Changes in soil chemical properties under three tillage systems in a long-term experiment

Benito A. de, Sombrero A.

in

Arrue Ugarte J.L. (ed.), Cantero-Martínez C. (ed.).
Troisièmes rencontres méditerranéennes du semis direct

Zaragoza : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 69

2006
pages 155-159

Changes in soil chemical properties under three tillage systems in a long-term experiment

A. de Benito and A. Sombrero
Instituto Tecnológico Agrario de Castilla y León (ITACYL), P.O. Box 271, 47071 Valladolid, Spain
email: benmunav@itacyl.es

SUMMARY – Tillage systems have a very important influence on soil properties. As shown by literature, these systems affect soil physical, chemical and biological characteristics. Conservation tillage improves soil and ground water quality and benefits soil microfauna and the environment. These changes depend on soil type, climatology, crops used and tillage management systems. This paper reports the results obtained on the evolution of soil organic matter content, pH and macronutrients under three tillage systems in a long-term experiment after ten years of trial. This work exemplifies the importance of these effects and the differences between tillage systems.

Keywords: Conservation tillage, crop rotations, soil organic matter, soil properties.

RESUME – *"Changement des caractéristiques chimiques du sol dans trois systèmes culturaux dans une expérience à longue durée". Les systèmes culturaux ont une influence décisive sur les propriétés du sol. Ces systèmes peuvent changer les caractéristiques physiques, chimiques et biologiques du sol et cette influence a été démontré partout dans le monde. Le travail superficiel et le semis direct améliorent les propriétés du sol ainsi que la qualité des eaux souterraines et sont bénéfiques pour la microfaune et l'environnement. Ces changements dépendent des types de sol, de la climatologie, des cultures et des itinéraires techniques. Cet article présente les résultats obtenus dans un essai de longue durée, de trois itinéraires techniques, sur l'évolution de la matière organique du sol, du pH et de certains éléments majeurs. Ce travail met en évidence l´importance de ces effets et les différences entre les trois techniques culturales.*

Mots-clés : *Labour de conservation, rotation des cultures, matière organique, propriétés du sol.*

Introduction

Conservation tillage improves soil and water quality and soil fauna and reduces environmental degradation. Regarding soil quality, minimum or no-tillage enhances soil structure, increasing organic matter present in the top layer of the soil, water retention and anaerobic activities (Kay, 1995). The degree of these effects depends on soil type, crops, and tillage management systems.

Conservation tillage is the most effective tool to control soil erosion by water and wind, maintaining a surface cover to protect agricultural lands (Soil and Water Conservation Service, 1995).

Soil organic matter (SOM) is a good indicator of soil quality and conservation (Doran and Parkin, 1994). Crops, crop rotations and the quality and quantity of crop residues on the soil surface can affect the increase of organic matter content (Wright and Hons, 2005). The relative importance of these factors is strongly dependent on both soil and climate conditions.

Likewise, the relationship between tillage and soil fertility status is determined by, amongst other factors, tillage system, crop rotation, nutrient cycling and fertilizer application techniques. In this work, we present the results of the influence of three tillage systems on soil chemical properties in a long-term experiment located in a semiarid area of Castile-Leon, northern Spain.

Materials and methods

This study was performed in a cereal producing area of Torrepadierne (Burgos) from 1994 to 2004. The soil is classified as a typical Calcixerolls (Soil Conservation Service, 1975). The climate is

Mediterranean semiarid with an annual average precipitation of 531 mm. The experimental design was a split plot with four repetitions, with tillage system (conventional tillage, CT; minimum tillage, MT; and no-tillage, NT) as main factor and crop rotations (cereal/cereal, C/C; cereal/fallow, C/F; and cereal/legume, C/L) as sub-factors. The sowing date for cereal (wheat and barley), and legume (vetch) was usually early November. Cereal and vetch were sown at a seeding rate of 180 and 160 kg/ha, respectively. At sowing, 400 kg/ha of NPK fertilizer (8:24:8) were applied to all plots, except to fallow plots. Ammonium sulphate was top-dressed in the early spring (when plants were in the first stage of stem extension) at a rate of 300 kg/ha. Spring weeds were controlled in all cereal plots with 2.5 l/ha of Oxitril (Ioxinil 7.5% + Mecoproc 37.5% + Bromoxinil 7.5%) plus 1.25 l/ha of Splendor (Tralkoxidin 25).

The soil properties were determined at the beginning of the experiments and texture was classified as sandy-clay-loam, with an organic matter content of 1.8% and a basic pH of 8.4. The initial soil samplings were taken at a depth of 0 to 30 cm.

Soil samples were taken every two years from different depths (0-15 cm and 15-30 cm), to determine SOM, nitrogen, and macronutrient contents and pH. Last year, 2004, soil samples were taken in the 0-10, 10-20 and 20-30 cm layers.

The data were analysed as a split-plot, using the general lineal model (GLM) procedure (SAS Institute, 1990).

Results and discussion

Soil organic matter (SOM) is one of the most important soil parameters because it is related to soil structure, porosity, stability, water retention, amongst other properties. This parameter was quantified from 1994 to 2004. SOM changes are very slow and until 1998 there was not any significant difference between tillage systems in the first 15 cm of soil (Fig. 1). From that year on, differences were statistically different, with values 18% and 30% higher under NT compared with CT in 2002 and 2004, respectively. In MT, the SOM contents were intermediate between CT and NT. We found the same tendency for the first 30 cm, where SOM content was greater under NT than under CT (data not shown).

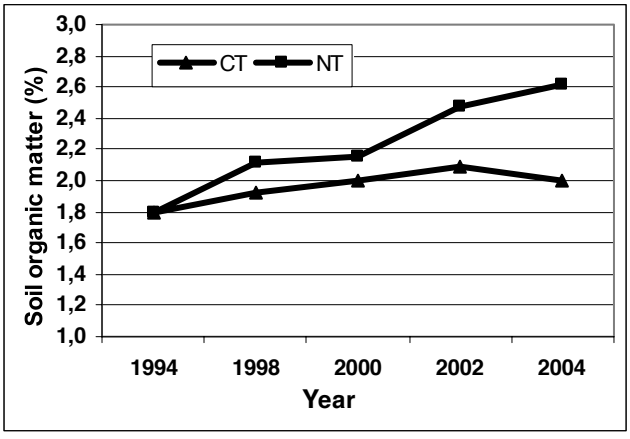

Fig. 1. Dynamics of soil organic matter content in the first 15 cm of soil for two tillage systems (CT, conventional tillage; NT, no-tillage) over the years of the experiment.

The soil nitrogen evolution for the three tillage systems is presented in Fig. 2.

Soil nitrogen content had a similar evolution than SOM in the first 15 cm of soil. In general, conservation tillage plots have more nitrogen than conventional plots.

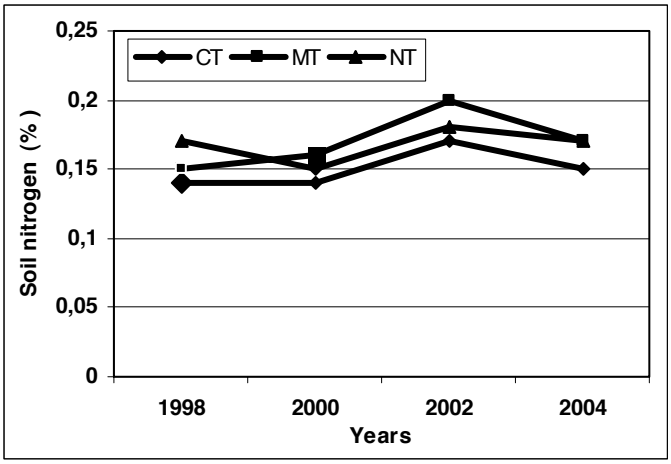

Fig. 2. Dynamics of total nitrogen content in the first 15 cm of soil for three tillage systems (conventional tillage, CT; minimum tillage, MT; and no-tillage, NT) over the years of the experiment.

Table 1 shows soil chemical properties for different depths and tillage systems after 10 years of the trial. The SOM content was significantly different between tillage systems for the 0-10 and 10-20 cm depths, showing higher values under NT, followed by MT and CT. However, these differences did not appear at the 20-30 cm depth. Whereas some authors observed a significant increase of SOM in conservation tillage systems only in the first 5 cm of soil (Pinheiro *et al*., 2004; Imaz, 2005), other authors, like Mrabet *et al.* (2001), found an increase of this parameter up to a depth of 15 cm. Our results show significant differences in the increase of SOM up to a depth of 20 cm in MT and NT systems, in agreement with results reported by Bessam and Mrabet (2003).

Table 1. Variation with depth in the upper 30 cm of soil chemical properties under three tillage systems after ten years of the trial

TS	Prof (cm)	OM (%)	pH	N (%)	P_2O_5 (mg/kg)	K_2O (mg/kg)
CT	0 - 10	2.0 c	8,36 a	0.16 c	39 b	660 c
MT	0 -10	2.6 b	8.25 b	0.21 b	96 a	953 b
NT	0 -10	2.9 a	8.27 b	0.24 a	122 a	1125 a
CT	10-20	2.0 b	8.21 a	0.16 b	41 a	530 c
MT	10-20	2.3 a	8.14 b	0.18 a	45 a	634 b
NT	10-20	2.3 a	8.12 b	0.18 a	40 a	731 a
CT	20 - 30	2.0 a	8.16 a	0.16 a	29 a	551 b
MT	20 - 30	2.1 a	8.12 b	0.16 a	33 a	543 b
NT	20 - 30	2.1 a	8.14 ab	0.16 a	35 a	620 a
CT	0 - 30	2.0 b	8.24 a	0.16 c	33 b	592 c
MT	0 - 30	2.3 a	8.17 b	0.18 b	58 a	714 b
NT	0 - 30	2.4 a	8.18 b	0.20 a	58 a	830 a

Values followed with a different letter for the same parameter and depth are significantly different (P=0.05).
TS = Tillage system; CT = conventional tillage; MT = minimum tillage; NT=No-tillage; OM = Organic matter, N = Total nitrogen.

Tillage also appeared to decrease soil pH in conservation agriculture systems after ten years of experiment. This parameter presented significant differences between CT and MT and NT for the three depths. This fact can be due to the possible effect of soil acidification produced by the organic matter accumulated in the surface layers (Karlen, 1995).

The nitrogen content showed highly significant differences between tillage systems at the 0-10 and 10-20 cm depths, with higher values in NT plots, followed by minimum tillage. At the 20-30 cm depth, the values of this parameter were similar in the three tillage systems, following the same tendency observed for the SOM content.

The phosphorus content presented significant differences in the first 10 cm of soil with higher values in MT and NT compared to CT. Likewise, there were significant differences between tillage systems in soil potassium with the following trend: NT>MT>CT.

Considering the 0-30 cm depth, results indicated that the contents of organic matter, nitrogen, phosphorus and potassium were significantly different between tillage systems, with higher values under NT and MT than under CT as a consequence of the differences observed in the first centimetres of soil.

Conclusions

From the results obtained it is possible to conclude that conservation tillage systems (minimum tillage and no-tillage) have had a positive influence on soil quality after 10 years of the trial. This was due to the general improvement of soil chemical properties such as soil organic matter and fertility.

Soil organic matter and total nitrogen increased under conservation tillage systems in the upper 20 cm of soil. This increase, which was already observed in the fifth year of study, has been more remarkable throughout the years.

The contents of phosphorus and potassium have also increased under conservation tillage systems in the upper 10 and 30 cm of soil, respectively. On the contrary, soil pH has decreased in the upper 10 cm under conservation tillage compared to conventional tillage.

Acknowledgments

The authors thank the Instituto Nacional de Investigación Agraria y Agroalimentaria (INIA) for funding this research work and the Caja de Burgos for its collaboration in the field trials.

References

Bessam, F. and Mrabet, R. (2003). Long-term changes in particulate organic matter under no tillage systems in semiarid soil of Morocco. In: *Soil and Tillage Research. International Conference,* Brisbane (Australia), 2003.

Doran, J.W. and Parkin, T.B. (1994). Defining and assessing soil quality. In: *Defining Soil Quality for a Sustainable Environment,* SSSA Inc Special Pub. No. 35, pp. 3-21.

Imaz, M.J. (2005). *Determinación y selección de indicadores de calidad de suelo para la evaluación de sistemas de Agricultura de Conservación en cultivo de cereal de zonas semiáridas en Navarra.* Tesis Doctoral. Universidad Pública de Navarra, 188 pp.

Karlen, D.L. (1995). Tillage effects on soil fertility. In: *Farming for a Better Environment*. Soil and Water Conservation Society White Paper, SWCS, Ankeny, IA, pp. 17-19.

Kay, B.D. (1995). *Soil quality: Impact of tillage on the structure of tilth of soil.* In: *Farming for a Better Environment*. Soil and Water Conservation Society White Paper, SWCS, Ankeny, IA, pp. 7-8.

Mrabet, R., Saber, N., El-Brahli, A., Lahlou, S. and Bessam, F. (2001). Total, particulate organic matter and structural stability of a Calcixeroll soil under different wheat rotations and tillage systems in a semiarid area of Morocco. *Soil & Tillage Research*, 57: 225-235.

Pinheiro, E.F., Pereire, M.G. and Anjos, L.H.C. (2004). Aggregate distribution and soil organic matter under different tillage systems for vegetable crops in a Red Latosol from Brazil. *Soil & Tillage Research,* 77: 79-84.

SAS Institute, Inc. (1990). SAS User's Guide. SAS, Inc., Cary, NC.

Soil Conservation Service (1975). *Soil Taxonomy. USDA*. Agricultural Handbook No. 436. USDA, Washington.

Soil and Water Conservation Service (1995). Summary. In: *Farming for a Better Environment*. Soil and Water Conservation Society White Paper, SWCS, Ankeny, IA,

Wright, A.L. and Hons, F.M. (2005). Soil carbon an nitrogen storage in aggregates from different tillage and crop regimes. *Soil Science Society of America Journal*, 69: 141-147.