EFFECTS OF APPLICATIONS OF CATTLE MANURE ON ORGANIC MATTER ACCUMULATION AND NITROGEN MINERALISATION

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1 INTRODUCTION

Animal manure is the main source of organic matter spread on agricultural areas in France, most of which is cattle farmyard manure, which represents 73% of national animal-manure supply (INRA, 2002). Application of animal manure to the soil increases soil organic matter (SOM) content and nitrogen mineralisation (Chang and Janzen, 1996, Schröder et al., 2005). There remains little information, however, on the effect of repeated applications on the accumulation and quality of the SOM, and between the accumulation of SOM and N mineralisation. Information from medium- and long-term experiments thus is needed to give an accurate prediction of the behavior of manures in soil and their effects on carbon and nutrient cycles.

A network of 11 medium- (8-15 years) and long-term (> 15 years) experiments, mainly located in western France, was used to assess the effects of cattle farmyard manure (FYM) and composted FYM (CFYM) on the accumulation of organic matter and N mineralisation. The upper soil layer was sampled 7 months to 4.5 years after the last animal manure application, depending on the experiment, and the effects of FYM/CFYM applications were measured by comparison with a control treatment that had not received any organic fertilizer during the experiment.

2 MATERIAL AND METHODS

2.1. Network presentation

The location of the 11 experiments, period of manure application, crop rotation, rates and frequency of application are presented in Table 1. Most of the experimental sites were located in western France, except for the St. Hilaire and Feucherolles sites. Manure was applied yearly or every two years on crop rotations, except at Derval and La Jaillière 2, where applications were spread on grass. The effect of manure application was studied in comparison with control treatments receiving only mineral fertilizers.

The soil surface layer corresponding to the tillage depth (25-30 cm) was sampled during late autumn, 7 months to 4.5 years after the last application of animal manure (Table 1). The soils were loam or sandy loam, with the silt content varying from 43-72% and the clay contents remaining relatively stable (15-19%). The soil C content ranged from 0.9-2.8%.

TABLE 1 **Presentation of the experiment network, with crop rotations, rates and frequency of manure application (TBLAS: Time Between Last manure Application and soil Sampling) in each experiment**

Experiment	Abbreviation	Manure application period	Crop rotation*	Spreading frequency	FYM application rates (t ha^{-1})	CFYM application rates (t ha^{-1})	TBLAS (y)
Crécom 1	CREC 1	1984-2003	m	once per y	25	-	0.6
Crécom 2	CREC 2	1987-2005	m/w	every 2 y	25/50	-	1.7
Derval	DER	1998-2005	gr/m/w	once per y	24	-	3.3
Feucherolles	FEU	1998-2008	m/w	every 2 y	40	-	1.5
La Jaillière 1	LAJA 1	1995-2005	m/w	once per y	20	20	0.9
La Jaillière 2	LAJA 2	1995-2005	gr	once per y	25	20	1.4
Rennes	REN	1995-2007	m/w	every 2 y	50	50	1.8
Rheu	RHEU	1995-2005	m	once per y	25	15, 25, 40	0.8
St Hilaire 1	ST HIL 1	1994-2003	r/w	once per y	30, 60, 90**	-	4.6
S Hilaire 2	ST HIL 2	1994-2003	m/w	once per y	30,60,90***	-	4.4
Trévarez	TREV	1987-2006	m/w	every 2 y	25	-	1.7

* m: forage maize; w: wheat ; r: rapeseed; gr: grassland

** from 1999-2003, respectively ; rates of application of 25, 25, 25, 30, and 30 t ha^{-1} from 1994 to 1998, followed by 3 different rates of application between 1999 and 2003

*** from 2000-2003, respectively ; rates of application of 25, 0, 25, 0, 25, and 0 t ha^{-1} from 1994 to 1999, followed by 3 different rates of application between 2000 and 2003

2.2. Manure composition

Large variations in manure composition were observed over the years for a given site, suggesting that subsequent short-term transformation of manure C and N also varied greatly. The mean composition of cattle manure also varied among experiments; the C:N ratios were relatively low for FYM, ranging from 13.6 to 16, consistent with stored and matured cattle manure, except for FYM applied at Crécom and Rennes. Within experiments, the mean compositions of FYM and CFYM differed significantly only at Rennes.

The amounts of applied organic C and total N varied greatly among application years, because of the variable composition of the manure, but also due to the experimental design (lower rates of application on wheat at La Jaillière 1 than on maize) and to protocol modification during the experiment at St. Hilaire (Table 1) and Rheu (lower rates of application during the final years).

2.3. Soil analysis and soil incubations

Total C and N contents of the soils were determined by elemental analysis (AFNOR, 1999). A fractionation method was used to determine the distribution of coarse (200-2000 µ), intermediate (50-200 µ) and fine (< 50 µ) SOM fractions. Soil N mineralisation was measured during incubation under controlled laboratory conditions at 15 °C for 240 days, simulating one year in the climatic conditions of western France.

3 RESULTS AND DISCUSSION

3.1. Relations between manure application and C accumulation

FYM and CFYM applications increased the C content of SOM by 3-55% (Fig. 1). C accumulation resulting from FYM applications varied greatly, from 19-65 % of cumulative applied C, with high values observed at St. Hilaire and Feucherolles and the lowest rates observed at Crécom. Less variability was observed for CFYM applications (mean rate of C accumulation = 37%, n = 3), though C-accumulation rates were higher for CFYM than for FYM at Rennes and La Jaillière 1.

This variability can be related to different factors: i) the short-term degradability of cattle-manure organic matter, which determines the residual amount of C at the end of the year following application, which may vary from 20-60% of the applied C (Morvan et al., 2005); ii) the duration of the experiment and the decreasing global rate of C accumulation with time (Jenkinson and Rayner, 1977); iii) the time interval between the last application and soil sampling, which varied greatly among sites; and iv) soil characteristics and climatic conditions – higher rates of C accumulation were observed at St. Hilaire and Feucherolles, where climatic conditions are warmer and less temperate than at other sites.

Fractionation of SOM showed that no C accumulation occurred in the coarse fraction in any experiment, regardless of the time interval between the last manure application and soil sampling. C was mainly observed in the finest fraction (< 50 µ).

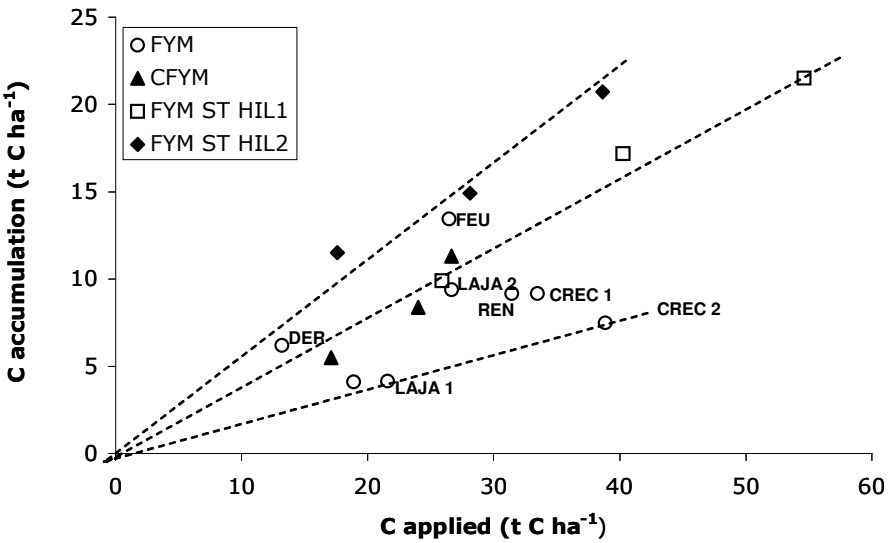

FIGURE 1 **Relation between C application and C accumulation resulting from repeated applications of uncomposted (FYM) and composted (CFYM) farmyard manure.**

3.2. Effects of manure application on nitrogen mineralisation

Soil N mineralisation varied from 25-40 mg N kg^{-1} soil over 240 d for control soils, with a higher rate at Derval (69 mg N kg^{-1} soil). Manure applications significantly increased soil N mineralisation for most experiments and treatments (Fig. 2), but weak extra mineralisation also was observed for FYM at La Jallière 1 and for FYM and low application rates of CFYM at Rheu. Soil N mineralisation increased by 0-47 % depending on the treatment, corresponding to extra N mineralisation ranging from 0-62 kg N ha^{-1} y^{-1} (mean = 25 kg N ha^{-1} y^{-1}).

Extra N mineralisation was poorly correlated with soil N accumulation resulting from manure application (r = 0.48, n = 22), which indicates that turnover rates of stored OM varied greatly among sites, likely because they were influenced by the same factors that influenced accumulation rates.

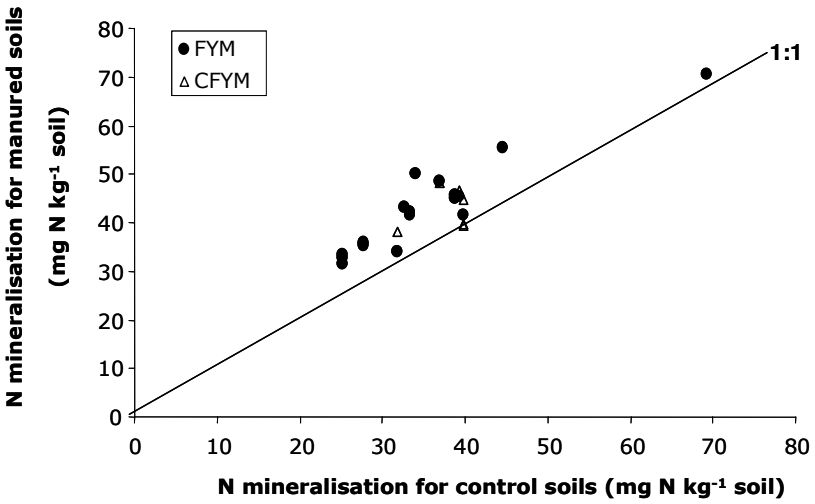

FIGURE 2 **Comparison of soil N mineralisation measured on control soils and soils with FYM and composted (CFYM) manure applied, during a 240-day incubation at 15°C.**

4 CONCLUSION

Repeated applications of cattle manure significantly increased soil C and N contents, and a large variability of C-accumulation rates was observed. This may result from the interaction of several factors, such as the short-term decomposition rate, application rates, the duration of the experiment, and climatic conditions... Thus, a modeling approach appears necessary to study these factors, and we think that as an initial approach, simple compartmental models (e.g., ROTH-C, AMG, ICBM) are more appropriate than mechanistic models (e.g., CANTIS, NC SOIL) to evaluate the relative magnitude of the effects of these factors. Organic matter accumulation was observed in the intermediate and fine SOM fractions, corresponding to low turnover pools. This is confirmed by the moderate rates of extra N mineralisation observed in most experiments. In fact, the lower rates of soil N mineralisation observed in manured soils than in control soils at Derval, La Jaillière and Rheu suggest a lower OM turnover in the manured soils and thus high OM stabilization following the short-term biodegradation phase.

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