Assessment of tillage systems in organic farming: influence of soil structure on microbial biomass. First results.

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Abstract

Soil tillage modifies environmental conditions of soil microorganisms and their ability to release nitrogen. We compare the influence of reduced tillage (RT) and mouldboard ploughing (MP) on the soil microbial functioning in organic farming. In order to connect soil structure generated by these tillage systems on the soil microbial biomass we adopt a particular sampling scheme based on the morphological characterisation of the soil structure by the description of the soil profile. This method reveals the influence of soil structure on soil microbial biomass and allows a more precise assessment of the impact of tillage managements on the soil microbial functioning.

Introduction

The soil microbial functioning is of primary importance for the quality and productivity of cultivations, especially in organic farming as nitrogen (N) supply is mainly dependent on the degradation of soil organic matter by microorganisms. Soil tillage is known to modify the biotic and abiotic conditions of soil microorganisms' environment and thus modifies qualitatively and quantitatively microbial communities (Young et al. 2000). Numerous studies report that reduced tillage leads to an accumulation of the soil microbial biomass and an important N release in the upper layers in comparison with conventional tillage. Usually, there is no difference when they consider the entire soil profile (Andrade et al. 2003, Young et al. 2000, Kandeler et al. 1998). Soil tillage induces also changes in soil structure at different scales, ranging from the soil profile to a few micrometers (Balesdent et al. 2000). Consequently, soil structure is greatly variable in time and space in cultivated fields, which makes it difficult to choose a convenient sampling scheme for studying soil processes (Roger-Estrade et al. 2004).

Our objective is to study the impact of different tillage systems in organic farming on the soil microorganisms and to consider the interactions between soil structure and the microbial functioning. In order to connect these parameters, we adopt a morphological description of the soil structure based on the description of the soil profile. This method enables to distinguish and quantify distinct structural zones in the soil profile: zones with loose structure composed by Γ clods and compacted zones, essentially composed by Δ clods. By measuring different microbial parameters on these clods with distinct physical properties (Boizard et al. 2004) we try to connect soil structure generated by tillage treatments with the soil microbial functioning. Indeed, this method enables to link the soil structure characteristics to the cultivation

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operations responsible for soil structure dynamics and to integrate the spatial heterogeneity in our analyses at the field scale (Roger-Estrade et al. 2004).

Materials and methods

Four tillage systems are compared on a Cambisol Dystrique (FAO classification; 48% silt, 20% clay and 32% sand) located in Brittany, north-west of France. The experimental design consist in 12 plots (12*25m²) randomised in three blocs. Treatments have been differentiated since 2003. We present the results from the conventional tillage treatment with an annual mouldboard ploughing to 20cm depth (MP) and a reduced tillage treatment to 15cm without soil inversion with a chisel (RT).

Soil structure is characterised by the spatial arrangement of aggregates, peds, clods and pore space on a pit according to Roger-Estrade et al. (2004). We distinguish and quantify the Γ and Δ clods (structural porosity clearly visible and non-eye visible porosity respectively) in the soil profile which have distinct physical characteristics (Boizard et al. 2004). Their respective proportion in soil profile is an indication of the evolution of soil structure under different tillage systems (Roger-Estrade et al., 2004). We measure the porosity of each type of clods by the petrol method at three depths (0-5 / 5-15 / and 15-20cm).

To connect the structural states of the treatments to their microbial functioning we measure on these Γ and Δ clods ($\pm$10cm^3) their microbial biomass (MB) (fumigation-extraction method), their labile soil organic matter (LOM) (Chaussod et al. 1988), and their potential C and N mineralization (Cmin and Nmin per 28 days at 28°C.). We deduce from these parameters the microbial respiration rate per unit of MB (qCO$_2$, mgC per day) (Nielsen and Winding, 2002). Organic carbon (NF ISO 10694) and total nitrogen (NF ISO 13878) were measured as the soil pH.

We briefly present the firsts results of the influence of MP and RT systems on the soil MB from distinct structural zones. Soil observations have been made 4 months after tillage operations. Statistical analysis is made with *statview 5.0* (SAS Institut Inc.). We use a multiple comparison test (Fischer's PLSD) using *pairwise comparisons*.
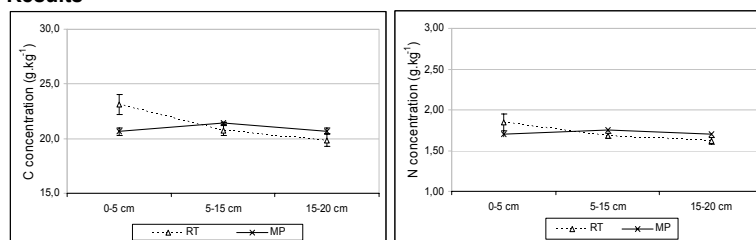
Results

Figure 1: Carbon concentration (g.kg^{-1}) (left) and nitrogen concentration (g.kg^{-1}) (right) of the reduced tillage (RT) and mouldboard ploughing (MP) treatments.

The concentrations in organic carbon (OC) and total nitrogen (N) (figure 1) of the Γ and Δ clods, from the same soil horizon, are not different but the porosity of the Γ clods is significantly higher than the Δ clods porosity (results not shown).

C concentration is significantly higher in the upper layer (0-5cm) in the RT than in MP (P<0,001). No differences appear in the other soil layers. We observe a vertical stratification of C concentrations in RT system. The C concentration in the upper layer is significantly different than the deeper one (P<0,05), and the 5-15cm layer have an intermediate concentration. In contrast, the C and N concentrations of the MP treatment are homogenously distributed in the soil profile, as the N concentrations in RT.
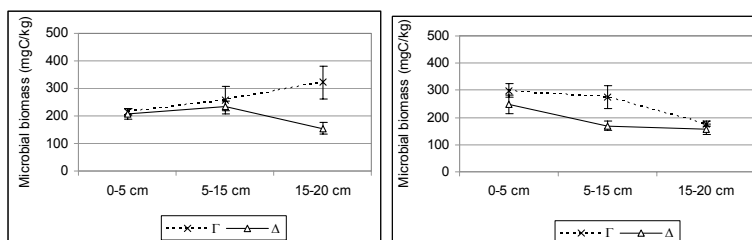

Figure 2: influence of the type of clods (or) and the soil depth on soil microbial biomass (mgC.kg^{-1}) for the MP (left) and RT (right) treatments.

Whatever type of clods, soil microbial biomass (MB) is significantly higher in RT than in MP for the upper layer (P<0,05). Soil MB is significantly higher in MP than RT for the Δ clods from the 5-15cm layer and for Γ clods from the 15-20cm layer (P<0,05 and P<0,001 respectively). Soil MB diminishes with the depth in RT whereas it increases in MP. Significant differences of MB appear between 0-5 and 15-20 cm in RT treatment and between all soil layers in MP when we considered Γ clods.

MB of the Γ clods is significantly higher than the Δ clods for the 15-20 cm layer in the MP treatment and for the 0-5 and 10-15cm layers (P<0,001 and P<0,05 respectively) for the RT treatment.

Discussion

We observed a vertical stratification of OC and MB in RT whereas OC is distributed homogeneously in the soil profile in MP as reported in numerous studies (Andrade et al. 2003, Stockfisch et al. 1999).

OC and total N concentrations in Γ and Δ clods are similar. Differences observed on soil MB between these two clods from the same soil layer may be due to their distinct physical properties. In a compacted environment, where microporosity dominates, O_2 circulation and substrates originating from raw materials (diffused via the soil solution) are lower (Ranjard et al. 2001). It could be the case in the Δ clods, where O_2 diffusion could limit the development of aerobic bacteria and poor nutrients diffusion, via the soil solution, could limit microbial growth. Indeed, Curmi (1988) demonstrated that anoxic conditions are higher in compacted clods. Besides, microorganisms are physically protected from protozoan predation in microporosity (Ranjard et al. 2001). So, Δ clods may physically limit this predation which stimulates microbial turn-over and accelerates nutrient cycling (Young et al. 2000).

Soil MB differences between Γ and Δ clods seem to be clearer in RT than in MP. The turn-over of the Δ and Γ clods between these tillage systems are different. In CT, Δ clods are subjected to an annual fragmentation by the plough pan and to climate effect

(freeze and thaw) when they are replaced near the soil surface (Boizard et al. 2004). In RT system this in not the case and Δ clods may cumulate adverse conditions for the soil microorganisms for years, which in turn results in an easier differentiation with Γ clods. But, this distinction is not so clear particularly when we consider the deeper soil layer. Others factors like OM quality, microbial communities structure or a different mechanic in the Γ, Δ turn-over seem to interact differently at this depth.

Conclusions

In order to connect soil structural properties, induced by different tillage systems, with the soil microbial functioning we adopted a particular sampling design based on the morphological description of soil structure. This method enables to measure the soil MB (and its activities) from distinct zones: zones with loose structure and zones with eye-visible porosity. We show a vertical stratification and a horizontal one which is due to physical differences between clods. This procedure enables to integrate the spatial heterogeneity of the soil structure and to connect and quantify more precisely the soil microbial functioning with the soil structure. The study of the influence of tillage systems on the soil microbial functioning requires to consider the burial depth of OM, the degree of compaction generated by these tillage systems and the dynamics of the compacted zones.

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