EVALUATION OF COMPOST EFFICIENCY FOR SOIL CARBON STORAGE BASED ON BIOCHEMICAL FRACTIONATION OF THEIR ORGANIC MATTER: VALIDATION USING A LONG TERM EXPERIMENT

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ABSTRACT

Intensive agriculture makes decrease the organic matter observed in many loamy soils of Ile-de-France where composts issued from the treatment of municipal organic wastes are used to restore soil organic matter. An index of biological stability (IBS), based on the biochemical fractionation of organic matter in soluble, cellulose, hemicellulose and lignin fractions represents the proportion of total organic matter of an amendment contributing to the upkeeping of soil organic matter.

A long term field experiment has been initiated in 1998 where three composts (municipal solid waste compost, MSW; sludge compost, GS, biowaste compost, BIO) are compared to a farmyard manure (FYM). Similar amounts or organic C are applied in all treatments. A larger increase in soil organic carbon was observed with the BIO and GS composts that were characterized by the largest IBS and the lowest C mineralization. The mass balance of organic C in the different organic treatments of the field experiment was used to validate the IBS as a valuable indicator of compost efficiency for soil carbon storage.

Keywords: *urban composts, organic matter, biochemical fractionation, soil.*

INTRODUCTION

Intensive agriculture has been responsible for the decrease in soil OM contents (Balesdent, 1996), with decreased soil fertility, lost of biological activity, increased erosion problems… Crop residue incorporation and animal manure have been traditionally used as OM sources for soils. On the other hand, organic wastes are other sources of OM, that could be recycled on cultivated soils, if they have been proved to be safe for the environment. In many areas in France, animal breading has disappeared and organic wastes become the main sources of OM.

The effects of compost application are expected after several applications and long-term field experiments are necessary to observe them. Such a long-term field experiment has been initiated in 1998 where composts are compared to farmyard manure and mineral fertilisation. The field is cultivated following real farmer practices. Results on soil OM evolution after 2 applications are presented and related to characteristics of compost OM.

MATERIALS AND METHODS

Composts

Three urban composts were compared to a farmyard manure (FYM): (1) a biowaste compost (BIO) issued from the co-composting of greenwastes and the source separated organic fraction of municipal solid wastes, (2) a compost issued from the co-composting of greenwastes and sewage sludge (SG), (3) a municipal solid waste compost (MSW). The composting processes have been described previously (Houot et al., 2003).

Composts and manure were analyzed for dry matter, total organic matter and organic C and N by elementar analysis. Carbon mineralization of the organic amendments was measured during incubations in controlled conditions on four replicates.

The Index of Biological Stability (IBS) was measured on all organic amendments. The method is based on Van-Soest et Wine (1967) and Weende, developed for fibre analysis in forage. The following compartments were measured: soluble OM (SOLU), cellulose (CEW), hemicellulose (HEMI), and lignin (LICU). IBS was then calculated as Linères and Djakovitch (1993): IBS = 2.112 - (0.02009* SOLU) - (0.02378* HEMI) - (0.02216* CEW) + (0.0840* LICU), where the OM fractions are expressed as a mass fraction of total OM. IBS represents the stable fraction in the compost.

Field experiment

The field experiment was located at Feucherolles (Ile de France, 50 km west of Paris). It included 4 blocks of 10 treatments. The 3 composts and the farmyard manure were compared to a control treatment without organic amendment. These 5 "organic treatments" were crossed with 2 "mineral N treatment": added mineral N fertilisation or no N fertilisation

The soil was a loamy clay (clay, 15%; silt, 78%; sand, 7%) with a low organic matter content on starting the experiment (OM : 19.1 g kg^{-1}) and pH 6.9 (in water). All plots were sampled before starting the experiment and soil characteristics were homogeneous. Soil density was measured at the beginning of the experiment and was 1.27 in the ploughed horizon (30 cm).

The field was cultivated with a maize-wheat rotation. Wheat straw was exported but maize residues were incorporated. Organic amendments were applied after wheat harvest in 1998, 2000 and 2002. The applied amounts of organic amendments were calculated to bring similar amount of organic carbon (about 4 TC ha^{-1}). Soil organic carbon (C) was measured in the ploughed horizon before each compost application in 1998, 2000 and 2002.

RESULTS AND DISCUSSION

Compost organic matter characterisation

The main characteristics of compost OM are presented in Table 1 and the kinetics of C mineralisation in Figure 1.

***Table 1**. Physico-chemical characteristics of the composts and farm yard manure applied in the field experiment in 1998 and 2000.*

	SG		MSW		BIO		FYM	
	1998	2000	1998	2000	1998	2000	1998	2000
Org. C[a] (g/kg)	273	191	304	313	158	2.6	287	385
OM[a] (%)	52.8	37.1	57.9	59.1	40.6	27,8	55.9	72.5
SOLU (% OM)	48.8	40.9	50.8	48.7	47.1	30.2	41.7	29.3
HEMI (% OM)	5.8	1.9	6.1	5.0	4.6	1.7	14.3	12.6
CEW (% OM)	25.7	35.6	33.2	35.8	31.5	54.2	26.3	41.1
LICU (% OM)	31.7	49.8	13.7	19.4	28.9	49.3	23.3	22.5
ISB	0.69	0.83	0.33	0.38	0.60	0.68	0.55	0.50

a : analysis expressed referring to dry matter

In both years, the largest proportions of C mineralisation were observed with the MSW composts, meaning that these composts had the less stabilised OM. The biowaste and the sludge composts (BIO and GS) were the most stabilised composts with less than 15% of organic C mineralised.. The proportion of stable OM in the composts and manure was estimated from the results of the biochemical fractionation and calculation of IBS. It increased in the order MSW<FYM<BIO<GS. The sludge compost had the largest proportion of stable OM. The quantities of organic amendments effectively applied were measured with the corresponding amount of total organic C inputs (table 2).

***Table 2**. Quantities of composts and farmyard manure applied in the different treatments of the field experiment; quantities of organic carbon and nitrogen (mineral and total) applied.*

	SG		MSW		BIO		FYM	
Applied amounts	1998	2000	1998	2000	1998	2000	1998	2000
Dry Matter (t/ha)	10.7	18.8	10.0	16.9	16.2	25.0	13.1	9.6
Organic C (t/ha)	2.9	3.6	3.0	5.3	2.6	4.4	3.8	3.7

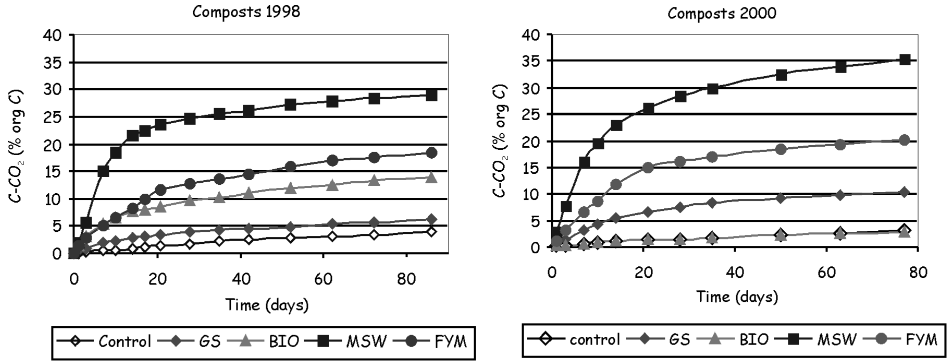

***Figure 1**. Compost organic carbon mineralisation during laboratory incubations.*

Soil organic carbon evolution

Soil organic C decreased in the control plots without organic applications (Figure 2), but increased in the plots receiving the organic amendments. The largest increases were observed in the treatments with GS and BIO composts where organic C concentrations were significantly larger than in the control treatment. Similar evolution in C concentrations was observed in the plots receiving organic products and mineral fertilizer. The observed increases did not correspond to the total amount of organic C entering the soils with the organic amendments. Some of the organic inputs mineralised after application and only a proportion of total applied organic C is incorporated into the soil organic matter.

The mass balance of organic C was calculated between 1998 and 2002 on a yearly basis as proposed in the Hénin-Dupuis model (1945):

C stock (Y+1)= C stock (Y) – K_2 * C stock (Y) + K_1* C_{OM} + K_1* C_{PR} where :

C stock (Y), in t C/ha, is the total stock of organic carbon on year Y, with the hypothesis that soil density did not change after 2 applications of organic products.

K_2 is the proportion of soil organic carbon mineralised every year, calculated as proposed by Rémy and Marin-Laflèche (1976): K_2=0.0206 was used.

C_{OM} is the total amount of organic C applied as organic amendments (Table 3)

C_{PR} is the total amount of organic C entering into the soil with the plant residues and plant roots. Root mass was estimated from references used in agriculture (4 t MO/ha for maize and 2 or 3 t MO/ha for wheat depending on the yield).

K_1 is the proportion of organic input incorporated into the soil organic matter. The IBS was used as estimation of K_1 for the organic amendments (Table 1). Usual K_1 were used for plant residues and root biomass (K_1= 0.15 for roots, 0.12 for maize residues).

The final calculated concentrations of organic C in the different treatments were significantly correlated to the actual measured concentrations (Figure 2).

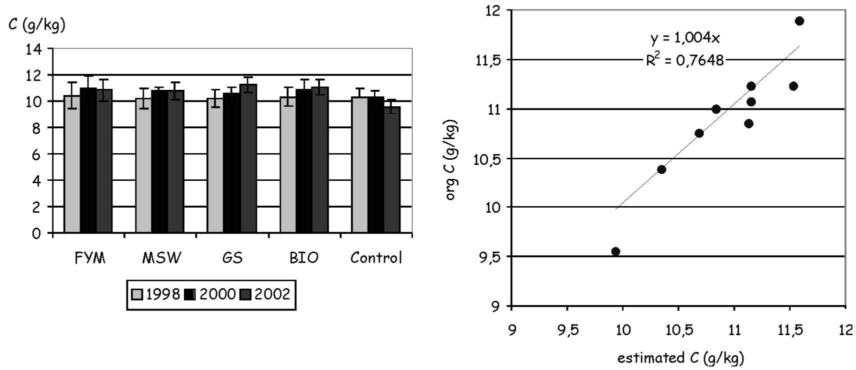

***Figure 2**. Organic C evolution in the ploughed horizon of the plots receiving no mineral fertilizers in the field experiment (left) and comparison of measured C concentrations in 2002 and estimated values from the mass balance (right).*

CONCLUSION

After 2 applications, with classical doses, soil organic C was significantly increased. Based on biochemical fractionation (standard method in France XPU 44-162), an index of biological stability (IBS) was used to estimate the proportion of stable organic matter entering the C cycle in soil. Good correspondence was found between the estimated C concentration and the measured concentrations after 4 years of experiment. So IBS can be considered as a good estimator of the proportion of amendment organic matter, “efficient” in increasing the organic matter stocks in soils.

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