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Implementation of chiselling and mouldboard ploughing in soil after 8 years of no-till management in SW, Spain: Effect on soil quality

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ABSTRACT

Long-term no-till practices (NT) have a positive effect on recovery and improving soil fertility and decreasing soil erosion. Nevertheless, long term no-till practices may also cause some inconveniences, such as soil compaction, water infiltration and problems in seed germination. Thus, in the present work we assess the effects of the implementation (October 2008) of a traditional tillage (mouldboard ploughing) (TT) and reduced tillage (chiselling) (RT) on soil quality in a dryland calcareous soil (Leptic Typic Xerorthent) after 8 years of soil no-till management (NT) in SW Spain. The results were compared to those found under no-till. We hypothesised that C fractions and biological properties would be adequate indicators of soil quality changes. To test the hypothesis soil samples were collected at three depths (0–5, 5–10 and 10–25 cm) and in three sampling periods, after tillage and sowing (January 2009) after harvesting (June 2009) a vetch crop (*Vicia sativa*, L) and after tillage and sowing (January 2010) of a wheat crop (*Triticum aestivum*, L). Total organic carbon (TOC) and carbon labile fractions (active carbon (AC) and water soluble carbon (WSC)) were determined. Biological status was evaluated by the analysis of soil microbial biomass carbon and nitrogen (MBC and MBN) and enzymatic activities [dehydrogenase activity (DHA), and β-glucosidase activity (Glu)]. The implementation of chiselling did not cause depletion in most of the studied soil properties compared to no-till in the first 5 cm of soil. However, the application of traditional tillage reduced 23% of TOC, 27% of WSC, 12% of AC, 19% of MBC, 44% of MBN, 37% of DHA and 51% of Glu in the upper layer of the soil (0–5 cm depth) with respect to no-till. Soil organic carbon and microbial parameter values decreased as depth increased, particularly in conservation tillage systems (RT and NT) in all sampling periods. Under our conditions, dryland Mediterranean areas, the mouldboard ploughing is not considered a suitable soil tillage system since it showed an early negative effect on soil organic fractions and biochemical quality. Although further studies would be necessary, the use of chiselling could be a solution in case of problems related to no-till.

1. Introduction

The use of land for agricultural purposes is one of the main causes of soil degradation, and therefore there is a relevant interest in quantifying the loss of soil quality generated by agricultural management (Lal et al., 1998). Among different agricultural practices, conservation agriculture maintains the preservation of soil structure, productivity and biodiversity through three basic principles: minimum tillage, cover crops and crop rotation (ECAF, 1999). There is a growing trend worldwide for the adoption of conservation tillage systems (no-till and reduced tillage), especially in tropical and semi-arid agroecosystems (Baudoin et al., 2009). Conservation tillage has numerous positive effects on soil, such as improvement of water-holding capacity, and reduction of soil erosion. Moreover costs are also reduced because of the lower fuel and labour inputs (Lindwall and Anderson, 1981).

In sustainable agricultural production systems, the maintenance of quantity and quality of soil organic matter is of great importance, since the recover of organic matter levels is slow and not easily achieved (Eswaran et al., 1993). The reduction of soil disturbance decreases mineralization of soil organic matter and it can result in larger storage of soil organic C (West and Post, 2002; Al-Kaisi et al., 2005). Several studies have shown the positive effect of no-till on improving soil physical, chemical and biological properties (Moreno et al., 1997; Cantero-Martínez et al., 2003; Acosta-Martinez et al., 2007; Melero et al., 2009a,b) compared to traditional tillage. Furthermore, the improvement of soil structure allows better soil aeration and water infiltration, and the

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preservation of a surface cover of residue enhances microbial activity and soil microbial biomass content (Doran et al., 1998).

These improvements in soil quality can also increase soil microbial diversity, thus protecting crops against pests and diseases through competition by soil nutrients and water supply (Brussaard et al., 2007).

However, long term no-till practices can also lead to soil compaction, which could affect water infiltration and seed germination. Therefore, the introduction of chisel or mouldboard ploughing may solve those problems. Nevertheless, the effect of soil tillage depends on its frequency, depth and soil texture (Six et al., 2002; Cookson et al., 2008).

In this sense, scarce information have been published about the effects of the implementation of mouldboard ploughing or chiselling on the quality of soil managed by no-till practices for a long time. Even though all physical, chemical, biological and biochemical properties are involved in soil functioning, biological and biochemical properties respond more quickly than other soil properties to changes produced by different soil management (Visser and Parkinson, 1992; Trasar-Cepeda et al., 2008). Also, the labile fractions of total organic carbon (TOC), such as active carbon are more available sources of carbon for soil microorganisms, and therefore influence nutrient cycles and many biologically related soil properties. Active organic C includes microbial biomass C (MBC), particulate organic matter and carbohydrates (Weil et al., 2003).

In general, the long-term effects of soil management practices on the size and activity of the microbial biomass have been closely related to soil organic matter content (Haynes and Beare, 1996), whereas short-term effects are more complex and also depend on soil conditions such as soil texture, climate, cropping system and the kind of crop residue, as well as on the management itself (Paustian et al., 1997; Al-Kaisi et al., 2005; Muñoz et al., 2007).

The objective of this work was to study the effects of a mouldboard ploughing and chiselling application on soil properties of a not tilled field for 8 years. We hypothesised that mouldboard ploughing and chiselling could affect soil quality. To test this hypothesis, soil organic C fractions (total organic carbon, active carbon and water soluble carbon) and biochemical properties (microbial biomass carbon and microbial biomass nitrogen and enzymatic activities (β-glucosidase and dehydrogenase) were analysed in order to evaluate the possible damage that those tillage systems could cause to soil quality.

2. Materials and methods

2.1. Site characteristics and tillage systems

This field experiment was established in 2008 at the "Las Navas" dryland experimental farm in Jerez de la Frontera (Cádiz, SW Spain) (36°50′29.92″N, 5°55′11″W) in a clay loam soil (323 g kg^{-1} sand, 315 g kg^{-1} silt and 352 g kg^{-1} clay) classified as a Leptic Typic Xerorthents (Soil Survey and Staff, 2006), with a carbonate content of 60%, pH of 8 and a organic carbon content of 1.5%. Leptosols (very widespread in the Mediterranean zone) are soils characterized by shallow depth or high stoniness, and limited soil volume makes them very vulnerable (Ryan et al., 2006). The climate of the zone is typically Mediterranean, with mild rainy winters (599 mm mean rainfall) and very hot and dry summers. The mean annual daily temperature is around 17.5°C, with the higher maximum and the lower minimum temperatures registered of 41 °C and −4 °C in July and January, respectively. Temperature and rainfall during experiment are shown in Fig. 1.

This commercial farm has been managed by the Spanish Association of Conservation Agriculture (AEAC.SV) under no tillage system over the previous eight years (from autumn 1999 to spring 2008), except in 2006 when a shallow disc harrowing was used in order to control weed. During this time the following crops were grown: Wheat (*Triticum aestivum* L. (in 1999 and 2002); *Triticum durum Desf.* (in 2001, 2004, 2006 and 2007) and sunflower (*Helianthus annuus* (in 2000, 2003 and 2005).

In October 2008, the experimental site was divided into 9 plots of 30 m × 10 m, with a 2.5 m corridor between plots. Three treatments were established: traditional tillage (TT), reduced tillage (RT) and no tillage (direct drilling) (NT), identical to the procedure used during the last 8 years, which was used as control treatment. The experiment was carried out in a completely randomised block design with three replicates per treatment.

The TT consisted of mouldboard ploughing (to a 25 cm depth) without residue, while RT consisted of the reduction of the number of tillage operations (only chiselling, 10–15 cm depth) and in NT no

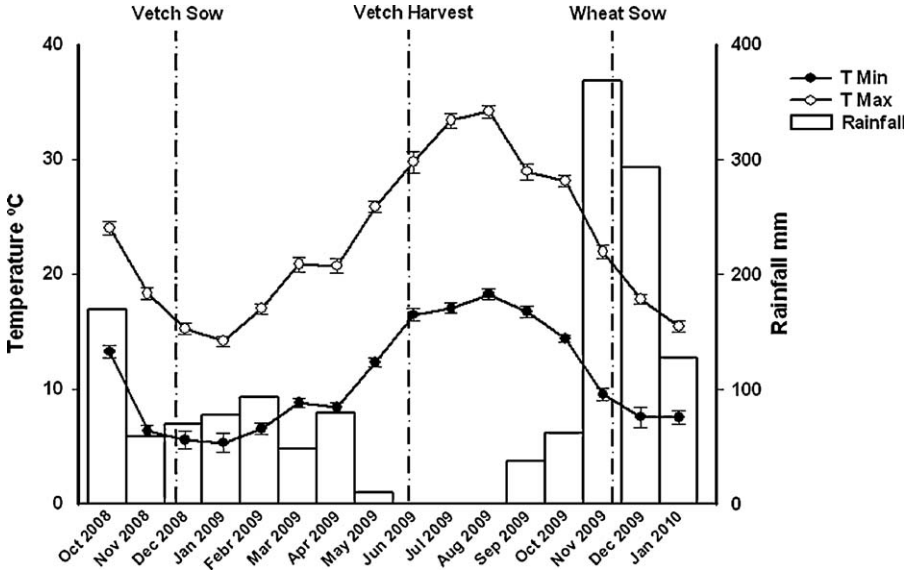

Fig. 1. Mean maximum and minimum temperature and rainfall during experimentation period.