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USE OF ORGANIC RESIDUES FOR THE RECOVERY OF SOIL AND ENVIRONMENTAL SUSTAINABILITY

UTILISATION DE RÉSIDUS ORGANIQUES POUR LA RÉCUPÉRATION DU SOL ET LA DURABILITÉ DE L'ENVIRONNEMENT

UTILIZZO DI RESIDUI ORGANICI PER IL RECUPERO DEL SUOLO E LA SOSTENIBILITÀ AMBIENTALE

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Summary

The aim of this work was to investigate the effects of different organic residues on soil fertility and climate change, through the evaluation of soil organic matter mineralisation, greenhouse gas emission, nutrient availability and soil microbial biomass content and activity. A degraded agricultural soil was amended with three different organic residues (pig slurry digestate, rapeseed meal, and compost) at three different doses (0.1, 0.25 and 0.5% w/w) and incubated for 30 days at 20 ºC. During incubation, soil CO_2 and N_2O emissions, K_2SO_4 extractable organic C, N, NH_4^+, NO_3^- and P, soil microbial biomass and some enzymatic activities were determined. Results obtained showed that rapeseed meal and pig slurry are best suited to improve soil chemical and biological fertility, while compost is more appropriate for the enhancement of soil organic matter content and to promote soil C sequestration.

Keywords: *Organic residues, Mineralisation, C sequestration, N_2O emissions, Soil organic matter*

Résumé

Le but de ce travail était d'étudier les effets de différents résidus organiques sur la fertilité des sols et les changements climatiques, grâce à l'évaluation de la minéralisation de la matière organique, des émissions de gaz à effet de serre, de la disponibilité de nutriments et du contenu en biomasse microbienne ainsi que de son activité. Un sol agricole dégradé a été amendé avec trois résidus organiques différents (digestion de lisier de porc, tourteau de colza et compost) à trois différentes doses (0.1, 0.25 et 0.5 % p/p) et incubé pendant 30 jours à 20 °C. Durant cette incubation ont été déterminés les émissions de CO_2 et de N_2O, ainsi que le contenu en C organique, N, NH_4^+, NO_3^-, P extractibles au K_2SO_4, la

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biomasse microbienne et certaines activités enzymatiques. Les résultats montrent que le tourteau de colza et le lisier sont mieux adaptés pour améliorer la fertilité chimique et biologique, tandis que le compost est plus approprié pour améliorer le contenu en matière organique et promouvoir la séquestration du carbone.
Mots-clés: *Résidus Organiques, Minéralisation, Stockage de C, Emissions de N_2O, Matière organique du sol*

Riassunto

Lo scopo di questo lavoro era la valutazione degli effetti di diversi residui organici sulla fertilità del suolo e sul cambiamento climatico, attraverso lo studio della mineralizzazione della sostanza organica (SO), delle emissioni di gas ad effetto serra, della disponibilità di nutrienti e del contenuto ed attività dei microorganismi. Un suolo degradato è stato ammendato con tre diversi residui organici (digestato anaerobico, farina di colza, compost da residui alimentari) a tre diversi dosi (0.1, 0.25 e 0.5% p/p) e incubato per 30 giorni a 20 ºC. Durante l'incubazione è stata misurata l'evoluzione di CO_2 e N_2O, il contenuto di C, N, NH_4^+, NO_3^-, e P estraibili, il contenuto di C della biomassa microbica ed alcune attività enzimatiche. I risultati ottenuti mostrano come la farina di colza ed il digestato sono più indicati per migliorare la fertilità chimica e biologica del suolo, mentre il compost è più appropriato per aumentare il contenuto di SO.
Parole chiave: *Residui organici, Mineralizzazione, Sequestro di C, Emissioni di N_2O, Sostanza organica del suolo*

Introduction

Soil organic matter (SOM) represents one of the most important soil components. However, the intensification of agricultural practices is leading to a significant decrease in SOM. The use of organic residues as amendments could offset SOM decline and, at the same time, solve the problem of waste disposal with an environmentally sound option. However, the sustainability of this strategy requires an exhaustive evaluation of the impact of residues on soil quality in order to avoid any adverse environmental effect.
The aim of this work was to investigate the effects of different organic residues on soil fertility and its implications on climate change, through the evaluation of SOM mineralisation, greenhouse gases emissions, nutrients availability and soil microbial biomass content and activity.

Materials and methods

The experiments were carried out with an agricultural soil proceeding from San Martino al Tagliamento, (PN, Italy). This soil was a Fluventic Eutrudept (USDA, 1999) with $pH_{(H2O)}$ of 8.3, 69% sand, 28% silt, 3% clay, 740 g kg^{-1} $CaCO_3$, 1.05% organic C, 0.12% total N and 114 mg kg^{-1} microbial biomass C. The soil was amended with 3 different organic residues: pig slurry digestate (PD) (37.9% TOC, 4.4% TN), rapeseed meal from biodiesel production (RSM) (45.9% TOC, 6.0%

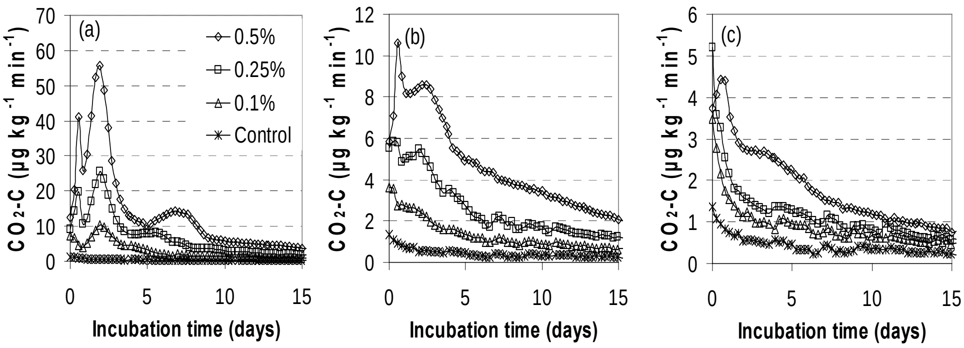
TN) and compost from the separate collection of household organic waste (HWC) (34.4% TOC, 2.3% TN). The amendments were applied at three different doses: 0.10, 0.25 and 0.50%, equivalent to 4, 10 and 20 ton ha^{-1}, respectively. The amended soil was thereafter incubated in the laboratory for 30 d at 20 °C.

During incubation, soil CO_2 and N_2O evolution was continuously measured every 6 hours by means of an automated system for continuous gas sampling and analysis (Mondini *et al.*, 2010), while aliquots of soils were taken after 2, 7 and 30 days of incubation for analysis of extractable NH_4^+, NO_3^-, available P, organic C (EOC) and N (EN) and some enzymatic activities. Soil microbial biomass was also analysed after 2 and 30 days of incubation. Extractable NH_4^+, NO_3^-, available P, EOC and EN were determined using a 1:4 (w/v) ratio of amended soil to K_2SO_4 0.5M extract. Extractable NH_4^+ was determined by a modified colorimetric method based on Berthelot's reaction (Sommer *et al.*, 1992). The content of NO_3^- was measured by reading the absorbance at 220 nm and subtracting the absorbance at 275 nm. The content of available P was determined by a colorimetric method (Van Veldhoven and Mannaerts, 1987). K_2SO_4-extractable organic C (EOC) and N (EN) were measured using a TOC-VCSN analyser (Shimadzu). Soil microbial biomass C (B_C) was determined by the fumigation-extraction method (Vance *et al.*, 1987). The different enzymatic activities were measured in soil extracts (Fornasier and Margon, 2007) utilizing a fluorescence method.

Results and discussion

CO_2 and N_2O emissions. Figure 1 shows CO_2 emissions during the first 15 days of incubation from soils amended at three different doses.

Figure 1 - *CO_2 emissions obtained during the first 15 days of incubation of soil amended with rapeseed meal (a), pig digestate (b) and compost (c).*



The organic residues were characterized by significant differences in their composition that clearly influenced the behaviour of the residues once applied to the soil. The highest CO_2 emissions were obtained with rapeseed meal. CO_2 emissions increased with the dose for all the residues.

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Cumulative extra CO_2-C (difference in cumulative respiration between amended and control soil) (Table 1) was generally not affected by the dose and was around 14% for rapeseed meal, 7% for pig digestate and 2.6% for the compost. With the compost, 97% of added C remained in the soil at the end of the incubation, indicating that this amendment favours the conservation of added C.

Table 1 - *Balance of C mineralisation in amended soil after 30 d of incubation. Extra CO_2-C is the difference in cumulative respiration between amended and control soil.*

Residue	**0.1%** Extra CO_2-C		**0.25%** Extra CO_2-C		**0.5%** Extra CO_2-C	
	(µg g^{-1})	(% added C)	(µg g^{-1})	(% added C)	(µg g^{-1})	(% added C)
Rapeseed meal	63.70	13.88	163.46	14.24	337.49	14.71
Pig digestate	26.63	7.03	61.85	6.53	122.92	6.49
Compost	14.41	4.19	22.12	2.57	44.10	2.56

N_2O emissions were detected only with rapeseed meal (Figure 2) and were correlated with the application dose. Cumulative N_2O emissions were less than 0.7% of N added with the residue.

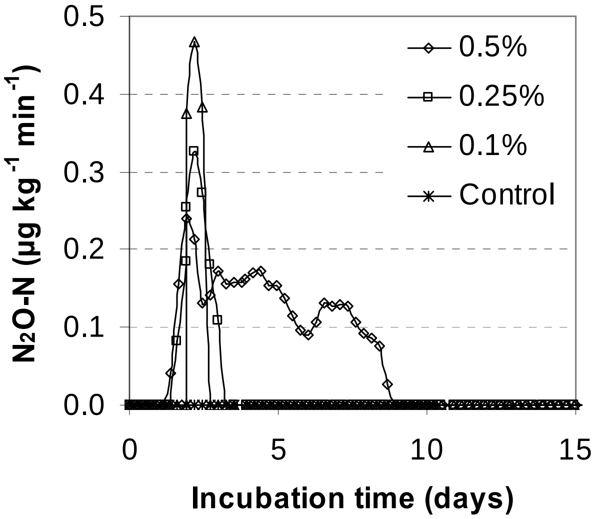

Figure 2

N_2O emissions during 15 days of incubation of soil amended with rapeseed meal.

Nutrients: N and P. The EN (Figure 3) of amended soil was positively correlated with the dose and incubation time for all the residues. The highest increase in EN content was obtained with rapeseed meal at the highest dose.

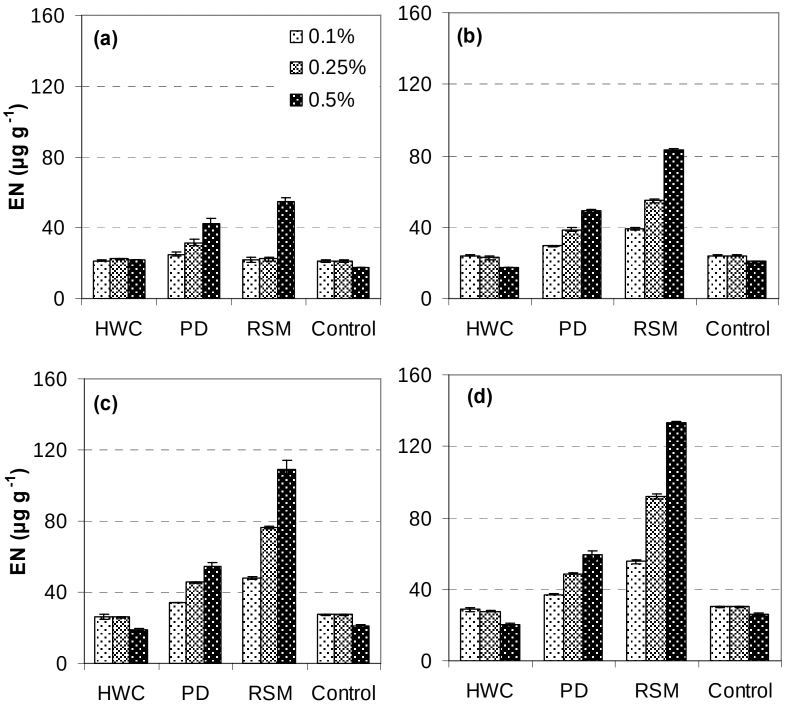

Figure 3

Extractable N in soil after 2 (a), 7 (b), 15 (c) and 30 (d) days of incubation.

Net (control subtracted) mineral N ($NO_3^- + NH_4^+$) at the end of the experiment (Table 2) was around 40% of added N for rapeseed meal and around 20% of added N for pig digestate. At the highest dose this corresponds to an increase in mineral N of 480 and 176 kg ha^{-1} for rapeseed meal and pig digestate, respectively. The addition of 0.1% of compost increased the net mineral N, however higher doses led to N immobilization.

Table 2 - *Balance of N mineralisation in amended soil after 30 d of incubation. Net mineral N is the difference between NO_3^- plus NH_4^+ in the amended soil and NO_3^- plus NH_4^+ in the control soil. Negative values indicate net N immobilization.*

Residue	0.1% Net mineral N		0.25% Net mineral N		0.5% Net mineral N	
	(µg g^{-1})	(% added N)	(µg g^{-1})	(% added N)	(µg g^{-1})	(% added N)
Rapeseed meal	24.33	40.56	60.90	40.60	134.87	44.96
Pig digestate	9.06	20.59	17.89	16.27	46.04	20.93
Compost	0.87	3.76	-0.62	-1.07	-8.40	-7.26

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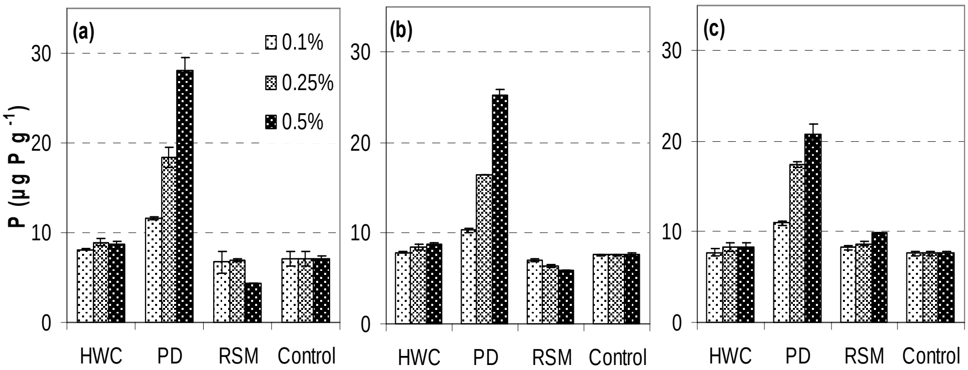
Information provided by short term laboratory incubation on the N mineralisation of amendments is valuable for the estimation of the N mineralisation under field conditions (Gale et al., 2006).
Available P (Figure 4) increased after the amendment with rapeseed meal and pig digestate (9 and 50 kg ha^{-1} respectively, at the highest dose).

Figure 4 - *Available P in soil after 2 (a), 7 (b) and 30 (c) days of incubation.*



Soil microbial biomass and enzymatic activity. Soil microbial biomass C content (Figure 5) increased after the addition of the amendments and was higher at the dose of 0.5%. The highest increase was again obtained with rapeseed meal and was more significant after 2 days of incubation.

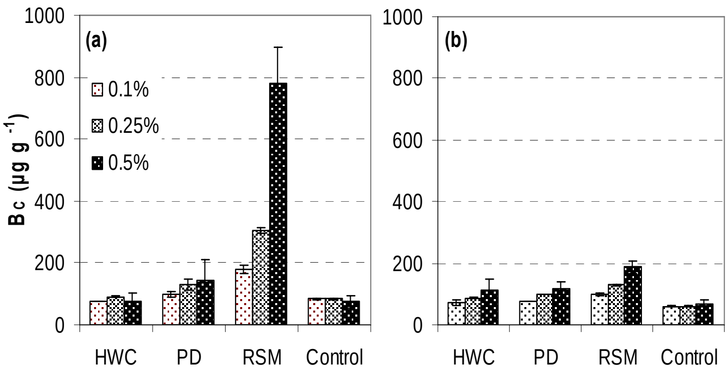
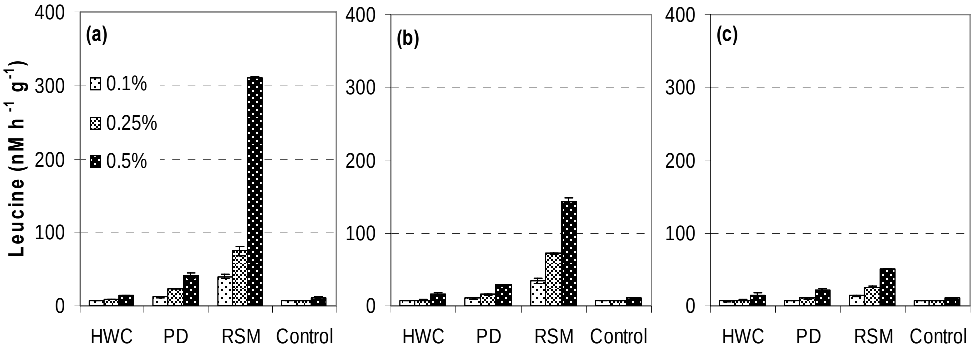


Figure 5

Microbial biomass C after 2 (a) and 30 (b) days of incubation.

Figure 6 shows the values of leucine aminopeptidase activity in amended soil as an example of the typical response of the measured enzymatic activities after soil amendment. The highest increase in enzymatic activity was obtained with rapeseed meal at the highest dose and after 2 days of incubation. The increase in soil microbial biomass content and activity represent a clear indication of an enhancement in soil biological fertility.

Figure 6 - *Leucine aminopeptidase activity after 2 (a), 7 (b) and 30 (c) days of incubation.*



Conclusions

The results obtained demonstrate that organic residues may represent an effective solution for the recovery and conservation of soil quality. Rapeseed meal and pig digestate provide nutrients (16-45% of added N, 9-50 kg P ha^{-1}) and increase soil biological fertility. The compost is best indicated for the recovery of soil organic matter content and to promote soil C sequestration.

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