé. L'objectif de cette étude, a été celui d'évaluer l'influence de l'addition de différentes doses (5, 10, 15, 20 et 25 t ha^{-1}) de la fraction solide du lisier de porc (FS) dans les quantités de cuivre (Cu), zinc (Zn), fer (Fe) et manganèse (Mn) extractibles du sol ainsi que dans la teneur et l'absorption de ces éléments par le blé. Un témoin NPK a été effectué. L'accroissement des quantités de FS additionnées au sol, a significativement augmenté les teneurs de Cu, Zn, Fe et Mn extractible dans la couche superficielle des deux sols utilisés. Le même effet a été produit sur les teneurs de Fe, Mn et Zn dans les plantes, ainsi que sur les quantités exportées. Par contre, la teneur de Cu dans le blé n'a pas été significativement influencé. Finalement, le pH a eu un fort effet sur l'absorption du Mn et du Zn par les plantes.

Mots-clés : blé, fraction solide du lisier de porc, lisimètres, microéléments

1. Introduction

In the last decades, intensification of pig husbandry has resulted in an increase of soil independent farms conducting to an accumulation of large amounts of pig manure. To overcome the problem of excessive pig slurries, Bianchi and Catalano (1993) proposed a technology consisting on a separation of the solid phase of fresh pig slurry from the liquid using a centrifuge with horizontal axis (3,000 rpm) allowing the concentrated liquid phase to come out of the centrifuge by means of evaporation panels before being reinjected into fresh pig slurry. The solid phase (SP) obtained is very different from pig slurries either in agricultural or environmental terms, since it has a much higher content in P, Ca, Mg and micronutrients and a much lower content in K, NO_3-N and NH_4 -N than pig slurries (Vasconcelos et al., 1997). This SP can either be used as an organic fertiliser, before or after composting, replacing traditional manure whose availability is often very poor (Giusquiani et al.,1995; Gigliotti et al., 1996). Because composting is an expensive process, the direct use on the soil can be a mean of reducing costs if it proves to be efficient while preserving environmental quality (Vasconcelos and Cabral, 1996; Vasconcelos et al., 1997).

The fertiliser value of SP is mainly determined by the technique used in the separation process, nutrient content and digestibility of pig's feed. The mineral composition of feed depends on its constituents, the fertility of the soil on which it was produced and the amounts of additives, e.g., copper sulphate and zinc sulphate. Copper sulphate is added to pig feed to increase feed efficiency and to control dysentery, while zinc sulphate is usually added to prevent copper toxicity and zinc deficiency in the animals (Christie, 1990). Copper and zinc content of the feed for fattening pigs has been lowering in agreement with European Union (EU) regulations. However, as the most of the dietary copper and zinc are excreted, there is a widespread concern about the consequences and largely irreversible retention of those toxic metals in agricultural soils due to long term SP applications. On the other hand the eventual presence of considerable concentrations of some other potentially toxic elements including manganese (Mn) and iron (Fe) may constitute one of the main problems associated with successive applications of SP to soils. In fact, these elements can leach through the soil profile and may pollute groundwater or accumulate in the upper soil layer and can be toxic to plants.

Thus, the main purpose of the present study was to evaluate the influence of the amendement with increasing rates of solid phase from pig slurry (SP), on Cu, Zn, Fe and Mn, content on both topsoil (0 -20 cm) and subsoil (20 - 50 cm) of two texturally contrasting soils. Wheat mineral composition and uptake by the plants was also investigated.

2. Material and methods

A two years (1993 to 1995) completely randomised design wheat experiment was conducted in lysimeters (1m^2 of available area and 1 m in depth) filled with either a

Cambic Arenosol (soil A) or Dystric Cambisol (soil B) (Table 1).

Determinations	Soil A topsoil	Soil A subsoil	Soil B topsoil	Soil B subsoil
Texture	sandy	_	silt sandy	_
Coarse sand (%)	69.50	nd	38.60	nd
Fine sand (%)	0.44	nd	33.40	nd
Silt (%)	9.40	nd	17.10	nd
Clay (%)	2.40	nd	10.90	nd
CEC cmol (+) kg^{-1}	1.22	0.85	3.26	1.81
pH (H_2O)	6.23	6.26	6.12	5.33
pH (KCl)	5.68	4.87	4.60	3.68
O.M. (%)	0.61	0.37	1.07	0.44
Extractable micronutrients				
Fe (mg kg^{-1})	29.62	14.60	38.50	39.50
Cu (mg kg^{-1})	0.81	0.80	1.66	0.30
Zn (mg kg^{-1})	6.94	1.20	2.81	0.80
Mn (mg kg^{-1})	7.77	2.10	3.55	6.40

Table 1.
Some physical and chemical characteristics of the soils

Treatments were replicated twice and consisted of: control (NPK), and 5, 10, 15, 20 and 25 t ha^{-1} of solid phase from pig slurry (SP), on a fresh weight basis (Table 2). A basic dressing of a NPK fertiliser consisting of: 50 kg N ha^{-1} (ammonium sulphate, 20.5% N), 58 kg K ha^{-1} (potassium chloride, 49.8 % K) and 17.5 kg P ha^{-1} (superphosphate, 7.9 % P) was performed. Two N topdressing (at tillering and just before head development) were applied in every treatment and consisted of 2 x 25 kg N ha^{-1} (ammonium nitrate, 26% N) application.

Determinations	1^{st} year	2^{nd} year	Determinations	1^{st} year	2^{nd} year
Moisture %	81.10	75.20	Fe (mg kg^{-1})	1146.00	1182.70
Org. matter %	12.53	17.12	Cu (mg kg^{-1})	128.00	127.60
pH	8.47	8.22	Zn (mg kg^{-1})	201.00	292.30
C/N	13.98	11.60	Mn (mg kg^{-1})	101.60	128.50

Table 2.
Chemical composition of solid phase from pig slurry (SP).

In the second year of the experiment, levels of mineral fertilisers and SP added to soils were the same as the first year.

At the beginning of the experiment, lysimeters were watered with sufficient demineralized water to allow seeds germination. Twenty-five grams of wheat seeds (250 kg ha^{-1}) were sown in rows on each lysimeter.

At the end of each year experiment soil samples were taken from each lysimeter and analysed. Plants were harvested, weighed, and chemical analysis performed.

Analytical Procedures

The particle size distribution (texture) of the soils was determined by the pipette method (Day, 1965), and organic carbon (C) determined by dry combustion at 1200ºC, using a Strohlein (Strohlein and 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 SP was determined by loss-on-ignition at 350-400º C for seven to eight hours.

Cu, Fe, Zn and Mn content in the SP and plant tissues was determined by atomic absorption spectrophotometry in a Pye Unicam SP-9 apparatus (Cambridge, UK), after hydrocloric acid mineralisation of the ash (Martí and Muñoz, 1957).

Extractable Fe, Cu, Zn and Mn in the soils were extracted by Lakanen & Ervio method (Lakanen and Ervio, 1971) and determined by atomic absorption spectrophotometry.

Statistical Analysis

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

3. Results and discussion

Soil extractable Fe, Cu, Zn and Mn

At the end of the first year of the experiment increasing application rates of SP did not significantly affect extractable Fe, Cu, Zn and Mn content on soil A either for topsoil or subsoil (data not shown). However, on soil B for topsoil significant differences between treatments corresponding to 5 t ha^{-1} and 25 t ha^{-1} SP applications were detected for extractable Cu, Zn and Mn. In fact, extractable Cu increased from 1.5 to 3.7 mg kg^{-1}, extractable Zn from 3.9 to 6.2 mg $kg^{-1}$and extractable Mn from 5.0 to 7.7 mg kg^{-1}.

Comparing soils after the second year of the experiment both had significant increases of extractable Fe, Cu, Zn and Mn in the surface layer from the increasing levels of SP applied (Table 3). These results are supported by several authors (Christie, 1990; Siegenthaler, 1990; Warman, 1990, 1993) although their studies are specifically referred to pig slurries. On the other hand, subsoil of both soils tested show a completely different behaviour. In fact, while for subsoil A a significant enhance was detected for extractable Cu, Zn and Mn content with increasing application rates of SP, for subsoil B no significant differences were detected. Since the main factors responsible for micronutrients availability are soil pH, cation exchangeable capacity (CEC), organic matter and clay content (Verloo, 1990), results obtained for subsoil A are probably associated to the low CEC and small organic matter and clay content present in that soil (Table 1).

		Soil A				Soil B		
Treat.	Fe	Cu	Zn	Mn	Fe	Cu	Zn	Mn
	2nd	year	topsoil		2nd	year	topsoil	
NPK	26.80 d	1.30 c	9.40 c	7.50 c	37.40 c	1.35 d	5.55 c	4.35 e
5 t	31.60 cd	2.36 bc	12.30 c	7.90 c	40.85 c	1.95 d	9.55 bc	5.60 de
10 t	39.80 bc	2.76 b	18.40 b	9.80 bc	51.90 d	3.55 c	10.90 b	8.05 cd
15 t	50.10 b	4.10 b	18.90 b	11.20 b	58.95 bcd	4.35 c	11.20 b	9.55 bc
20 t	55.70 b	4.50 b	20.00 b	11.50 ab	74.50 b	5.45 b	12.15 b	11.60 ab
25 t	68.00 a	6.00 a	26.90 a	14.50 a	84.30 a	6.50 a	18.10 a	13.85 a
	2nd	year	subsoil		2nd	year	subsoil	
NPK	20.30 b	1.00 c	1.30 d	4.00 b	54.00 a	1.20 a	1.30 a	6.55 a
5 t	21.30 b	1.30 bc	1.40 d	3.50 b	54.80 a	1.30 a	1.25 a	7.75 a
10 t	22.80 b	1.30 bc	1.80 cd	3.50 b	55.50 a	1.30 a	1.10 a	8.60 a
15 t	24.50 b	1.30 bc	2.90 bc	5.10 a	54.65 a	1.45 a	1.05 a	6.50 a
20 t	25.00 b	1.70 ab	4.00 b	5.10 a	59.75 a	1.60 a	1.45 a	8.30 a
25 t	33.70 a	2.20 a	7.50 a	6.10 a	57.05 a	1.50 a	1.50 a	7.70 a

* Values followed by the same letter are not significantly different as judged by Scheffe - F test ($p < 0.05$).

Table 3
Extractable Fe, Cu, Zn and Mn (mg kg^{-1}) on both soils at the end of the two-year experiment.

Plants Fe, Cu, Zn and Mn composition and uptake

Fe, Cu, Zn and Mn composition of wheat plants (grain and straw) after the second year of the experiment are given in Table 4. Uptake of those elements by the plants are shown in Table 5.

	Soil A (2nd year)							
	Grain				Straw			
Treat.	Fe	Cu	Zn	Mn	Fe	Cu	Zn	Mn
NPK	65.0 bc	14.8 a	43.3 a	24.0 a	170.5 d	16.8 a	66.0 a	16.3 a
5 t	54.0 c	12.3 a	29.3 b	9.5 b	162.7 d	13.5 a	37.6 c	8.5 b
10 t	53.5 c	13.0 a	36.8 ab	8.5 b	173.0 d	16.5 a	38.4 c	8.3 b
15 t	57.3 c	11.0 a	37.5 a	8.9 b	261.0 c	16.0 a	47.5 bc	9.3 b
20 t	75.5 ab	11.0 a	37.3 a	11.6 b	319.3 b	15.0 a	48.7 bc	9.5 b
25 t	80.3 a	12.0 a	42.5 a	18.0 a	378.8 a	15.5 a	62.3 ab	14. 8 a
	Soil B (2nd year)							
	Grain				Straw			

NPK	66.0 a	5.7 a	47.0 c	29.3 abc	263.0 b	8.3 a	44.0 b	52.0 a
5 t	61.3 a	5.7 a	49.7 bc	23.7 c	253.7 b	6.3 a	43.3 b	37.7 b
10 t	62.7 a	8.3 a	51.3 abc	26.0 bc	290.0 ab	6.7 a	51.7 a	38.0 b
15 t	69.0 a	8.7 a	58.3 ab	29.0 bc	315.7 a	8.0 a	53.0 a	38.3 b
20 t	72.3 a	8.0 a	58.7 ab	31.7 ab	318.0 a	8.0 a	54.0 a	38.7 b
25 t	75.0 a	9.3 a	60.7 a	34.3 a	327.0 a	8.3 a	56.3 a	41.3 b

* Values followed by the same letter are not significantly different as judged by Scheffe - F test ($p < 0.05$).

Table 4

Fe, Cu, Zn and Mn composition (mg kg^{-1}) of wheat plants (grain and straw) grown on both soils at the end of the experiment.

Soil A (2nd year)								
	Grain				Straw			
Treat.	Fe	Cu	Zn	Mn	Fe	Cu	Zn	Mn
NPK	17.81 c	4.02 a	11.88 b	6.59 a	90.86 d	8.91 a	35.08 a	8.64 a
5 t	13.29 d	3.76 a	7.18 c	2.33 c	57.41 e	4.70 a	13.36 c	2.96 b
10 t	15.18 cd	3.74 a	10.40 b	2.42 bc	74.19 de	7.08 a	16.46 c	3.54 b
15 t	16.23 cd	3.11 a	10.62 b	2.87 bc	128.97 c	7.86 a	23.42 b	4.57 b
20 t	24.88 b	3.53 a	12.09 b	3.77 b	167.36 b	7.84 a	25.46 b	4.97 b
25 t	30.11 a	4.50 a	15.87 a	6.75 a	225.54 a	9.24 a	37.47 a	8.82 a
Soil B (2nd year)								
	Grain				Straw			
Treat.	Fe	Cu	Zn	Mn	Fe	Cu	Zn	Mn
NPK	13.17 ab	1.06 ab	9.10 a	5.64 ab	81.29 d	2.25 cd	7.36 d	16.35 ab
5 t	11.36 b	0.93 b	8.85 a	4.26 c	63.53 e	1.64 a	11.39 c	9.58 c
10 t	11.00 b	1.42 ab	8.61 a	4.97 bc	84.90 d	1.95 cd	13.08 c	10.58 bc
15 t	14.27 b	1.77 ab	11.85 a	6.00 ab	107.34 c	2.58 bc	17.93 b	13.44 b
20 t	15.23 a	1.71 ab	12.17 a	6.64 a	121.76 b	3.42 ab	20.68 ab	14.82 ab
25 t	15.63 a	2.01 a	11.99 a	6.91 a	140.55 a	3.49 a	22.83 a	17.52 a

* Values followed by the same letter are not significantly different as judged by Scheffe - F test ($p < 0.05$).

Table 5

Fe, Cu, Zn and Mn uptake (mg/lysimeter) by wheat plants grown on soil A at the end of each year of the experiment

After the first year of the experiment, no significant differences where observed on plant micronutrients content and uptake (data not shown). At the end of the second year, Cu content in the plants was not significantly affected from increasing application doses of SP on both soils tested. However, Cu uptake increased significantly from application additions of SP greater than 10 t ha^{-1} on soil B. Since during the two years of the experiment the largest yields were obtained from the greatest rates of SP applied (Vasconcelos et al., 1997), Cu content in the plants correspondent to those treatments is probably due to a dilution effect. Nevertheless, as the lowest pH values for both soils occurred in control (Figure 1), plants Cu uptake is most likely due to a pH effect. This fact is consistent with the finding that for both soils, only for the treatments where the greatest rates of SP were applied, the concentration effect of that element over passed the pH effect.

Plants Zn content significantly increased from increasing additions of SP, especially on soil B. Similarly, Zn uptake by the plants was strongly affected from increasing levels of SP. For control plants, a similar behaviour occurred for Zn content and uptake as for Cu. Also in this case results obtained seems to be related to a pH effect.

Fe content in the plants as well as its uptake on both soils was enhanced with increasing doses of SP applied, this increase being particularly evident at the end of the second year of the experiment.

Finally the greatest content in Mn in the plants on both soils was always present at the NPK treatment. This fact is most likely related to the increase of pH values due to the increasing additions of SP applied to soils (Figure 1), that was conducive to a reduction in Mn uptake by the plants. However, the pH effect did not affect so intensively the treatment correspondent to the greatest amount of SP applied (25 t. ha^{-1}) probably due to the greatest concentration in Mn present on the topsoil. Furthermore, a comparison between the SP treatments allows us to conclude that increasing doses of SP led to an increase of Mn in the plants content and uptake with particular relevance at the end of the experiment.

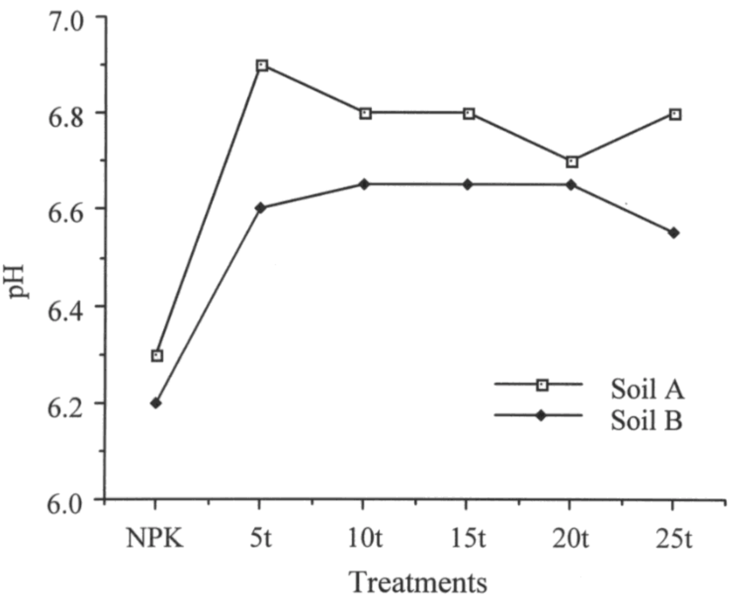

Figure 1
Soil pH values after two years experiment.

4. Conclusions

From the results obtained the following conclusions can be drawn :

- ➢ Increasing doses of solid phase from pig slurry (SP) led to a significant enhance of extractable Cu, Zn, Fe and Mn content on the topsoil of the two texturally contrasting soils tested. Similar results were detected only for subsoil A. This fact is probably associated to the low fixation capacity presented by soil A due to its small cation exchange capacity (CEC) and small organic matter and clay content.

- ➢ Increasing additions of SP led at the end of the two years experiment and for both soils to an increase in the Fe, Mn and Zn content in the plants as well as in its uptake. On the contrary, Cu content in the plants was not significantly affected by SP applications to the soils.

- ➢ pH values exert a strong effect in the Mn and Zn uptake by the plants. In fact, the uptake of these elements was always greater for NPK treatment except when 25 t. ha^{-1} of SP were applied. In this particular case it is possible to conclude that the concentration effect was high enough to over pass the pH effect.

- ➢ According to the results obtained by the same authors (Vasconcelos et al., 1997), application doses of SP greater than 10 t ha^{-1} led to a strong increase in the available phosphorus (P) for both topsoil and subsoil of the two soils tested, that under leaching conditions can cause surface and ground waters contamination. This fact, and taking into account results from the present study allow us to conclude that the success of SP as an organic fertiliser, without causing detrimental environmental effects, will depend on the convenient monitorisation of its utilisation considering not only the application doses but also physical and chemical characteristics of the soils.

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