Soil structure and earthworm activity under different tillage systems in organic farming

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Abstract

Organic farmers are encouraged to adopt conservation tillage to preserve soil quality and fertility and prevent erosion. However, many studies in different soil and climate conditions have demonstrated that the compaction of the untilled layer is higher in conservation tillage than in conventional tillage. As earthworm activity may help alleviate soil compaction in organic farming, the impact on the soil structure and earthworm population and activity was studied for 4 different tillage managements (1) mouldboard ploughing (MP), (2) shallow ploughing (SP), (3) reduced tillage (RT) and (4) no-tillage (NT), in 3 french areas. The first results are: (1) MP soil structure is better than SP, RT and NT, (2) water infiltration is higher at soil surface in SP, RT and NT, lower at 17 cm depth, (3) more earthworms, especially anecic species, are found in NT, (4) but more opening channels are found in MP. Then, during the first years of transition from MP to NT, soil structure is better in MP, and whereas earthworm numbers is reduced, it favours earthworm activity.

Introduction

Organic farmers are encouraged to adopt conservation tillage to preserve soil quality and fertility and prevent erosion. Conservation tillage leaves organic mulch at the soil surface, which reduces runoff, increases the soil organic matter content and improves aggregate stability which limits soil erosion (Franzluebbers 2002). These benefits can improve soil fertility, soil quality and environmental impact of organic crop production. However, Koepke (2003) reported that organic farmers generally use conventional tillage systems with a mouldboard plough, and, occasionally till to a greater depth than in conventional agriculture. Conservation tillage improves superficial soil structure and can reduce compactibility thanks to the concentration of decomposing crop residues. However, many studies in different soil and climate conditions, have demonstrated that the compaction of the untilled layer is higher in conservation tillage, with a decrease of total porosity (Kay et al. 2002). Earthworm quantity and activity increases in conservation tillage compared to conventional tillage. Increase of fresh organic matter in organic farming is an additional resource stimulating trophic and burrowing activity of earthworms (Gerhardt 1997). Thus, organic farming and conservation tillage may represent an efficient association to improve earthworm activity, and soil structure. To understand how earthworm activity can remediate to soil compaction due to tillage in organic farming, we study soil structure and earthworm population and activity on a large range of tillage managements.

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Materials and methods

3 experimental fields associated with 2 on-farm surveys have been carried out in 3 regions of France: Rhône Alpes (area A), Pays de la Loire (area B) and Bretagne (area C). In this paper, we only present the results obtained on the experimental fields. On each area (table 1), 4 tillage managements are compared and a completely randomised block design with 3 replicates is used: 1) Traditional mouldboard ploughing (MP) (30 cm depth), 2) Shallow ploughing (SP) (20 cm depth for area A and B, 15 cm for area C), 3) Reduced tillage (RT) with tine tool (15 cm depth for area A and B, 12 cm for area C) and 4) no tillage (NT). At the beginning of the essay (areas A and C), no tillage was managed under a cover crop.

Table 1: Description of the 3 experimental fields.

Area	Organic farming conversion	Start of the essay	Soil type	Crop rotation
A	1999	2003	Sandy loam (luvic brunisol)	Alfalfa (3 years) – Maize – **Soybean (2006)** – Winter wheat – Soybean - Maize
B	2000	2005	Silty (cambisol)	Maize – Field bean – Winter **wheat (2006)** – Lupin crop
C	1996	2003	Silty	Maize – cereal – wheat – **winter pea (2006)** - cereal

We adopt a morphological description of the soil structure. It allows integrating and explaining temporal and spatial variation of the soil structure at the field scale. We characterise the spatial arrangement of the aggregates, peds, clods and pore space on a pit (3 m in length, 1 m deep) according to Roger-Estrade et al. (2004). This method permits to distinguish and quantify in the soil profile distinct structural zones in the soil profile: % of zones with loose structure noted Γ clods (visible porosity) and % of compacted zones, noted Δ clods (non-eye visible porosity).

Soil hydraulic conductivity was measured with disk infiltrometer at water potentials of 6, 2 and 0.5 h Pa which correspond to pore diameter of 0.05 cm, 0.15 and 0.6 cm.

We measure the earthworm abundance (number / m^2) and species diversity (grouped in ecological category) with the formaldehyde method (Bouché et al. 1984). Each sample is taken on the same spot than the morphological description of the soil structure (plumb with the pit). Moreover, at the same place, we measure the impact of earthworm activity on soil structure through the presence or absence of channels in the soil profile. Opening channels are counted at a depth of 30 cm (junction of subsoil and topsoil) in the soil pit on a 0.2 m^2 plan (corresponding to the plan where earthworms were taken at the soil surface).

Results

We present results obtained in area C, after 3 years of experiment, and results obtained in area A, after 1 year of experiment. Results of area B are not yet available.

Morphological description of the soil structure: For both areas, we observe more 'porous' soil structure in MP, and also SP, than in RT and NT soil profiles. Indeed, clods are easier to discern (table 2), especially in the layer not cultivated with RT and NT, and % Γ clod (porous) is higher.

Table 2: observed spatial arrangement and porosity of clods of soil structure created by MP, SP, RT and NT in area A and C.

Area (year of experiment)	Spatial arrangement of clods : clods easily to discern		% Γ clod	
A (1 year)	**0-20 cm :** MP=SP=RT > NT	**20-30* cm :** MP>SP=RT=NT	**0-20 cm :** MP>SP=RT=NT	**20-30* cm :** MP=SP>RT=NT
C (3 years)	0-15 cm : MP=SP=RT=NT	15-30* cm : MP=SP>RT=NT	**0-15 cm :** MP>SP=RT=NT	**15-30* cm :** MP=SP>RT=NT

*: Uncultivated layer for SP, RT, NT

Water infiltration (area C only): Hydraulic conductivity is higher in RT, NT and SP at soil surface compared to MP, and inversely at 17 cm soil depth (figure 1).

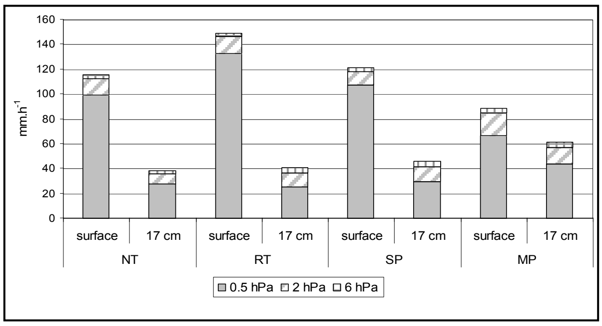

Figure 1 : hydraulic conductivity (mm.h^{-1}) at 6, 2 and 0.5 h Pa potentials which correspond to diameters pore of 0;05 cm, 0.15 and 0.6 cm respectively in soil surface and at 17 cm depth in june 2006 for the 4 tillage systems (NT: no-tillage; RT: reduced tillage; SP: shallow ploughing; MP: mouldboard ploughing) - area C.

The macroporosity (especially pore diameter > 6 mm) is higher at soil surface in conservation tillage (RT, SP, NT) and lower in soil depth compared to MP. More crop residues are left on soil surface in RT, NT and also SP, then there is no crust at the soil surface compared to MP which improves water infiltration. At 17 cm depth, more macroporosity is found in MP which is correlated with the morphological description of the MP soil profile (table 1). Then, after 1 and 3 years of conservation tillage, soil structure is more compacted than with MP. Moreover, the difference observed with morphological description is confirmed by water infiltration.

Abundance and diversity of earthworms: In area A, more earthworms were found in NT than in MP, SP and RT (significant difference with Kruskal-Wallis test) (figure 2). NT presents higher epigeic (in crop residues or cover crop at the soil surface) and anecic (vertical channels). After 3 years of experiment, identical results are found in area A and area C

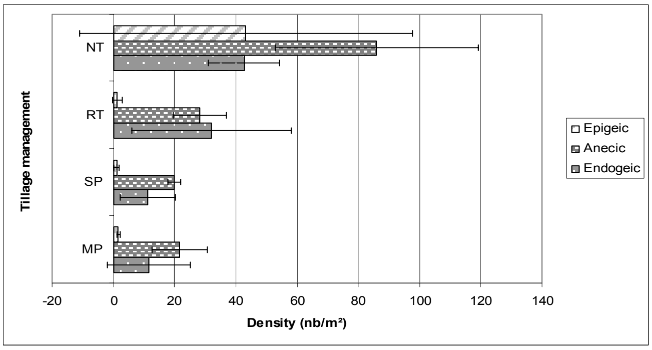

Figure 2: Number of earthworms (by ecological category) per m^2 according to the 4 tillage (NT: no-tillage; RT: reduced tillage; SP: shallow ploughing; MP: mouldboard ploughing) managements in October 2006 – area A

Earthworms Activity: In area A, there is no difference of counted opening channels at 30 cm depth whereas in area B, there is more counted opening channels at 30 cm depth in MP than to SP, RT and NT. Even if more earthworm abundance and diversity are found in NT and RT, more channels in depth (anecic) are found in MP.

Discussion and conclusion

Better soil structure is obtained with MP than with the SP, RT and above all NT after 1 year in a sandy loam soil and 3 years in a silty soil. Similar results were found by Kouwenhoven et al. (2002) and Munkholm et al. (2001) in organic farming. Even if higher earthworm abundance and diversity are found in NT and RT, more earthworm channels are found in depth in MP. At short term, earthworms are not able to improve soil structure in conservation tillage compared to conventional tillage. Results from area B may confirm these first results. On soil with low shrinking- welling effect, quality of soil structure can decrease in conservation tillage with time. Thus it is necessary to know if the long term increase of earthworms will have a positive impact on soil structure.

References

Bouché M.B., Gardner R.H., (1984): Earthworm functions VII, Population estimation techniques. Rev. Ecol. Biol. Sol. 21: 37–63.

Franzluebbers A. J. (2002): Soil organic matter stratification ratio as an indicator of soil quality. Soil Till. Res. 66:95-106.

Gerhardt R.-A. (1997): A Comparative Analysis of the Effects of Organic and Conventional Farming Systems on Soil Structure. Biol.l Agr. Hort. 14:139-157.

Kay B. D., VandenBygaart A. J. (2002) Conservation tillage and depth stratification of porosity and soil organic matter. Soil Till. Res. 66:107-118.

Koepke U. (2003): Conservation agriculture with and without use of agrochemicals. In Proceedings of the 2nd World Congress on Conservation agriculture, Iguassu Falls, Paraná, Brazil.

Kouwenhoven J. K., Perdok U. D., Boer J., Oomen G. J. M. (2002): Soil management by shallow mouldboard ploughing in The Netherlands. Soil Till. Res. 65:125-139.

Munkholm L. J., Schjonning P., Rasmussen K. J. (2001): Non-inversion tillage effects on soil mechanical properties of a humid sandy loam. Soil Till. Res. 62:1-14.