CARBON, NITROGEN, AND PHOSPHORUS CONTENT IN SOIL FOLLOWING PIG-SLURRY APPLICATION TO CROP ROTATIONS WITH DIFFERENT INPUT LEVELS

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ABSTRACT

A multi-year experiment was started in 1993, the aim being to evaluate the suitability of selected cropping systems to receive pig slurry applications, whilst limiting the negative effects on the environment. The organic carbon (C), total nitrogen (N), and available phosphorous (P) concentration in soil at 0 to 0.8-m soil depth was measured in plots of sugar beet–sorghum–winter wheat and soybean–barley+sorghum second crop rotations, at 3 technical input levels: traditional, reduced and minimal. The leguminous- and second crop-including crop rotation, supplied with a more intensive application of pig slurry, was more effective in allowing the maintenance of good soil fertility levels.
***Keywords**: pig slurry, crop rotations, fertilisation, carbon sequestration.*

INTRODUCTION

The supply of animal wastes to agricultural soils may contribute to the improvement of soil fertility as well as to soil C sequestration. The quantification of these effects is essential in order to better understand the consequences of crop manuring on both crop productivity and environmental quality. Sharpley et al. (1995) found that the continual long-term application of beef feedlot manure, poultry litter and pig slurry increased up to eight fold the total N and P content of several soils in the top 0- to 5-cm depth. Hountin et al. (1997) observed greater total C, N and P concentrations in the soil profile after 14 years of pig slurry applications.

A multi-year experiment was started in 1993 at San Prospero (Lower Po Valley), the aim being to evaluate the suitability of selected cropping systems to receive pig slurry applications, whilst limiting the negative effects on the environment. In the present study we focus our attention on changes in soil C, N, and P content, and their relationship with nutrient supply (including pig slurry as a nutrient source) and crop rotation.

MATERIALS AND METHODS

The experimental site is located in the Modena province, lower Po Valley, Northern Italy (44°47′ N, 11°01′ E), on a La Boaria silty clay soil (fine, mixed, mesic Vertic Ustochrept). Each rotation was conducted with three different sets of agronomic inputs (including tillage, pig slurry, and mineral fertilisation), corresponding to three different production orientations (traditional, *A*; reduced, *B*; and minimal, *C*). Plot size was equal to 775 m^2. The experimental design was an unbalanced split–plot, with two replications for the *A* and *B* input levels and one replication for the *C* input level. Crop residues were buried (except for winter wheat and barley residues, from 1996 on). Experimental details are reported by Ceotto (1999).

Soil samples were collected to a depth of 0.8 m, in 0.2-m increments, at the beginning of the experiment, in March 1994, and again 7 years after the start of the experiment, in winter

2000–2001, in plots of the sugar beet (*Beta vulgaris* L.)–sorghum (*Sorghum bicolor L.*)–winter wheat (*Triticum aestivum* L.) rotation (BeSrWW), and of the soybean (*Glycine max* L. Merr.)–winter barley (*Hordeum vulgare* L.)+sorghum second crop rotation (SyBa+SrII). Sugar beet was the preceding crop in the BeSrWW rotation, whereas soybean was the preceding crop in the SyBa+SrII rotation. Walkley & Black organic C, Kjeldahl total N, and Olsen available P in soil were measured according to Page et al. (1982). Preliminary results, relevant to only one out of two blocks, are here reported.

The average pig slurry composition, based on the analysis of 70 samples collected at the pig slurry-spreading time, in the 1994–2000 period, was: total solids, 4.35% (ds=1.257); total organic matter, 2.47% (ds=0.665%); total ammonium N, 0.16% (ds=0.047); total N, 0.28% (ds=0.064); total P, 0.14% (ds=0.037). On the basis of this average pig-slurry composition, the total amount of C, N, and P supplied during the 7-year period could be estimated (Tab. 1).

The soil nutrient and organic C content was subjected to analysis of variance (ANOVA, GLM procedure, SAS, 1987) for the evaluation of the effect of crop rotation, input level, and soil depth at the beginning (year 1994) and 7 years after the start of the experiment (year 2000).

***Table 1**. Total amount of nutrients supplied by industrial fertilisers and pig slurry in the 1994-2000 experimental period. Notations: BeSrWW, sugar beet-sorghum-winter wheat; SyBa+SrII, soybean-barley+sorghum second crop.*

Rotation	Input level	Fertiliser N(1)	Pig slurry N	Total N	Fertiliser P	Pig slurry P	Total P	Pig slurry C(2)
		---------------------------------kg ha^{-1}----------------------------------						
BeSrWW	A (traditional)	880	500	1380	415	269	684	2356
	B (reduced)	480	500	980	0	269	269	2356
	C (minimal)	320	0	320	164	0	164	0
SyBa+SrII	A (traditional)	540	750	1290	349	404	753	3534
	B (reduced)	345	750	1095	0	404	404	3534
	C (minimal)	150	0	150	262	0	262	0

(1) urea; (2) Total C was estimated to be equal to 51% of the total organic matter.

RESULTS AND DISCUSSION

Crop rotation and soil depth, and their interaction with the YEAR factor, were the most important sources of variance (Tab. 2). The organic C content in the year 2000 was on average lower than in 1994 (Tab. 3), whereas the soil total N and available P levels were not significantly modified by the treatments, on the whole (YEAR effect not significant, in the ANOVA table). However, the soil C and N content in the year 2000 in the plots of the SyBa+SrII rotation was higher than at the start of the experiment, whereas in the BeSrWW rotation it was lower. The rotation effect on the soil P content was not significant. The nutrient and organic C amount increased, from year 1994 to 2000, in the top 0–0.4 m soil layer; it decreased in the subsoil layer (0.4–0.8 m). The available P content in year 2000 was higher than in 1994, in the *A*- and *B*-input plots, whereas it was lower in the C-input plots (significant interaction YEAR×INPUT, in the ANOVA table). Soil C and N amounts in the year 2000 were higher in the *A*- and *B*-input plots than in the *C*-input plots. These differences, already present at the beginning of the experiment, should not be attributed to the treatment effect, but rather to soil spatial variability.

Differences in soil C, N and P content at cropping system level may be due to (i) differences in nutrient removal; (ii) differences in the amount of residues left in the field; (iii) differences in the amount of nutrients supplied either by industrial fertilisers or by pig slurry. In order to isolate the contribution of the crop rotation to nutrient removal from that of the input level we estimated the total amount of N and P removed in a 7-year period by the two crop rotations on

Table 2. *Analysis of variance (mean square) of the organic C, total N and available P content in the 0-0.8 m soil layer at the beginning of the experiment (year 1994) and 7 years after (year 2000), for 2 crop rotations (sugar beet-sorghum-winter wheat and soybean-barley+sorghum second crop) at 3 technical input levels (A, traditional; B, reduced; C, minimal), at San Prospero, Modena (Italy).*

Source	d.f.	Organic C ($g\ C\ kg^{-1}$)	Total N ($g\ N\ kg^{-1}$)	Available P ($mg\ P\ kg^{-1}$)
Soil sampling year (YEAR)	1	3.18*	0.037	1.12
Rotation (ROT)	1	16.31***	0.612***	1.35
Technical input (INPUT)	2	6.66**	0.181***	109.75***
Soil depth (DEP)	3	26.35***	0.329***	77.08***
YEAR×ROT	1	13.74***	0.134**	66.15***
YEAR×INPUT	2	0.44	0.028	20.32**
YEAR×DEP	3	8.11***	0.140***	31.43***
ROT×INPUT	2	0.77	0.037	10.00*
ROT×DEP	3	2.51*	0.010	0.36
INPUT×DEP	6	0.60	0.009	10.61**
Error	23	0.73	0.011	2.60

*, **, *** *Significant at 0.05, 0.01, and 0.001 probability level, respectively.*

Table 3. *Average values of the organic C, total N and available P content in the 0-0.8 m soil layer at the beginning of the experiment (year 1994) and 7 years after (year 2000), for 2 crop rotations at 3 technical input levels (A, traditional; B, reduced; C, minimal), at San Prospero, Modena (Italy). BeSrWW: sugar beet-sorghum-winter wheat; SyBa+SrII: soybean-barley+sorghum second crop(1).*

Factor	Year 1994			Year 2000		
	Organic C ($g\ C\ kg^{-1}$)	Total N ($g\ N\ kg^{-1}$)	Available P ($mg\ P\ kg^{-1}$)	Organic C ($g\ C\ kg^{-1}$)	Total N ($g\ N\ kg^{-1}$)	Available P ($mg\ P\ kg^{-1}$)
Rotation						
BeSrWW	12.3a	1.31b	7.14a	10.7b	1.26b	5.09b
SyBa+SrII	12.4a	1.43a	5.12b	12.9a	1.59a	7.78a
Technical input						
A	12.7a	1.42a	8.04a	12.6a	1.54a	10.56a
B	12.4a	1.39a	4.39c	11.8b	1.47a	4.77b
C	11.8b	1.30b	5.97b	11.0c	1.26b	3.98b
Soil depth (m)						
0–0.2	12.9a	1.43a	7.40a	14.4a	1.71a	12.25a
0.2–0.4	12.7a	1.40a	6.15ab	12.8b	1.57a	6.54b
0.4–0.6	12.1b	1.35ab	5.71b	10.9c	1.32b	3.94c
0.6–0.8	11.5c	1.30b	5.26b	9.1d	1.10c	3.02c
Mean	12.3	1.37	6.13	11.8	1.42	6.44

(1) Within year and factor (rotation, technical input and soil depth) means followed by the same letter are not significantly different at P=0.05, according to the Fisher's Least Significant Difference test.

the basis of average data of crop production and nutrient removal (data not shown). Given that crop residues were buried, and assuming that the soybean crop, when N is lacking in soil, can fix about 90% of its needed N from the atmosphere, we estimated an average total removal, for a 7-year period, of 882 kg N ha^{-1}, and of 170 kg P ha^{-1} for the BeSrWW rotation. The estimated N and P removal was equal to 635 kg ha^{-1} and 204 kg ha^{-1}, respectively, for the SyBa+SrII rotation; therefore the SyBa+SrII rotation can remove on average less N than the BeSrWW rotation, whereas the P removal is of the same order of magnitude, for both rotations. The residues left in the field (not including the root contribution) were estimated to contain on average 13.4 t C, 272 kg N, and 38 kg P ha^{-1}, in the BeSrWW rotation; and 19.9 t C, 527 kg N, and 54 kg P ha^{-1}, in the SyBar+SrII rotation. Therefore the SyBaSrII rotation can leave in the crop residues a considerably higher amount of nutrients and C than the BeSrWW rotation. As far as the differences in the nutrient levels supplied to the two crop rotations are concerned, the SyBa+SrII rotation received on average less N than the BeSrWW rotation. However, in the SyBa+SrII rotation, the nutrient supply from pig slurry was higher than that from industrial fertilizers (Tab. 1). The C supply from pig slurry to the SyBa+SrII rotation was also higher than that to the BeSrWW rotation.

CONCLUSIONS

In our experiment the leguminous- and second crop-including crop rotation, supplied with a more intensive application of pig slurry, was more effective in allowing the maintenance of good fertility levels in the soil layer explored by crop roots. The management of cropping systems at both traditional- and reduced-input level, including pig slurry as a nutrient source for crops, produced a substantial build-up of N and P in the surface soil layer; organic C levels were also affected. However, a subsoil nutrient and organic C depletion counterbalanced the increase observed in the topsoil layer.

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