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Tillage and crop rotation effects on barley yield and soil nutrients on a *Calciortidic Haploxeralf*

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Abstract

Reduced tillage with appropriate crop rotation could increase the viability of dry land agriculture in semiarid zones. The effects of tillage and crop rotation on soil physico-chemical properties, soil organic carbon (SOC) and N have been studied widely in long and short-term experiments. However, their effects on nutrient levels and fertility losses have not been extensively studied in Mediterranean soils. We determined SOC, N, P, K, Fe, Mn, Cu and Zn distribution in the soil profile and in plant uptake, on a *Calciortidic Haploxeralf* in Spain. Three tillage systems [CT, conventional tillage (mouldboard plow); MT, minimum tillage and NT, no tillage] and three crop rotations [BB, continuous barley (*Hordeum vulgare v.* Tipper), FB, fallow-barley and VB, vetch (*Vicia sativa v.* Muza)-barley] were compared. SOC and N were higher for CT than for MT and NT in the first year, but higher for NT and MT than CT in the next years. In the 0–15 cm depth, SOC and N in NT also became higher than in MT for the fourth crop season. In the 15–30 depths, NT and MT had also higher SOC than CT since the second year. However, NT had only higher N than MT after three crop seasons. The increase in SOC was 75% for NT and MT while CT had a decrease of 17% in the 0–15 cm layer. The increase in N was 154% for NT, 108% for MT and 30% for CT in the upper 15 cm. NT had higher P, K and Cu than MT and higher P, K, Fe, Mn, Cu and Zn than CT in the upper layers due to the higher SOC level and to the fact that these systems maintain surface-applied K and P fertilizer. On the other hand, neither SOC nor N were affected by crop rotation. Tillage and rotation interactions were not significant for SOC, N and, in general, nutrient levels in the different soil depths. In general, the main factor that affected SOC, N and nutrients was tillage, which had reduced influence with depth. Highest yield was for CT-FB and CT-VB, but not different from NT-FB and NT-VB, meanwhile highest nutrient levels were obtained for interactions that included NT. These results suggest that NT, and to a lesser extend MT, preserved SOC and nutrient levels in the upper layers and, with NT-VB and NT-FB interaction, could also obtain high yields and keep soil fertility in the upper depths during the first 4 years.

Keywords: Tillage; Crop rotation; Soil organic carbon; Nitrogen; Phosphorus; Potassium; Micronutrients

1. Introduction

The purpose of soil tillage is to prepare the soil with adequate physical conditions for plant growth. Traditionally, the action of climatic agents (freeze–thaw, temperature fluctuations, soil water content changes, etc.) has been considered insufficient to provide optimal physical and chemical properties to the soil. Conventional tillage (CT) is used to mix top-soil to recover

Abbreviations: BB, continuous barley; CT, conventional tillage; FB, fallow-barley; MT, minimum tillage; NT, no tillage; OM, organic matter; SOC, soil organic carbon; VB, vetch-barley

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nutrient losses due to crop exportations. However, excessive tillage could produce compaction, soil crusting and damages to soil biota (Urbano, 1992).

The objective of crop rotation is to maintain soil fertility and to allow natural processes in the soil to take place, such as N-enrichment of the soil by leguminous plants, to allow the improvement of soil structure and to reduce erosion processes (Eltz and Norton, 1997). Crop rotations that are economically useful to farmers depend on the correct choice of crops, appropriate water and nutrient supply and adequate soil and climatic conditions (Urbano, 1992).

The effects of tillage and crop rotation on soil bulk density, soil water retention, compaction, aerobic condition, organic matter (OM) and N have been studied widely in long and short-term experiments. However, the effect on nutrient levels and fertility losses produced by different tillage and crop rotation systems has not been extensively studied for Mediterranean soils with a semiarid climate. The effect of tillage and crop rotation has significant influence on soil OM, residue amount and composition, due to changes in mineralization processes. As a consequence, tillage and crop rotation affect soil N, P, K and micronutrient contents as well (Cole et al., 1990; Havlin et al., 1990). In general, CT decreases soil OM due to a more rapid mineralization. No tillage (NT) techniques reduce the interaction between soil aggregates and fresh soil OM so that mineralization rate is often slower, which improves soil properties, such as higher resistance of soil structure against water erosive action (Beare et al., 1994). Soil OM accumulation also produces SOC, total N and NO_3^--N accumulation in the upper 5 cm of soil (Cole et al., 1990; Havlin et al., 1990; Franzluebbers et al., 1995; Rhoton, 2000; Motta et al., 2002). Another reason for total N increases in soil with NT is delayed nitrification due to reduced aeration of the soil (Stevenson, 1986). According to Collins et al. (1992) and Bowman et al. (1999) fallow promotes OM losses.

N return to soil is affected by the quality of crop residue. Leguminous crop residues often decompose more quickly than cereal residues due to lower C/N composition, but the amount of crop residue that reverts to the soil is often higher for cereals than for legumes (Primavessi, 1984). Therefore, the incorporation of N_2-fixing legumes in the cropping sequence provides, in a short time, N enrichment to the soil. N increase of the surface layer was higher for continuous crop than for crop-fallow rotations (Bowman et al., 1999).

Soil OM content and its mineralization rate can influence levels of K, P and micronutrients in soil. Residue accumulation at the soil surface produces higher K and P concentration under conservation tillage than under CT (Cole et al., 1990; Franzluebbers and Hons, 1996; Holanda et al., 1998; Varsa and Ebelhar, 1999; Thompson and Whitney, 2000). However, Rhoton (2000) and Motta et al. (2002) found higher P concentration under NT than CT in the upper 2.5 cm as well as the 15–22.5 cm depth. Conventional tillage also accelerates organic P mineralization and nutrient accumulation in deeper soil layers (Varsa and Ebelhar, 1999). According to Campbell et al. (1995), Soon and Arshad (1996) and Riedell et al. (1998) leguminous crops produce a higher depletion than cereal crops of soil K and P. These results do not have a clear explanation since a leguminous crop accumulates about 60% of the P present in cereal crop with a similar amount of P exportation (Riedell et al., 1998).

Low P return from crop residue with fallow causes lower P recycling with respect to other rotations (Bowman and Halvorson, 1997). Micronutrients tend to be in higher concentration in soils under NT, especially Zn and Mn, because of higher OM concentration (Franzluebbers and Hons, 1996); although these micronutrients could be leached through complexation with humic acids. Westermann and Sojka (1996) did not find differences in micronutrient concentration among tillage systems, but Rhoton (2000) found higher levels of Mn and Zn and lower levels of Fe and Cu under NT than under CT.

The effects of tillage and rotation have been studied previously, but tillage and rotation interactions remain unclear. López-Bellido et al. (1996) and Halvorson (2000) reported that NT yield in dry years was higher than in CT, but in wet years the opposite was true. Continuous NT wheat (*Triticum aestivum* L.) cropping sequestered twice the C as NT fallow-wheat and five times the C as CT fallow-wheat (Curtin et al., 2000). It is also important to study tillage-crop rotation interactions to find the combination that optimizes high yield with preservation of soil nutrients.

The aim of this work was to study the effect of tillage, crop sequence and tillage-rotation combination on soil fertility. We achieved this aim by studying SOC, N, P, K, Fe, Mn, Cu and Zn distribution in the soil profile under dryland production of barley (*Hordeum vulgare* L.) in a semiarid climate. Crop nutrient uptake was also studied.

2. Materials and methods

A field was situated near Alcalá de Henares (40°32′N, 3°20′W), 35 km northeast of Madrid, Spain.