EFFECT OF ORGANIC AMENDMENTS ON SOIL AGGREGATE STABILITY

M. Annabi[1,2], S. Houot[1,2], M. Poitrenaud[2], J.N. Rampon[1], H. Gaillard[3], Y. Le Bissonnais[3]

[1]UMR INRA INA-PG "Environment and Arable crops", 78850 Thiverval-Grignon, France, [2]CREED, 78520 Limay, France. [3]INRA, Soil Science, Ardon, 45 166, France

ABSTRACT

Intensive agriculture is known to cause a decline in soil organic matter content and alter soil structure. The objective of this study was to compare the effect of two urban composts (a municipal solid waste compost, MSW and a biowaste compost, BW) and a farmyard manure (FYM) on aggregate stability in a loamy soil under field condition. Laboratory incubations of calibrated aggregates added of the same organic amendments were realized in controlled conditions (28 and 4 °C) to confirm the effects observed in field conditions. After one application of the MSW and BW composts in the field experiment, aggregate stability increased compared to the control plot. In lab conditions, MSW and FYM enhanced the aggregate stability, more at 4°C than at 28°C. In both experiments, the aggregate stability were related to the stimulation of microbial activity after addition of still highly biodegradable organic amendments, more persistent at 4°C than at 28°C.

INTRODUCTION

Soil aggregate stability is one of the main factors controlling topsoil crustability and erodibility. The most important soil properties influencing structure stability are texture and organic matter content (Le Bissonnais, 1996). The degradation of soil structure is mainly due to aggregate breakdown under rainfall action. Intensive agriculture production is known to cause a decline in soil organic matter content, that leads to the alteration of soil structure stability. The addition of exogenous organic matter generally results in the improvement in soil organic matter content and soil stability (Metzger et *al*, 1987). The effects observed on aggregate stability vary with the characteristics of both exogenous organic matter and the soil. The organic matter increases aggregate stability by the enhancement of aggregate hydrophobicity and the inter-particle cohesion. Hydrophobic compounds diminish the rate of aggregate wetting. Microbial activity influences both aggregate properties (Lynch & Bragg, 1985). Farmyard manure is traditionally used as organic amendment. But in many cropping areas where the breeding activity has disappeared there is a shortage of these kinds of organic matter and composts made from urban organic wastes can be useful amendments for agriculture.

The aim of this study was to compare the effect of traditional farmyard manure to two kinds of urban waste composts on aggregate stability in a loamy soil under lab and field conditions, and to relate the observed effects to microbial activity.

MATERIAL AND METHODS

Field experiment: The field experiment was located in Ile de France (Center North of France). The soil was a silty loam (redoxic Luvisol), the initial average organic carbon content was 1.1%. The site was designed to evaluate urban compost fertility and their environmental impacts (Houot et al, 2001). The effect of a municipal solid waste compost (MSW_1), a biowaste compost (BW_1) and a farmyard manure (FYM_1) were compared to control plots, without organic amendment (Table 1). The organic products were spread during October 1998 at an average dose of 4t C ha^{-1} and ploughed into the top soil. At the beginning of the experiment and 18 months after the organic product addition, the surface layer of the plots was sampled and the 3-5 mm diameter aggregates were recovered. The aggregates were used to evaluate soil aggregate stability according to fast wetting test of Le Bissonnais method (1996). This test simulates slaking occurring when dry aggregates are rapidly immersed in water under a heavy storm. After 10 min of brutal aggregate submersion in water, the residual aggregates are collected, dried and sieved with six sieves: 2, 1, 0.5, 0.2, 0.1 and 0.050 mm. Results were expressed as a mean weight diameter (MWD: sum of the fraction of soil remaining on each sieve multiplied by the mean aperture of the adjacent sieves).

Carbon mineralization of the organic amendments was measured during incubations in controlled conditions. Soil-organic amendment mixtures were incubated during 43 days at 28°C. Organic products were added in order to bring similar proportion of C as used in the field experiment. The CO_2-C released during the incubation was trapped in 0.5 N NaOH and was measured using colorimetric method on a continuous flow analyser (Skalar, The Netherlands). Soil polysaccharides were extracted on 1.5g with water (20 ml) at 80°C for 24h, the polysaccharides C content of the extracts was determined by colorimetric method at 490nm according the phenol /Sulfuric Acid method (Puget et *al*, 1999). The wettability of 3-5 aggregates was assessed with the water drop penetration time (WDPT) method (Chenu et *al*, 2000). All measurements were done in triplicate, except WDPT with 25 repetitions.

Incubation Experiments: Additional incubations of soil-organic amendment mixtures in laboratory controlled conditions were realized. Another set of organic products was sampled on the same plants (MSW_2, BW_2 and FYM_2) (Table 1). Soil aggregates were sampled in the surface layer of a control plot in the field experiment. The incubations were realized with 250 g of 3-5 mm calibrated aggregates. Organic amendments were added in order to represent three times more C than in field conditions (5.85 g C kg^{-1}) and incubated during 43 days at 28°C and 4°C. At the end of the incubation, we measured the same variables that we did in the field trial.

***Table 1**. Main characteristics of the organic amendments (on dry matter basis)*

	Organic amendment used in the field experiment			Organic amendment used in the incubation experiment		
	MSW_1	BW_1	FYM_1	MSW_2	BW_2	FYM_2
Total organic C (TOC) (%)	30.4	15.8	28.7	31.3	17.6	38.5
Total N (%)	2.0	1.6	2.4	2.1	1.2	1.9

RESULTS AND DISCUSSION

Microbial activity:

After 43 days at 28°C in both sets of organic amendments, C mineralization were larger with MSW and FYM than with the BW-compost (Table 2). The BW_1 was more biodegradable than BW_2 since less than 1% of organic carbon was mineralized in BW_2 treatments, against 10% in BW_1. The kinetics of C mineralization were used as indicator of the effect of organic amendment addition on microbial activity in soils. So, the highest microbial activity was observed with FYM and MSW. As expected, mineralization was highly decreased at 4°C because of the inhibiting effect on microbial activity.

After 18 months, no difference of polysaccharides content and WDPT were observed between plots receiving different organic treatments (Table 2). On the other hand, the polysaccharides content and the WDPT were increased significantly with the addition of organic amendments in the lab conditions. After 43 days, the polysaccharide content were lower in samples incubated at 28°C than in samples incubated at 4°C, because polysaccharides were rapidly consumed by the microflora, more activated at 28°C than at 4°C. The hot water extractable polysaccharides can be considered to be principally composed by exocellular polysaccharides of microbial origin (Puget et *al*, 1999). They have an important role on soil aggregation directly by increasing the mineral particle cohesion and indirectly, as energy source for the microflora (Lynch & Bragg, 1985).

Table 2*. Carbon mineralization, microbial polysaccharides, hydrophobicity and aggregate stability in field and laboratory experimentations.*

Condition	Treatment	carbon mineralization (%TOC added)		Polysaccharides (mg C g^{-1} DM)	Median value of WDPT (s)		MWD (mm)	
		After 10 days	After 43 days		Initial	End of trial	Initial	End of trial
Field trial	MSW_1	20.9±0.3	29.7±0.4	0.178±0.017 *	0.53	0.62	0.25±0.01	0.55±0.02
	BW_1	5.7±0.1	9.8±0.5	0.165±0.005 *	0.64	0.59	0.22±0.01	0.52±0.05
	FYM_1	6.5± 0.2	14.7±0.6	0.176±0.001 *	0.64	0.64	0.26±0.00	0.30±0.02
	Control	-	-	0.175±0.020 *	0.59	0.62	0.24±0.01	0.38±0.03
Lab at 28°C	MSW_2	13.0±0.1	23.9±0.2	0.174±0.014	-	1.15	-	0.59±0.04
	BW_2	0.29±0.0	0.7±0.02	0.170±0.012	-	1.20	-	0.42±0.07
	FYM_2	10.1±0.7	21.5±1.3	0.172±0.022	-	0.92	-	0.45±0.04
	Control	-	-	0.155±0.012	-	0.44	-	0.35±0.02
Lab at 4°C	MSW_2	2.6±0.03	11.5±0.2	0.225±0.037	-	2.55	-	1.29±0.20
	BW_2	0.14±0.03	0.41±0.06	0.170±0.020	-	1.06	-	0.42±0.02
	FYM_2	1.2±0.06	9.0±0.9	0.211±0.029	-	1.03	-	0.58±0.02
	Control	-	-	0.168±0.006	-	0.43	-	0.46±0.02

Aggregate stability:

Before organic amendment addition, similar aggregate stability was measured in all plots showing the initial homogeneity of the field soil experiment (Table 2). Eighteen months after the organic amendments addition, aggregate stability was improved in all the treatments, included the control plot. Such variability could be attributed to differences in crop and climatic conditions. However, differences among the treatments were observed, aggregate stability was higher in MSW_1 and BW_1-treated plots than in the control and FYM_1 treatments. Aggregate stability could be related to the larger stimulation of the microbial activity after MSW_1 addition than BW_1 and FYM_1, as showed by several authors adding different exogenous organic matter (Metzger et *al*, 1987; Diaz et *al*, 1994; Roldan et *al*, 1994). No relationship was found between aggregate stability and polysaccharides or with WDPT, probably because of the rapid disappearance of easily biodegradable organic amendments pool (as polysaccharides, lipids, etc.).

At the end of the incubation and at both temperatures, aggregate stability was slightly increased with organic treatments, significantly with MSW-composts. The MWD of MSW_2 incubated at 4°C was higher than at 28°C because of the larger content in hydrophobic substances, probably less decomposed at 4°C.

Based on carbon mineralization intensity, microbial activity after 43 days of incubation at 4°C was equivalent to the microbial activity after 10 days at 28°C. So, it may be hypothesized that aggregate stability could follow the same pattern. Measurement of aggregate stability should have been done after 10 days at 28°C and compared to aggregate stability after 43 days of incubation at 4°C. FYM_2 less improved aggregate stability than MSW_2-compost although the microbial activity was stimulated similarly. This can be explained by lower hydrophobicity or could be related to differences in the involved microbial populations.

CONCLUSION

In both experiments, the MSW-compost improved aggregate stability the most. This was in relation with the biodegradability of its organic matter. The microbial activity generated after addition of easily biodegradable organic matter such as MSW-compost used in our study, could generate stabilizing substances (as polysaccharides and hydrophobic compounds) or provoked the development of efficient stabilizing microorganisms as filamentous fungi. However, the effects of highly biodegradable amendments are expected to be more transitory than in the case of stable composts, more efficient in increasing SOM and having longer term effect on aggregate stability but with smaller amplitude. More research is under progress to provide clear explanations.

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