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# Soil quality is positively affected by reduced tillage and compost in an intensive vegetable cropping system

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ABSTRACT

Soil quality in vegetable cropping systems is seriously threatened by intensive tillage and fertilization practices and by limited crop rotations. Inclusion of cover crops, compost application and reduced tillage may help to sustain soil quality. A three-year field trial was set up on horticultural land to explore the combined effects of compost amendment at three rates (0, 15 and 45 Mg $ha^{-1}$ $year^{-1}$) and tillage practices (reduced tillage versus conventional ploughing) on soil quality. Cover crop was not a factor in the experiment, but cover crops were included in the rotation for reasons of good agricultural practice. The highest compost dose supported the initial level of total organic carbon in the arable layer. The decrease in pH in the arable layer was considerably limited by compost application, irrespective of the dose applied. Reduced tillage resulted in a favorable stratification for different soil quality indicators both by placement of organic inputs near the soil surface and by a reduction of leaching of base cations and organic carbon compounds. Differences between tillage practices and compost doses were most striking in the 0–10 cm soil layer. Compost application at the highest rate enhanced organic C content by 16% compared to the content in the non-amended soil. Reduced tillage induced a 13% higher organic C content in the 0–10 cm soil layer than that in the underlying 10–30 cm layer. Combining reduced tillage and recurrent compost application resulted in a different soil microbial community structure in the 0–10 cm surface layer, as revealed by phospholipid fatty acids analysis. Total microbial biomass was 44% higher under reduced compared to conventional tillage and increased by 27% due to compost application at a rate of 45 Mg $ha^{-1}$ $year^{-1}$. Fungal biomass doubled in the surface layer by reduced tillage. Actinomycetes and arbuscular mycorrhizal fungi were favored by both reduced tillage and compost application. Conversion to reduced tillage allowed for sustaining crop production in this intensive vegetable cropping system. Compost application and reduced tillage counteracted soil degradation.



## 1. Introduction

In Europe, soil degradation has only recently been identified as a widespread problem (Holland, 2004; Zdruli et al., 2010). Intensive vegetable cropping systems are characterized by a high input of inorganic N, frequent soil tillage and short-lived crops in a limited rotation. These practices are not favorable for soil quality as they may result in soil organic matter (SOM) decline, structure deterioration and biodiversity losses. Proper soil management by diversifying fertilization, reducing soil tillage and including cover crops in the rotation may counteract soil degradation and sustain soil quality. Degraded soils may be restored if farming practices are changed to favor increase in SOM and soil biological activity (Blank, 2008). SOM is crucial for many soil functions. Total organic carbon content (TOC), as a proxy for SOM, is a keystone soil quality indicator inextricably linked to other physical, chemical and biological soil quality parameters (Reeves, 1997). Particularly, the presence of beneficial fungi is essential to obtain a diversified food web that guarantees nutrient retention and cycling (de Vries et al., 2011), a good soil structure (Ritz and Young, 2004) and pathogen suppression (Garbeva et al., 2006).

Inclusion of cover crops in an intensive vegetable cropping system is in favor of efficient nutrient management, sustains crop productivity, enhances soil microbiota and controls soil-borne diseases (Collange et al., 2014). Cover crops prevent residual nitrogen (N) from being lost by leaching in intensive vegetable cropping systems which are prone to N losses (Jackson et al., 1993). Conservation agriculture maximizes biomass production by

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**Abbreviations**

| | |
|---|---|
| $C_0$, $C_{15}$, $C_{45}$ | Application of 0, 15 and 45 Mg farm compost $ha^{-1}$, respectively |
| CT | Conventional tillage |
| RT | Reduced tillage |
| NT | No-tillage |
| AMF | Arbuscular mycorrhizal fungi |
| ∑Ca,Mg,K,Na | Sum of plant available base cations (cmol $^+kg^{-1}$) |
| PLFA | Phospholipid fatty acid |
| FAME | Fatty acid methyl ester |

inclusion of cover crops and minimizes soil tillage (Scopel et al., 2013). Soil biota may be positively affected by inclusion of legumes in the rotation and animal manure application and negatively by mineral N fertilizers (Truu et al., 2008; Ge et al., 2008). Soil tillage enhances SOM decomposition which lowers aggregate stability and hydraulic conductivity (Chan et al., 1993; Loch, 1994; Naidu et al., 1996). Not inverting the soil by reduced tillage maintains crop residues and organic amendments near the soil surface resulting in an increased organic matter content (D'Haene et al., 2009) and larger aggregate stability (Cannell, 1985) in the surface layer. Improved habitat and food resources for soil biota under reduced tillage favor a different range of organisms compared to a plough-based system in which crop residues are buried (Rasmussen and Collins, 1991). Besides inclusion of cover crop crops and a reduced tillage practice, compost application may protect and recover soil quality by favoring soil organic matter status and hence soil biota and soil structure (Alluvione et al., 2013; Pfotzer and Schuler, 1997; Six et al., 2000). Compost application affects many soil properties due to the incorporation of stabilized organic matter, macro- and micronutrients and beneficial microbiota (Zebarth et al., 1999; Tejada et al., 2001; Abawi and Widmer, 2000). Repeated application is expected to increase long term N availability (Chalhoub et al., 2013) and to favor soil physical properties and hence nutrient uptake and plant growth. D'Hose et al. (2012) reported a positive yield effect of recurrent farm compost application caused by both extra N supply and improved crop growth conditions. Compost application increases nutrient availability and microbial populations and activity (Bernard et al., 2012; Duong et al., 2013).

Few studies have explored the combined effect of compost amendment and reduced tillage practice on soil quality, particularly in intensive vegetable cropping systems. In a study of Alluvione et al. (2013) at two Italian sites with contrasting pedoclimate, minimum tillage was compared to conventional mouldboard ploughing, however, included compost treatments were only conventionally tilled and it concerned a maize-based cropping system. Jackson et al. (2004) performed a study in an intensive vegetable production system in a coastal Mediterranean climate, however, they combined compost application with growing a rye cover crop. We started our field trial at a Belgian site in a temperate coastal climate in September 2008 in a cooperative research project with a commercial vegetable grower. Six different soil management regimes were established, i.e., combinations of soil tillage practice (reduced versus conventional tillage) and compost application (3 rates). Winter cover crops were included in the rotation for reasons of good agricultural practice. Soil tillage and compost amendment were assessed on soil parameters indicative for soil quality, hypothesizing that soil quality would be affected in the short-term (3 years) by these practices. Besides that, we hypothesized that attained differences in soil quality would result in differences in crop yield.

## 2. Materials and methods

### 2.1. Field trial

This two-factorial experiment ran from September 2008 until February 2012, a period that covered three full growing seasons. The field was located N 50°57′1.91″, E 3°15′7.79″, 25 m asl, on a sandy loam soil (63% sand, 30% silt and 7% clay) with a 40 cm Ap horizon, classified as endogleyic stagnosol (hypereutric, loamic) according to WRB-2007 (Dondeyne et al., 2013).

The soil was tilled either conventionally (CT) by mouldboard ploughing or according to reduced non-inversion tillage (RT) with a chisel plough (Actisol). Soil tillage depth was approximately 30 cm for both soil tillage practices.

Farm compost was prepared at the Institute of Agricultural and Fisheries Research (ILVO) in a windrow composting system. Farm compost was applied each autumn, starting in 2008, at three different rates, namely 0, 15 and 45 Mg $ha^{-1}$ (henceforth named $C_0$, $C_{15}$ and $C_{45}$). Composts applied in 2008 and 2009 were obtained from two compost trials described by Steel et al. (2012). Feedstock composition in 2008 was 75% (v/v) ground poplar bark and 25% (v/v) straw of clover, supplemented with urea, cane molasses and wasted maize silage. The feedstock mixture in 2009 consisted of 7% (v/v) crop residues of leek, 27% (v/v) straw of grass, 16% (v/v) wasted maize silage and 50% (v/v) ground poplar bark. In 2010, the compost was prepared from grass clippings and straw, wood chips, tree bark and old compost, in proper proportions. Aerobic conditions and optimum moisture content levels were maintained using a Sandberger compost turner. This resulted in well ripened compost (high $N-NO_3$:$N-NH_4$ ratio) with a high organic matter content (Table 1). Dry matter content strongly varied due to outdoor storage.

Combining two tillage methods and three compost doses resulted in six different soil management regimes which were replicated four times and arranged according to a split-plot design with tillage as the main plot factor and farm compost application as the subplot factor (Fig. 1). Individual subplots were 6 by 18 m. The following soil properties were measured to characterize general soil quality at the start and at the end of the experiment: dry soil bulk density (BD), TOC, hot water extractable carbon content (HWC), pH-KCl and plant available nutrients.

### 2.2. Crop rotation, cultivation and soil sampling and yield determination

The first sampling took place per main plot end of September 2008 in cereal stubble in order to determine initial TOC, HWC, BD and pH-KCl of the 0–10, 10–30 and 30–60 cm soil layers.

**Table 1**
Composition of the farm compost applied in the years 2008–2010 DM: dry matter; OM: organic matter; EC: electrical conductivity.

| | | 2008 | 2009 | 2010 |
|---|---|---|---|---|
| DM | % | 23.1 | 38.3 | 65.6 |
| OM | % on DM | 69.7 | 43.4 | 51.4 |
| EC | $\mu S\,cm^{-1}$ | 901 | 615 | 1308 |
| $pH-H_2O$ | – | 9.4 | 8.2 | 8.4 |
| $N-NH_4$ | $mg\,l^{-1}$ | 7.5 | <5.0 | <5.0 |
| $N-NO_3$ | $mg\,l^{-1}$ | 93.5 | 24.0 | 46.5 |
| N | % on DM | 2.0 | 1.2 | 1.7 |
| P | $g\,kg^{-1}$ DM | 3.34 | 1.51 | 3.24 |
| K | $g\,kg^{-1}$ DM | 16.64 | 7.38 | 10.70 |
| Ca | $g\,kg^{-1}$ DM | 44.28 | 20.87 | 17.59 |
| Mg | $g\,kg^{-1}$ DM | 4.34 | 1.76 | 2.25 |
| Na | $g\,kg^{-1}$ DM | 0.75 | 0.58 | 0.39 |
| C/N | – | 19.0 | 19.6 | 16.5 |