Soil & Tillage Research 142 (2014) 8–14

Contents lists available at ScienceDirect

Soil & Tillage Research

journal homepage: www.elsevier.com/locate/still

Effect of conventional and no-till practices on solute transport in long term field trials

Elena Okada [a,b,*], José. L. Costa [b], Francisco Bedmar [c], Pedro Barbagelata [d,e], Alicia Irizar [f], Edgar A. Rampoldi [g,h]

[a] Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina
[b] Estación Experimental Agropecuaria Balcarce – Instituto Nacional de Tecnología Agropecuaria (INTA) Balcarce, Dto. Agronomía CC 276, 7620 Balcarce, Argentina
[c] Facultad de Ciencias Agrarias, Universidad Nacional de Mar del Plata, Ruta 226, Km 73, Balcarce, Argentina
[d] Estación Experimental Agropecuaria Paraná – INTA Paraná, Ruta 11 Km. 12,5, 3101 Oro Verde, Entre Ríos, Argentina
[e] Facultad de Ciencias Agropecuarias, Universidad Nacional de Entre Ríos, Oro Verde, Argentina
[f] Estación Experimental Agropecuaria Pergamino – INTA Pergamino, Av. Frondizi (Ruta 32) Km 4,5, 2700 Pergamino, Buenos Aires, Argentina
[g] Estación Experimental Agropecuaria – INTA Manfredi, Ruta Nacional N 9 km 636, 5988 Manfredi, Córdoba, Argentina
[h] Universidad Nacional de Córdoba, Facultad de Ciencias Agropecuarias, Ciudad Universitaria, Av. Valparaíso s/n, CC 509, 5000 Córdoba, Argentina

ARTICLE INFO

Article history:
Received 19 September 2013
Received in revised form 17 March 2014
Accepted 4 April 2014

Keywords:
Tillage
Solute transport
Soil structure

ABSTRACT

The prediction and description of water and solute movement in soils under different tillage systems is essential to the study of pesticide contamination in soils and groundwater quality. However, the impact of tillage practices in soil physical characteristics varies across locations and types of soil. In this work we analyzed the long-term impact of no till (NT) and conventional tillage (CT) on solute transport within three different Argentinian soils. Bromide transport studies were conducted under controlled conditions in the laboratory using undisturbed soil columns. Samples were taken from long term field trials, with a history of over 16 years of NT and CT practices. The studied soils were: Paraná soil (PAR), a silty clay loam soil (<37% clay), and Mandfredi (MAN) and Pergamino (PER), both silty loam soils (<26% clay). Breakthrough curves were fitted using the non-equilibrium equation model (CDEneq). The following transport parameters were estimated from the fitted curves: velocity (v), hydrodynamic dispersion coefficient (D), dispersivity (λ), mobile water content (β), and mass transfer coefficient (ω). The relationship between the estimated parameters and soil properties was analyzed. Also, the parameters were compared between soils and tillage practices using a mixed linear model. Parameters v and D were positively correlated to soil clay content in NT samples. Such correlation was not observed in CT samples. This would suggest that clay content in soils under conservational tillage, favors the transport of solutes, as it increases v and D. In this study, no differences were found between soils or tillage practice regarding the estimated v parameter. Differences were found for D and λ between CT and NT samples in PAR soil. In this case, the magnitude of solute dispersion was higher in the NT samples. For the other soils (MAN and PER), no difference in D and λ between tillage practices was found. Effects of tillage on solute transport was not substantial in these soils, even when no till management had been applied for over 30 years. Whereas in PAR (the soil with higher clay content), soil management had an important effect on structure, and therefore on solute and water transport. These results suggest that in the PAR clayey soils studied, structure is well preserved under conservational tillage, and this could lead to an increase in the risk of leaching of solutes or chemical substances.

1. Introduction

The study of soil functions and their impact on the environment is a relevant topic nowadays. Sometimes the impact can be evident at the macroscale, but it can also be determined at the microscale based on interactions between soil architecture and the transport and transformation processes occurring in the soil infrastructure, including the pore system (de Jonge et al., 2009). The prediction

* Corresponding author at: EEA INTA, Ruta 226, Km 73, Balcarce, Argentina. Tel.: +54 2266 439100x536.
E-mail address: eleokada@yahoo.com (E. Okada).

http://dx.doi.org/10.1016/j.still.2014.04.002
0167-1987/

and description of water and solute movement in soils under different tillage systems is essential to study the problem of pesticide contamination of soils and groundwater. Nevertheless, the relationship between agricultural practices and groundwater quality has not been addressed as extensively or effectively as have other pollution processes (Cullum, 2009).

Soil tillage has a major impact on flow and solute transport as it can affect pore size distribution and porosity (Lipiec et al., 2006). The tillage system may modify soil physical properties depending on factors such as cropping history, soil type, climatic conditions and the previous tillage system (Mahboubi et al., 1993). Also, soil management may have a significant effect on structural features of soils, which in turn, can considerably affect the macropore characteristics such as type, shape, size distribution, origin, geometry and continuity of macropores (Ersahin et al., 2002). Conventional tillage generally reduces solute transport by cutting shallow functional macropores (Jarvis, 2007). Whereas, conservational tillage systems promote the formation of continuous macropores (Locke and Bryson, 1997), favoring preferential flow of water and solutes.

In the agricultural environment, preferential flow and agrochemical transport in structured soils may significantly affect the quality of water resources (Sinkevich et al., 2005). However, it is important to highlight that the impact of different tillage practices on soil hydraulic properties is not consistent across locations, soils, and experimental designs (Schwen et al., 2011). Further research is needed to better understand and to quantify the effect of different management practices on changes in soil structure and pore functioning with respect to both water and solute transport (Vogeler et al., 2006).

Miscible displacement experiments using undisturbed soil cores are used to evaluate solute movement and estimate transport parameters, such as velocity (ν) and dispersivity (λ). As a first approach to study flow phenomena in undisturbed columns, non reactive molecules are used as tracers to model water movement. Akhtar et al. (2011) has highlighted the importance of laboratory column experiments on preferential flow for a comprehensive assessment of soil functions such as its retardation capacity for various substances and groundwater protection under field conditions.

To the authorś best knowledge, there exist no studies on the comparison of effects on solute transport of different tillage systems in long-term field trials (more than 16 years of no tillage and conventional tillage). Therefore the main objectives of the present study were: (i) to compare the effects of long-term tillage in different soils on solute transport, and (ii) to find a relationship between these parameters and soil physical characteristics. Studies were performed under controlled conditions in the laboratory using undisturbed soil columns from three different soils of Argentina, under long-term no-tillage (NT) and conventional tillage (CT). Transport parameters were estimated using the non-equilibrium convection-dispersion equation (CDE).

2. Materials and methods

2.1. Site description and column sampling

The present research was conducted with soil samples from three different experimental stations with long term field trials of the Instituto Nacional de Tecnología Agropecuaria (INTA).

The Manfredi (MAN) experimental site is located in Córdoba Province (31° 56′ 55″ S 63° 46 ′ 30″ W) and was established 30 years ago. The average annual rainfall of the site is 759 mm. The soil corresponds to a coarse-silty, mixed, termic Entic Haplustoll of the Oncatrivo series (INTA, 1987). Samples were taken from treatments under NT and CT with a maize-soybean rotation.

The Parana (PAR) experimental site is located in Entre Ríos Province (31° 51′ 15″ S, 60° 32′ 10″ W) and has an average annual rainfall of 1030 mm. The soil belongs to the Tezanos Pinto series (fine, mixed, termic Acuic Argiudoll) (INTA, 1998), and is characterized as deep and moderately well drained. Soil samples were taken from a long term field trial (16 years) under NT and CT, with a wheat/soybean-maize rotation.

The Pergamino (PER) site is located in Buenos Aires Province (33° 57′ S, 60° 33′ W). The annual precipitation is 946 mm and the soil is classified as fine, termic, illitic, Typic Argiduoll (Pergamino series) (INTA, 1972). This soil is well drained, with medium permeability. The field trial was established 34 years ago under NT and CT, and it has a maize-wheat/soybean rotation.

Tillage operations corresponded to the usual practices performed in each soil. For CT MAN, moldboard plowing and disc harrowing is used as primary tillage and field cultivator as secondary. In CT PAR, conventional tillage involves chisel plowing and combined vibrocultivator. And for CT PER, moldboard plowing is used as primary tillage and disc harrowing as secondary tillage.

Four replicate undisturbed soil columns were sampled in blocks from each tillage practice, resulting in 4 columns per soil per treatment (total number of columns = 24). Core samples were obtained introducing stainless steel cylinders of 8 cm wide inner diameter and 15 cm length into the top soil. Samples were then sealed with plastic lids and stored at 4 °C until transport studies.

Disturbed soil samples were also collected from each site, for physical and chemical analysis. Particle size distribution was obtained with the sieving and pipette method (Soil Conservation Service, 1972) and organic carbon content (OC) was measured by oxidation with chromic acid (Walkley and Black, 1934).

2.2. Transport experiments

Displacement studies were carried out under isothermal (20 °C) and unsaturated steady-state flow conditions using an experimental setup similar to that described by Montoya et al. (2006) and Bedmar et al. (2008). Prior to the leaching experiment, columns were slowly pre-saturated from the bottom of the column with a 0.01 M $CaCl_2$ solution. Afterwards they were sealed with a cap containing a stainless steel plate with holes on both ends of the column, which allowed a uniform distribution of the inlet flow. Columns were irrigated with a 0.01 M $CaCl_2$ solution at a constant flow of 4.16 mm h^{-1} using a syringe pump. At the lower boundary condition, the columns were connected to a vacuum chamber keeping a constant tension of −11 KPa. Inside the chamber a fraction collector was used to collect the effluent at different time intervals. When steady state flow was reached, a pulse of KBr (equivalent to 150 kg ha^{-1}) dissolved in $CaCl_2$ (0.01 M) was applied for 15 min. The columns were then leached with a 0.01 M CaC_2 solution for several pore volumes. The collected samples of the effluent were analyzed to determine bromide concentration using an ion-selective electrode (EA940 Orion) with a lower detection limit of 0.0005 mmol L^{-1}. The relative concentrations (C/C_o) of Br^- were determined by dividing the concentration of the tracer in the effluent collected by the concentration of the tracer in the stock solution.

At the end of the leaching experiments, columns where weighed and then dried at 105 °C to estimate bulk density (ρ_b). Total porosity (ϕ) was calculated as $\phi = 1 - \rho_b/\rho_p$, assuming a particle density of ρ_p = 2.62 g cm^{-3}.

2.3. Model fitting

Most mechanistic models for solute transport in porous media are based on the convection-dispersion equation (CDE). The CDE is a partial differential equation representing mass continuity for