SOIL MANAGEMENT EFFECTS ON AGGREGATE DYNAMICS IN SEMIARID ARAGON
(NE SPAIN)

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Abstract

During decades, in semiarid rainfed Aragon, intensive soil tillage and low crop residue input have led to the loss of soil structure and soil degradation. Conservation tillage and cropping intensification can improve soil structure in these areas. The objective of this study was to determine the influence of three different tillage systems (traditional tillage, reduced tillage and no-tillage) under two cropping systems (fallow-barley rotation and barley monoculture) on soil aggregation dynamics during a cropping season. A decrease in tillage intensity resulted in a higher mean size of dry aggregates and a greater water aggregate stability in both cropping systems particularly under no-tillage.

Keywords: Soil aggregation; Tillage; Cropping systems; Semiarid areas.

Introduction

A loss in soil structure implies to a decrease in soil quality and productivity. Soil structure controls a significant number of soil processes and properties such as water and nutrient availability for plant growth, crop residue decomposition dynamics, soil erosion susceptibility and, eventually, crop yield (Bronick and Lal, 2005). Recent review works on this topic (Carter, 2004; Kay and Munkholm, 2004; Bronick and Lal, 2005) summarize a wide variety of worldwide studies about factors affecting soil structure and management practices that preserve soil structural stability. Factors affecting soil structure and its temporal variation have been broadly studied by several authors worldwide (Chan et al., 1994; Yang and Wander, 1998).

Semiarid agroecosystems of Aragon (NE Spain) are characterized by a low and erratic rainfall and a low soil organic matter content due to insufficient crop residue input. In these agroecosystems, the continuous use of intensive tillage implementation (moldboard plowing) and long fallowing (from 16 to 18 months) has led to a decrease on soil aggregation and, finally, into a loss of soil structure. Therefore, in these agroecosystems, it is crucial to search for alternative management practices that improve soil aggregation.

The aim of this study was to determine the influence of three tillage systems under two small grain cropping systems on dry soil aggregate size distribution and wet aggregate soil stability during a cropping season in a long-term tillage experiment in a semiarid rainfed area of Central Aragon.

2. Materials and methods

The study was carried out after 15 years of experimentation on the long-term conservation tillage plots established in 1989 at the experimental dryland farm of the Estación Experimental de Aula Dei (CSIC) in the Zaragoza province (41°44'N, 0°46'W). The soil is a loam (fine-loamy, mixed, thermic Xerollic Calciorthid) according to the USDA soil classification (Soil Survey Staff, 1975). Selected soil chemical and physical properties are shown in Table 1. The climate is

semiarid, with an average annual precipitation of 340 mm and an average annual air temperature of 14.7 °C. Three tillage treatments were compared namely the conventional tillage (CT), with moldboard plowing to 35-40 cm depth as primary tillage, the reduced tillage (RT), with chisel plowing to 25-30 cm depth and the no-tillage (NT). Two cropping systems were compared: a continuous barley cropping (CC) and a barley-fallow (BF) rotation.

During the 2003-2004 cropping season the soil surface (0-5 cm) was sampled for five times corresponding to the different crop growth stages and soil management phases, February (crop emergence), May (post-anthesis), July (post-harvest), September (fallow) and November (post-tillage in CC and fallow in BF).

The dry soil aggregate size distributions were conducted on a vertical electromagnetic sieve apparatus (FRITSCH *Analysette 3 PRO*) with next sieve sizes of 4; 2; 1; 0,85; 0.5; 0.25 and 0.05 mm. The mean weight diameter, MWD (Youker and McGuiness, 1957) was used to express the dry soil aggregate size distribution. The water aggregate stability (WAS) was determined in 1-2 mm dry aggregates following the wet sieving method of Kemper and Rosenau (1986).

3. Results and discussion

The MWD was greater in NT than in the other two tillage treatments for the two cropping systems throughout the experiment (Fig. 1). In CC, the average MWD in NT was 2.99 mm, whereas in CT and RT this was 2.44 and 2.36 mm, respectively. In the BF rotation, the average MWD was 2.94 mm in NT and 2.37 and 2.59 mm in CT and RT, respectively. The MWD dynamics during the season was similar in both cropping systems. The greatest MWD values were found in spring, particularly in May during the post-anthesis period (3.34 mm in CC and 3.05 mm in BF, on average for the three tillage treatments) and the lowest in September during the summer fallow (2.12 mm in CC and 2.21 mm in BF) (Fig. 1).

The soil under NT showed, likewise, a significantly greater WAS than under RT and CT in both cropping systems (Fig. 2). In CC, WAS averaged 0.47 in NT and 0.23 and 0.28 in CT

and RT, respectively. In the BF rotation, WAS was 0.35 in NT and 0.25 in CT and RT. Along the season, the evolution of WAS was similar in both cropping systems with greater stability values in summer and lower in winter. Thus, the greatest WAS was registered in September with values of 0.64 in CC and 0.66 in BF and the lowest in February with values of 0.17 in CC and 0.12 in BF (Fig. 2).

Mrabet et al. (2001), in semiarid conditions of Morocco, also observed greater MWD values in NT as compared with other tillage treatments. However, the authors did not find differences in WAS. Conversely, Hernanz et al. (2002) in semiarid conditions of Central Spain found differences in WAS between NT and CT in a continuous wheat system. These authors attributed this fact to the greater soil organic carbon (SOC) measured in NT compared with CT. In our study, SOC would also explain the aggregation differences among treatments. Thus, in CC the SOC content in the NT soil surface (0-5 cm) was 850 gm^{-2} compared with 535 and 575 gm^{-2} in CT and RT, respectively. In the BF rotation, the SOC content was slightly lower than in CC but the differences among tillage treatments were consistent (675, 480 and 505 gm^{-2} in NT, CT and RT, respectively). The narrow correlations found between the SOC contents and MWD ($r^2=0.947$ in CC and $r^2=0.919$ in BF) and between the SOC contents and WAS ($r^2=0.992$ in CC and $r^2=0.984$ in BF) confirm the importance of the SOC content in the formation and stability of large size aggregates under our experimental conditions. SOC induces the soil aggregate stability by means of a greater union and a lower wetability, thus avoiding a rapid breakdown of the dry aggregates due to the action of water (Chenu et al., 2000). Consequently, higher amounts of crop residues left on the soil surface under NT leads to an increase in SOC contents and, therefore, to a greater soil aggregate size and stability.

However, MWD and WAS dynamics during the cropping season followed a completely opposite pattern. In both cropping systems, when the WAS values were the highest, the MWD values were the lowest and vice versa. According to Gale et al. (2000), low amounts of stable macroaggregates are formed at the rhizosphere during crop growth. However, it is after crop

senescence when stable macroaggregates begin to build up. The authors observed that products derived from microbial root decomposition lead to an increase in macroaggregate stability with time. The results of our study are in agreement with this conceptual model. Hence, the high MWD values observed during crop growth (February-May) are associated to a greater macroaggregate content but with a low WAS. However, due to their low stability these aggregates gradually broke up and decreased their MWD after harvest (Fig. 1). On the other hand, an increase in aggregate stability was observed after harvest which, according to Gale et al. (2000), results from the decomposition of root residue left by the harvested crop.

4. Conclusions

Results from this study indicate that in semiarid rainfed areas of Aragon (NE Spain), a shift from conventional tillage to no-tillage leads to an improvement in soil structure. In these agroecosystems, a greater soil aggregate size and stability observed under no-tillage management implies the less susceptibility of the soil to degradation processes.

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Table 1. Selected soil physical and chemical characteristics at the experimental site (0-20 cm depth).

Soil characteristics	
<i>Particle size distribution (g kg⁻¹)</i>	
Sand (2000 < Ø < 50 µm)	208
Silt (50 < Ø < 2 µm)	633
Clay (Ø < 2 µm)	159
pH (H ₂ O, 1:2.5)	8.1
Electrical conductivity (1:5) (dS m ⁻¹)	2.0
Organic matter (g kg ⁻¹)	15.9
CaCO ₃ (g kg ⁻¹)	352
Gypsum (g kg ⁻¹)	171

Figure legends

Figure 1. Aggregate mean weight diameter (MWD) dynamics in the soil surface (0-5 cm) during a cropping season under three tillage treatments (CT, conventional tillage; RT, reduced tillage; NT, no-tillage) and two cropping systems (CC, continuous cropping; BF, barley-fallow rotation). Bars indicate LSD ($P<0.05$) for comparisons among tillage treatments at the same date, where significant differences were found.

Figure 2. Water aggregate stability (WAS) dynamics in the soil surface (0-5 cm) during a cropping season under three tillage treatments (CT, conventional tillage; RT, reduced tillage; NT, no-tillage) and two cropping systems (CC, continuous cropping; BF, barley-fallow rotation). Bars indicate LSD ($P<0.05$) for comparisons among tillage treatments at the same date, where significant differences were found.

Figures

Figure 1

Figure 2