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# Effect of long-term conservation tillage on soil biochemical properties in Mediterranean Spanish areas

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ABSTRACT

In semi-arid Mediterranean areas, studies of the performance of conservation tillage systems have largely demonstrated advantages in crop yield, soil water storage and soil protection against wind and water erosion. However, little attention has been given to interactions between soil biochemical properties under different tillage practices. Biochemical properties are useful tools to assess changes caused by different soil tillage systems in long-term field experiments. This study deals with the effect of long-term tillage practices (reduced tillage and no-tillage vs. traditional tillage) on soil chemical properties and microbial functions in three different sites of Spain (two of them located in the Northeast and one in the Southwest) under semi-arid Mediterranean conditions. Soil biological status, as index of soil quality, was evaluated by measuring microbial biomass carbon (MBC) and dehydrogenase (an oxidoreductase) and protease (a hydrolase) activities at three soil depths (0–5, 5–10 and 10–25 cm). In the three experimental areas, increases in soil organic matter content, MBC and enzymatic activities were found at the superficial layers of soil under conservation tillage (reduced tillage and no-tillage) in comparison with traditional tillage. Values of the stratification ratio of some biochemical properties were significantly correlated with yield production in Northeast sites.

Conservation tillage has proven to be an effective strategy to improve soil quality and fertility in Mediterranean areas of Spain.



## 1. Introduction

Benefits from conservation tillage, including improvement of soil properties, savings of time, energy and water, and wind erosion control, have been reported in many studies carried out under different environment conditions (Griffith et al., 1986; Lal, 1989). Thus, traditional, intensive inversion tillage (TT) is being replaced by conservation tillage systems. Conservation tillage systems reduce labour, fuel, and machinery expenses and also have some agronomic and environmental implications. Conservation tillage protects the soil against water and wind erosion and reduces soil evaporation by leaving crop residues on the soil surface, thus promoting greater soil moisture content (Lafond, 1994).

To be considered conservation tillage (CT), any tillage and planting system must maintain at least 30% of the soil surface covered by residue after planting to reduce soil erosion by water. Where soil erosion by wind is a primary concern, the system must maintain a 1.1 Mg ha$^{-1}$ flat small grain residue equivalent on the surface during the critical wind erosion period (Gajri et al., 2002). Some times, there is no distinction between CT, MT (minimum tillage) or reduced tillage (RT) (Bradford and Peterson, 2000). Types of CT include no-tillage (NT), ridge tillage, mulch tillage and zone tillage (Hill, 1996).

Under semi-arid climate, CT is one of the best options to store and conserve soil water (Rawitz and Hadas, 1994). Many short-term studies and a few long-term studies have evaluated the effect of tillage systems on plant productivity (Cantero-Martinez et al., 2003; Moreno et al., 1997). In general, the lack of negative effect on yield, make conservation tillage attractive attending the reduction in operating costs and soil quality increase (Franzluebbers, 2004). Soil quality can be defined as its capacity to work properly within ecosystem boundaries maintaining biological productivity, environment quality and also to promote plant and animal health (Doran and Safley, 1997). The definition of soil quality has focused on some properties that affect soil health and quality (Doran and Safley, 1997). Soil microbial biomass and enzymes have been suggested as potential indicators of soil quality because of their relationship to soil biology, ease of measurement (i.e., potential to be adopted by commercial laboratories for routine soil testing), rapid response to changes in soil management and high sensitivity to temporary soil

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changes originated by management and environment factors (Nannipieri, 1994). Conservation tillage increases organic matter levels in superficial layers of the soil (Franzluebbers, 2004). Thus, biological activity has been found to be higher in soils under CT than under TT (Bolinder et al., 1999). Also, under CT, an increase of the activity of some enzymes (acid phosphomonoesterase, arylsulphatase, dehydrogenase, urease and β-glucosidase) has been found (Angers et al., 1993; Eivazi et al., 2003).

During the past 20 years, conservation tillage practices, as RT or NT, have been introduced in the Mediterranean areas with different success (Cantero-Martinez et al., 2003; Lopez et al., 1996, 2005; Moreno et al., 1997). In these areas, studies of the performance of conservation tillage systems have demonstrated advantages in yield, water profitability (water storage, water use by crops) and protection of the soil against erosion by water and wind (Álvaro-Fuentes et al., 2008a; Cantero-Martinez et al., 2003; Mrabet, 2002; Muñoz et al., 2007). Reduction of $CO_2$ fluxes to the atmosphere derived from conservation tillage adoption has also been reported (Álvaro-Fuentes et al., 2008b). Despite some disadvantages such as the increase of the use of herbicides, CT appears to be the most important sustainable alternative system to traditional agriculture to cope with negative agro-environmental problems derived from TT, including the diminution in soil biodiversity. However, comparatively little attention has been given to soil biochemical properties under different tillage systems (Madejón et al., 2007).

The aims of the study were to determine the effects of long-term conservation tillage on soil chemical properties and microbial function in three sites of Spain under semi-arid Mediterranean conditions. We hypothesized that conservation tillage would have a positive effect by increasing soil organic matter and fertility, and, enhancing soil microbial functionality.

## 2. Materials and methods

The study was carried out in three different experimental sites of the semi-arid Spain located specifically in the provinces of Lleida (LLE), Zaragoza (ZAR) and Sevilla (SEV) (Fig. 1). All the sites have a long history of experimentation of conservation tillage (12–18 years).

### 2.1. Experiment at Lleida

The experiment was established in the fall of 1996 in a farm of Agramunt in the Lleida province (NE Spain). Soil was classified as Typic Xerofluvent (USDA, 1996). The area has a temperate continental Mediterranean climate with rainfall variable ranging between 350 and 550 mm. The rainfall distribution has two peaks, in autumn and late spring, respectively, with little rain in the winter and summer months. More details of the site and soil characteristics are shown in Table 1. Three tillage systems (TT, RT and NT) were established. The TT consisted of one moldboard ploughing (25–30 cm depth) plus one or two cultivator passes (15 cm depth) before sowing during August or September each year, depending upon the soil moisture. The RT was conducted with one or two cultivator passes (10–15 cm depth) in each September in the same soil moisture conditions as the TT. The NT consisted of sowing by direct drilling after spraying with herbicide (1.5 L 36% glyphosate [N-(phosphonomethyl)-glycine] plus 1 L of 40% MCPA (2-(4chloro 2-metilfenoxi) acetic acid) per ha). Barley (*Hordeum vulgare* L. cv. "Hispanic") was sown in late October to early November each year. Sowing was performed with a no-till disc and harvesting was done with a standard, medium-size combine. Nine replicate plots (50 m × 6 m) for each tillage system were randomly established. More details of the crop management practices are given in Cantero-Martinez et al. (2003).


**Fig. 1.** Location of the sampling areas.

**Table 1**
Site and soil characteristics in the Ap soil layer.

| Site and soil characteristics | Experimental site | | |
|---|---|---|---|
| | Lleida | Zaragoza | Seville |
| Latitude | 41°48′N | 41°44′N | 37°17′N |
| Longitude | 1°07′E | 0°46′W | 6°3′W |
| Elevation (m) | 330 | 270 | 30 |
| Mean annual air temperature (°C) | 14.2 | 14.5 | 17.5 |
| Mean annual precipitation (mm) | 430 | 390 | 494 |
| Soil classification[a] | Xerofluvent typic | Xerollic Calciorthid | Xerofluvent |
| Ap horizon depth (cm) | 28 | 30 | 30 |
| pH ($H_2O$, 1:2.5) | 8.5 | 8.2 | 7.9 |
| EC1:5 (dS $m^{-1}$) | 0.15 | 0.29 | – |
| Water retention (g $g^{-1}$) | | | |
| −33 kPa | 0.16 | 0.20 | 0.23 |
| −1500 kPa | 0.05 | 0.11 | 0.12 |
| TOC (g $kg^{-1}$) | 5.58 | 11.4 | 9.20 |
| Particle size distribution (%) | | | |
| Sand (2000–50 μm) | 30.1 | 32.4 | 49.8 |
| Silt (50–2 μm) | 51.9 | 45.5 | 29.1 |
| Clay (<2 μm) | 17.9 | 22.2 | 21.1 |

[a] USDA classification (USDA, 1996).