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Short communication

Use of ^{13}C abundance to study short-term pig slurry decomposition in the field

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Abstract

Applying pig slurry (PS) on agricultural soils is a common practice. However, its impact on soil organic C dynamics is not clear. This experiment investigated the use of natural ^{13}C abundance to study the short-term C mineralization of anaerobically stored PS under field conditions. Measurements of $\delta^{13}C$–CO_2 were made on soil air samples obtained from a bare sandy loam during 22 d following incorporation of either PS alone, PS + barley straw, or barley straw alone; an unamended treatment was used as a control. Slurry C was enriched in ^{13}C (−20.0‰) because of the high corn (*Zea mays* L.) content of the animal diet. This value contrasted with $\delta^{13}C$ of −28.4‰ for the soil organic matter and of −29.0‰ for the barley straw. A peak of high $\delta^{13}CO_2$ values (average of −9.2‰) was observed on the day of PS application and was attributed to the dissociation of PS carbonates when mixed with the relatively acidic soil. After this initial burst, 36% of the evolved CO_2 originated from the decomposing PS. After 22 d of incubation, approx. 20% of the PS-C had been lost as CO_2. This short-term field study did not show any priming effect of PS on the mineralization of straw or native soil C. Due to its heterogeneity, the use of the isotopic composition of the evolved CO_2 for estimating PS decomposition requires precaution either through the use of a specific experimental design involving comparable C3 and C4 treatments, or calculations to account for the presence of ^{13}C-enriched inorganic C in the PS.

Keywords: ^{13}C natural abundance; Pig slurry; Carbon; Mineralization

Pig slurry (PS) is most often disposed of by land application after several months of anaerobic storage. Contrary to solid animal manure, repeated application of PS does not always increase soil organic C content (N'Dayegamiye and Côté, 1989; Plaza et al., 2005; Carter and Campbell, 2006), partly because of its low C content and rapid mineralization (Rochette et al., 2000; Chantigny et al., 2001, 2004). In addition, PS is suspected to stimulate the mineralization of other soil C sources (Bernal and Kirchmann, 1992; Sørensen, 1998).

Variations in ^{13}C abundance in animal excreta has been used to study the fate of animal excreta such as cattle dung (Dungait et al., 2005) or cattle slurry (Glaser et al., 2001) in soil or soil fractions. Natural ^{13}C abundance of the evolved CO_2 has also been used under laboratory conditions to study the decomposition of sheep faeces (Kristiansen et al., 2004) and fresh cattle slurry (Bol et al., 2003).

Using an approach developed by Rochette et al. (1999a, b) to study *in situ* crop residue decomposition or rhizosphere respiration, the objective of this work was to use natural ^{13}C abundance to study the short-term mineralization of PS-C under field conditions.

The study site was located on the Chapais Research Farm of Agriculture and Agri-Food Canada, 3 km south from Québec City (46°48′N, 71°23′W), Canada. The experiment was initiated 21 June 1998 on a St-Pacôme loamy sand (Gleyed Eluviated Sombric Brunisol) (98 g kg^{-1} clay and 842 g kg^{-1} sand) that had been cropped to barley from 1993 to 1997. In summer 1998, the site was kept free of vegetation and subdivided into 16 plots of 2 m × 2 m in size. The treatments were no amendment

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(control), PS at a rate of 6 L m^{-2}, barley straw added at 400 g m^{-2} dry matter, and combined PS (6 L m^{-2}) and barley straw (400 g m^{-2}). Each treatment was replicated four times and arranged in a randomized complete block design and analysis of variance was performed using this design. Selected characteristics of the soil and the amendments are presented in Table 1. The PS was obtained from a commercial finishing operation where pigs were fed a corn-based diet. The PS had been stored anaerobically for six months.

In order to simulate the soil inversion resulting from moldboard plowing, the first 10 cm of soil were removed from all plots including the control. Except for the control, organic materials were then spread over the excavated surface. The plots not amended with PS were supplied with an equivalent amount of water. The excavated soil was replaced on top of the plots immediately after organic materials and/or water were added. The amounts of C and N applied were 68.4 g C m^{-2} and 14.3 g N m^{-2} for PS alone, 163.5 g C m^{-2} and 3.5 g N m^{-2} for barley straw alone, and 231.9 g C m^{-2} and 17.8 g N m^{-2} for the PS+straw treatment.

Soil air was collected at 10 cm below the soil surface 10 h, and 1, 2, 3, 4, 7, 10, 14 and 22 d after treatment application. Sampling was performed with air probes consisting of tubing (Bev-A-Line IV, Labcor, Anjou, Que.) attached to a series of four plastic mesh cylinders containing glass beads (3 mm dia.) (Rochette et al., 1999b). Probes were installed close to the center of each plot by placing the mesh cylinders 40 cm apart of each other and just above the organic amendments. Before collecting soil air, 20 mL of air was withdrawn with a syringe to purge the dead volume of probes. Soil air was collected by connecting an evacuated 250-mL glass gas sampling flasks fitted with high-vacuum stopcocks (Kontes, Vineland, NJ) to the probe valve. The CO_2 in the soil air sample was extracted cryogenically following the technique described by Rochette et al. (1999b).

Soil air and organic samples were analyzed for m/z ions 44, 45, 46 on a triple collector isotopic ratio mass spectrometer (Sira 12, VG Isotech, Middlewich, Cheshire, UK). Isotopic composition was expressed using the δ notation

$$\delta^{13}\mathrm{C} = [(^{13}\mathrm{C}/^{12}\mathrm{C}\ \text{sample})/(^{13}\mathrm{C}/^{12}\mathrm{C}\ \text{standard})] - 1. \quad (1)$$

The international standard for CO_2 samples is CO_2 from Pee Dee Belemnite (PDB) limestone. The values are presented in parts per mil (‰).

The proportion of the soil CO_2 derived from PS (X_{ps}) was calculated as

$$X_{\mathrm{ps}} = (\delta^{13}\mathrm{CO}_{2\ \mathrm{ps}} - \delta^{13}\mathrm{CO}_{2\ \mathrm{ctrl}})/(\delta^{13}\mathrm{C}_{\mathrm{ps}} - \delta^{13}\mathrm{C}_{\mathrm{soil}}), \quad (2)$$

where $\delta^{13}\mathrm{CO}_{2\ \mathrm{ps}}$ and $\delta^{13}\mathrm{CO}_{2\ \mathrm{ctrl}}$ are the δ^{13}C of the soil CO_2 in the PS and control plots, respectively, and $\delta^{13}\mathrm{C}_{\mathrm{ps}}$ and $\delta^{13}\mathrm{C}_{\mathrm{soil}}$ are the δ^{13}C of the PS and soil C, respectively.

The mineralization rate of PS ($F_{\mathrm{CO}_2\ \mathrm{ps}}$) was calculated as the product of the total soil respiration (F_{CO_2}) (data obtained from Chantigny et al., 2001) by the contribution of PS to the total respiration (X_{ps}):

$$F_{\mathrm{CO}_2\ \mathrm{ps}} = X_{\mathrm{ps}} \times F_{\mathrm{CO}_2}. \quad (3)$$

Since there was no history of corn cropping at this study site, the organic matter of the soil had a δ^{13}C of −28.4 ± 0.3‰ (Table 1). This is very close to the value measured for the barley straw (−29.0 ± 0.4‰). In contrast, the PS showed a significant enrichment in ^{13}C with a value of −20.0 ± 0.2‰, reflecting the effect of corn in the ration of the pigs.

The δ^{13}C value of soil CO_2 in the control plots was relatively constant at −23.0‰ except for a low of −27‰ at day 10 (Fig. 1). The average δ^{13}C of CO_2 in the control plot was 5‰ higher than the value of the soil organic matter from where it originated (−28.4‰). This difference was consistent with the 4.4‰ difference predicted by models based on the slower diffusion of heavier $^{13}CO_2$ molecules than that of the $^{12}CO_2$ molecules (Cerling et al., 1991) and

Table 1
Selected properties[a] and natural ^{13}C abundance of the soil and organic amendments

Properties	Soil	Pig slurry	Barley straw
Total C (g kg^{-1})[b]	30.0	411.8	449.0
Total N (g kg^{-1})	2.0	86.0	9.5
pH_{H_2O}	5.8	7.9	NA
Dry matter (g L^{-1})	NA	2.7	NA
Dry matter (g kg^{-1})	NA	NA	920.6
SOC (% of total C)	NA	32.1	NA
IC (% of total C)	NA	6.5	NA
VFA-C (% of total C)	NA	30.1	NA
δ^{13}C (‰)	−28.4 (0.3)[c]	−20.0 (0.4)	−29.0 (0.2)

[a] Adapted from Chantigny et al. (2001).

[b] SOC, soluble organic C; IC, inorganic C; VFA-C, C present as volatile fatty acids; NA, not applicable.

[c] (± standard deviation).

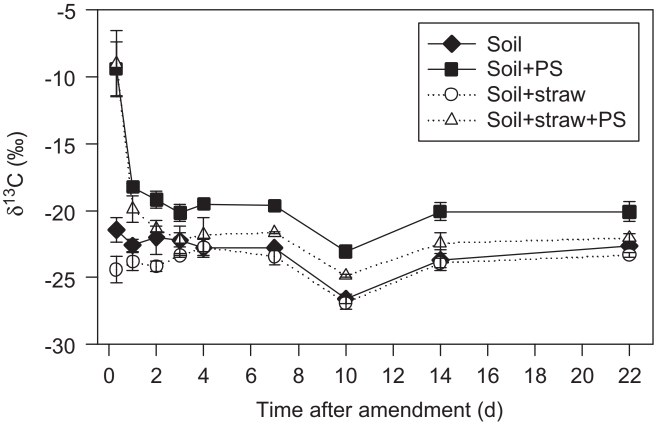

Fig. 1. δ^{13}C values of soil CO_2 following soil amendment with pig slurry (PS), barley straw, both or none (control).