Initial study of the spatial variability of microbial indicators and its utilities for the assessment of tillage systems on the soil microbiological functioning in organic farming

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***Abstract* – Reduction tillage, in modifying the soil microorganisms' environment, modifies their potential to supply plants nutrients. This is of primary importance in organic farming as the nutrients availability is mainly dependent on the organic matter degradation by microorganisms. To study the effect of tillage on soil physical and microbiological properties, we compare 4 tillage practises (deep and shallow ploughing, chisel and no tillage) in an experimental field near Lyon. Our objective is to link a structural statement with a microbiological functioning in order to study the microorganisms' abilities to supply nitrogen and phosphorus. For such studies, it is of primary importance to use a convenient sampling design as the microbiological properties are highly variable in space and time. So, we first studied, before the treatments differentiation, the spatial variability of some microbiological properties. We first present this study briefly and its utilities for the future assessment of the tillage practises on the soil microbiological functioning.[1].**

INTRODUCTION

The soil microbial functioning is of primary importance in organic farming as nutrient supply is only dependent on the soil organic matter (SOM) degradation by the soil microorganisms. Tillage management plays a key role in the SOM turnover. It modifies quantitatively and qualitatively the soil microorganisms' communities (Young et al., 2000) and their activities. Then, in organic farming (OF), the choice of tillage system requires to consider its impact on nutrient supply contribution of soil microbial activity. In field experiments, organic carbon and nitrogen (OC and ON), soil microbial biomass (MB) and its activities are usually used to describe the soil microbial functioning (Nielsen and Winding, 2002). However, their high spatial variability causes a serious limitation for their current use in field (Nael *et al.*, 2004). These variables are often spatially structured over distances of tens to hundred meters (Ettema and Wardle, 2002). To compare the effect of 4 tillage conditions (deep plough, shallow ploughing, chisel and no-tillage) on soil microbial functioning, it is therefore desirable to use a convenient sampling design which takes into account the spatial heterogeneity at both field and plot scales.

In this experiment, a preliminary analysis of the spatial heterogeneity of the soil MB and its activities was done in February 2005 before the differentiation of the plots. The spatial heterogeneity of each parameter was charted with geostatistics.

MATERIALS AND METHODS

Area description

The experimental field was located in the south of France (Lyon) and conducted in organic farming since 1999. The soil was a sandy loam (58% sand, 27 % silt and 15% clay). The spatial analysis was achieved on the first of the three bloc of the experimental field (144*80 m) cultivated with a three years old alfalfa.

Soil analysis

63 soil samples were collected according to a 10 x 10 m grid. On each of these samples, 10 parameters were measured: soil water content; soil pH; CEC Metson; OC and ON; microbial biomass (MB) (fumigation-extraction method; Chaussod et al., 1988); labile soil organic matter (LOM) (Chaussod et al., 1988); potential C and N mineralization (Cmin and Nmin per 28 days at 28°C.) (Nielsen and Winding, 2002).

Two parameters were calculated: C/N ratio and specific respiratory (qCO_2), which is the microbial respiration rate (Cmin, in mgC/day) per unit microbial biomass (MB) (Nielsen and Winding, 2002). This parameter can also be expressed as $1/qCO_2$ which corresponds to the residence time (in days) of C in the microbial biomass.

The geostatistical analysis (Goovaerts, 1998) was performed with the software GS+ (version 1.21, Gamma Design Software, Plainwell, MI, ISA) to provide unbiased estimates of the non sampling points.

RESULTS

Variables description

All the variables showed a high variability except pH and C/N ratio.

We mapped this spatial variability by the krigging method (Goovaerts, 1998). Seven maps were built with a fitted model: CEC (fig. 1a), moisture, ON, OC (fig. 1b), MB (fig. 1c), LOM and $1/qCO_2$ (fig. 1d).

The quantitative variables display a similar spatial variability: lower values in North-East and in South-West of the field and higher values in the center of the field (diagonal) (Fig. 1a, b and c).

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The spatial variability of $1/qCO_2$ (fig. 1d) differs from the other variables. Comparison of obtained maps shows that higher values of $1/qCO_2$ (low microbial activity) are located near the higher values of organic pools (MB, LOM) and conversely. Several hypotheses can be done on theses discrepancies: the clay content, the SOM quality or the genetic structure of the microorganisms' communities between these areas are dissimilar, which in turn lead to a distinct soil microbiological functioning in these areas.

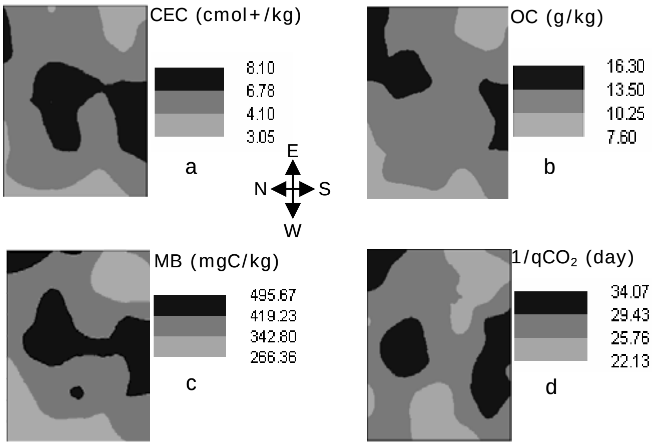

Figure 1: spatial variability of CEC (a), OC (b), MB (c) and $1/qCO_2$ (d).

Discussion and perspectives

Quantitative variables of organic pools (MB, LOM, OC and ON) and microbial activity variables (Cmin, Nmin and qCO_2) present a high spatial variability in this experimental field. This variability could mask the effects of the tillage treatments on the soil microbial functioning.

The geostatistic analysis shows 3 distinct zones (fig.1) for the studied variables. It permits to judiciously locate the 3 replicates of the 4 treatments on the experimental field, to record the initial values and to adopt a stratified sampling scheme for future measurements. These three points will allow an accurate assessment of the effects of the starting treatments by minimizing the variance of each variable and therefore will allow differentiating the effects of the treatments (Stein and Ettema, 2003).

We locate the sampling points in a homogenous area (diagonal of the field) to assess accurately the link between the soil structure, induced by tillage and organic farming specificities (SOM, macroorganisms' activities...), and the soil microbial functioning. The sampling period corresponds to the transition period between conventional to reduce tillage (fig.2), a crucial phase for plants nutrition in OF. We characterise the structural modifications induced by tillage systems and their consequences on:

- the size and the repartition of the different organic and microbiologic pools in the soil profile (0-30 cm);
- the global activity of the microorganisms through the C and N mineralization;
- the genetic structure of the soil microbial communities involving in N dynamics (nitrifiers and denitrifiers) and P dynamics (arbuscular mycorrhizal fungi).

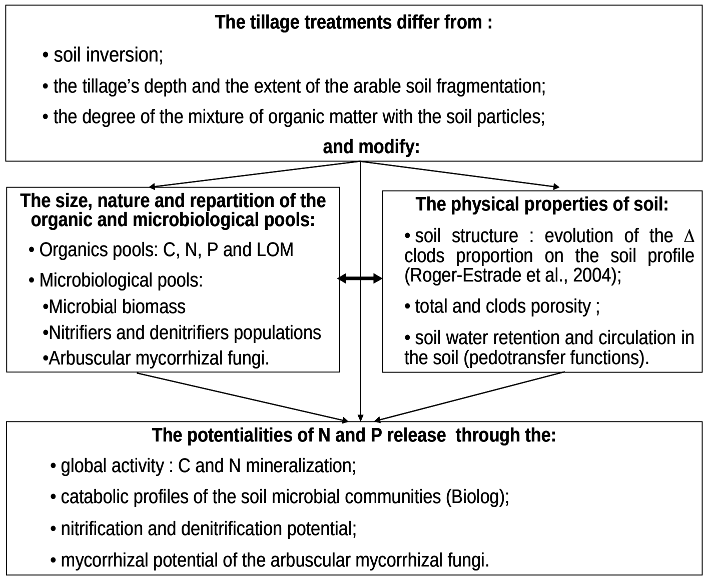

Figure 2: modifications of the physical and microbiological soil properties induced by tillage.

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