Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA)
Available online at www.inia.es/sjar
Spanish Journal of Agricultural Research 2010 8(2), 377-384
ISSN: 1695-971-X

Tillage system does not affect soil macrofauna in southeastern Buenos Aires province, Argentina

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Abstract

Soil degradation increased incessantly in the Pampas region of Argentina, due to the intensification of agricultural activities, when carried out with conventional tillage (CT) systems. No-tillage system was adopted as conservation practices by the farmers. The objectives of this study were: a) to determine the macrofauna taxa and their relative abundance under CT and NT in two different seasons; and b) to evaluate soil tillage and seasonal effects on the density of the main macrofauna taxa. The study was conducted from 2002 to 2004 in 46 production farms, in Balcarce, Argentina. Ten soil monoliths (25.2 cm side; 30 cm depth) ramdomly directed field at July-August; and at October-November to determine the number of individuals of macrofauna and Enchytraeidae. Soil macrofauna density did not differ between tillage systems. Oligochaeta Megadrilli density was generally not affected by the tillage system ($P > 0.05$) except in 2004 when it was greater under CT in July-August ($P = 0.0002$). Chilopoda density was greater in soils under NT, with significant differences in 2002 in October-November ($P = 0.0070$). In July-August of 2003 it was higher in CT ($P = 0.0109$). Diplopoda were more abundant only under NT in July-August 2004 ($P = 0.0010$). In July-August a significantly ($P < 0.05$) higher density of Enchytraeidae was found in CT than NT fields. No differences were observed in the taxonomic composition and the relative abundance of the macrofauna when comparing CT and NT. It can be then concluded that in the study region tillage systems affected slightly soil macrofauna and significantly Enchytraeidae.

Additional key words: abundance, conventional tillage, no-tillage, soil invertebrates.

Resumen

El sistema de labranza no afecta a la macrofauna en el sudeste de la provincia de Buenos Aires, Argentina

En la región pampeana argentina se ha producido una creciente degradación del suelo debido a la intensificación de las actividades agrícolas llevadas a cabo con sistemas de labranza convencionales (LC). Los agricultores, como práctica conservacionista, han adoptado la siembra directa (SD). Los objetivos de este estudio fueron determinar los taxa de la macrofauna y su abundancia relativa bajo LC y SD en dos estaciones diferentes y evaluar los efectos de los sistemas de labranza y estaciones sobre la densidad de los principales taxa de la macrofauna. El estudio fue llevado a cabo desde 2002 hasta 2004 en 46 lotes de producción en Balcarce, Argentina. En cada lote se tomaron diez muestras de suelo al azar (de 25,2 cm de ancho y 30 cm de profundidad) en julio-agosto y octubre-noviembre para determinar el número de individuos de la macrofauna y de los Enchytraeidae. La densidad de la macrofauna no difirió entre sistemas de labranza. La densidad de Oligochaeta Megadrilli no fue afectada por el sistema de labranza ($P > 0,05$), excepto en 2004 cuando fue mayor bajo LC en julio-agosto ($P = 0,0002$). La densidad de Chilopoda fue mayor bajo SD, aunque solo se observaron diferencias significativas en octubre-noviembre de 2002 ($P = 0,0070$). En julio-agosto de 2002 la densidad fue mayor en LC ($P = 0,0109$). Diplopoda fue más abundante bajo SD sólo en julio-agosto de 2004 ($P = 0,0010$). La densidad de Enchytraeidae fue mayor en LC que en SD en el período julio-agosto ($P < 0,05$). No se observaron diferencias en la composición taxonómica y en la abundancia relativa de la macrofauna entre LC y SD. Se concluye que en la región de estudio los sistemas de labranza causan sólo efectos leves en la macrofauna del suelo y algunos efectos sobre los Enchytraeidae.

Palabras clave adicionales: abundancia, invertebrados del suelo, labranza convencional, siembra directa.

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Received: 07-04-09; Accepted: 25-02-10.

Abbreviations used: CT (conventional tillage), NT (no-tillage).

Introduction

Since the 1980s the increased agricultural activities in Argentina and in the Pampas region particularly, were accompanied by the use of intensive tillage systems (Studdert, 2003; Manuel-Navarrete *et al*., 2005). Conventional tillage (CT) systems were characterized by an excessive use of plowing, chiseling and/or harrow disking, thus leading to soil degradation and erosion (Studdert and Echeverría, 2000; Miccuci and Taboada, 2006). This accelerated soil erosion and other degradation processes influence agronomic productivity and the environment through their impact on the physical, chemical and biological factors related to soil quality (Lal *et al*., 2007). As a consequence, farmers have been adopting sustainable cropping systems based on conservation agricultural practices such as direct drilling or no-tillage (NT). These systems are expected to improve physical and chemical soil properties and enhance soil microorganism activity (Pankhurst *et al.*, 1997).

It is generally believed that tillage has a negative impact on soil organisms living both in topsoil and subsoil horizons. The repeated mechanical disturbance of the substratum and removal of plant cover or a protective surface of leaf litter causes unstable microclimatic conditions in the profile of soil (wide fluctuations in temperature and moisture). These effects can produce high mortality of soil animals (Wallwork, 1976). On the other hand, under NT systems, crop residues are accumulated at surface, thus generating a complex biological system and creating more stable microclimatic conditions. In this environment soil fauna not only feed on crop residues but are also protected by them. Adopting NT practices therefore directly or indirectly modifies the taxonomic composition of the soil fauna (Stinner and House, 1990; Fereres Castiel, 1998).

Soil fauna is composed of a diverse group of organisms with body diameters that range from micrometers to several centimeters. Mesofauna body diameter ranges from 0.1 to 2 mm and includes enchytraeids (Annelida: Oligochaeta, Enchytraeidae) and microarthropods (Symphyla, Pauropoda, Acari, Collembola, Protura and Diplura). Enchytraeidae, one of the most important bioindicators groups, are the largest and most active of the mesofauna organisms and are related to organic matter decomposition, humification and nutrient cycling. In addition, Enchytraeidae biogenic structures and burrowing activities modify soil aggregation and porosity (Van Vliet *et al.*, 1993), increasing pore volume and water infiltration (Linden *et al.*, 1994).

Macrofauna includes organisms larger than 2 mm and has the most direct effect on soil properties. This community includes Annelida: Oligochaeta, Megadrilli (earthworms), Crustacea: Isopoda (woodlice), Chilopoda (centipedes), Diplopoda (millipedes), Insecta: Hymenoptera (ants) and Coleoptera and Diptera (adult insects and larvae). Macrofauna disintegrates and distributes organic litter throughout the soil profile, increasing organic substrate accessibility for microorganism activity (Linden *et al.*, 1994). Certain macrofauna groups, such as Oligochaeta Megadrilli and ants, modify the soil structure through the formation of soil aggregates and macropores (Lee and Foster, 1991), increasing soil infiltration, porosity and solute drainage. These processes promote soil root exploration and favor crop growth and development (Linden *et al.*, 1994).

In southeastern Buenos Aires province, Argentina, macrofauna and Enchytraeidae communities have been characterized in several farming systems (Clemente *et al.,* 2003; López *et al.,* 2005; Gizzi *et al.,* 2009), but not yet under NT systems in the region. These systems are widespread at present. Soil moisture, soil temperature, availability of food (quantity and type) are key environmental and biological factors responsible for the seasonal fluctuations in the population of soil fauna (Gupta and Yates, 1998). The purposes of this study were: i) to determine the taxa of macrofauna and the relative abundance under conventional tillage and no-tillage in two different seasons, and ii) compare the density of the enchytraeids and the main macrofauna taxa in both tillage systems and seasons.

Material and methods

Study area and systems management

Forty-six fields were sampled under CT or NT was studied in Balcarce (Buenos Aires, Argentina) in production farms with at least five years under NT. The climate in this area is mesothermal, humid to subhumid (according to Thornthwaite classification) or as temperate humid without dry season (according to Köpen classification). The mean annual temperature is 13°C and a mean annual rainfall is 928 mm (averaged from years 1970 to 2000), with 80% of the rainfall occurring during spring and summer. Sampling periods were characterized by relatively cold winters (July-August mean daily air temperature of 7.4°C and 9.1ºC, respectively) and moderate climate springs (October-November mean daily air temperature, 13.2°C and 16.0°C, respectively). Land is mainly devoted to extensive crop production; the soil was developed under grass vegetation, and eolic sediments (loess), which were transported during the Quaternary period and are rich in calcareous materials. Sampling sites are located in a lowly undulated area (116 to 160 m above sea level; 0.5 to 2.5% slope). Soil is a complex mixture of fine, mixed, thermic Typic Argiudolls and fine, illitic, thermic Petrocalcic Paleudolls (USDA classification). Both soil types have similar properties at surface. Their A horizon has pH 6.0 (1:2.5 in water), 33.1 cmol kg^{-1} cation exchange capacity, 5.0 mg kg^{-1} Bray and Kurtz P and 37.7 g kg^{-1} soil organic C contents (Studdert and Echeverria, 2000). Under CT seedbed preparation required harrow disking or chiseling, while under NT glyfosate was required at a dose of 2-2.5 L ha^{-1} to control weeds about three months before the planting date of each crop. Phosphorus fertilizer was applied at sowing as diamonic phosphate (100-150 kg ha^{-1}) and nitrogen as urea was surface broadcasted during crop vegetative. No insecticides were applied in both tillage systems.

Sampling and fauna analysis

Ten soil monoliths (25.2 cm side; 30 cm depth) were taken in each field following a 50 m long transect with a random direction, according to the Tropical Soil Biology and Fertility Program Method (Anderson and Ingram, 1989). Soils were sampled before wheat (*Triticum aestivum* L.) (July-August) and maize (*Zea mays* L.) (October-November) sowing in 2002, 2003 and 2004. In 2002, four CT and five NT fields were sampled in July-August and two CT and five NT fields were sampled in October-November. In 2003, four fields with every combination of tillage systems and seasons were sampled. In 2004, four CT and NT fields were sampled in July-August and three CT and four NT fields were sampled in October-November.

To separate specimens, the soil was sequentially sieved through two of 10 mm and 2.5 mm screen opening sieves. Stones and large debris were removed by hand from the first screen; and smaller organisms were removed from the second screen. The soil was separated in visually homogeneous 1-4 mm thick layers, from which the specimens (macroarthropods and Annelida: Oligochaeta, Megadrilli and Enchytraeidae) were removed by hand-sorting (Blair *et al*., 1996). Arthropoda were counted and placed in a 75% alcohol solution and Annelida (Oligochaeta Megadrilli and Enchytraeidae) in 5% formol solution for later observation. Then, the individuals were examined using a stereomicroscope at 160 magnifications to verify species identification.

The percentage of each taxon in the macrofauna in three years of study was determined for each tillage system and season. Density was expressed as the number of individuals per square meter for *Enchytraeidae*, total macrofauna, *Oligochaeta Megadrilli*, *Chilopoda* and *Diplopoda*. Due to the aggregated or contagious disposition of soil organisms, differences in density of each taxa among cropping systems were analyzed with general linear models assuming a binomial negative distribution, canonical link function and linear predictor in function of cropping system effect (McCullagh and Nelder, 1989).

Results

In general terms, specimens corresponding to the Annelida and Arthropoda phyla were found. During July-August 2002, 2003 and 2004, 5,418 individuals were collected and 55.2% of the population was composed by annelids. During October-November, 8,046 individuals were counted of which 58.7% were annelids.

Two phyla were found in the macrofauna community: Annelida and Arthropoda (Table 1). In both seasons and tillage systems the same taxa composition was observed within these phyla. The Arthropoda were the most abundant individuals (> 63%) in both tillage systems, and among Arthropoda the Insecta, ranged 38-50.1% under NT and 47.1-60.2% under CT in both seasons and years. This class was essentially composed of Hymenoptera, Coleoptera (Carabidae, Staphylinidae, Scarabaeidae and Curculionidae) and Diptera. Coleoptera herbivores (Scarabaeidae and Curculionidae principally) were more abundant in CT than in NT, whereas Coleoptera predators density (Carabidae and Staphylinidae) were similar between seasons and tillage systems. In «Others» were included additional insects order such as Lepidoptera, Coleoptera: Chrysomelidae larvae and Orthoptera and Hemiptera: Heteroptera nymphs and adults. On the other hand, Chilopoda (centipedes) and Diplopoda (millipedes) represented 4.6 to 15.4% and 6.6 to 20.3%, respectively and Arachnida (spiders) showed the smallest percentages (Table 1).

Table 1. Number of individuals per square meter of each macrofauna taxa in July-August and October-November under conventional (CT) and no-tillage (NT). In parentheses, percentage of the collected taxa during years 2002, 2003 and 2004

Phylum	Class	Order/*Family*	July-August		October-November	
			CT	NT	CT	NT
Annelida	Oligochaeta		80.0 (32.0)	69.5 (24.3)	95.1 (19.2)	136.2 (37.0)
Arthropoda	Insecta	Coleoptera				
		Scarabaeidae	10.3 (4.1)	6.0 (2.1)	43.1 (8.7)	16.6 (4.5)
		Elateridae	0.5 (0.2)	1.1 (0.4)	2.0 (0.4)	0.9 (0.3)
		Curculionidae	16.3 (6.5)	6.9 (2.4)	15.8 (3.2)	1.1 (0.3)
		Carabidae	8.8 (3.5)	10.0 (3.5)	12.9 (2.6)	12.3 (3.3)
		Staphylinidae	9.8 (3.9)	7.7 (2.7)	6.4 (1.3)	8.0 (2.2)
		Diptera	17.5 (7.0)	24.5 (8.5)	73.3 (14.8)	10.0 (2.7)
		Hymenoptera				
		Formicidae	19.2 (7.7)	44.2 (15.4)	72.9 (14.7)	37.8 (10.3)
		Others	35.2 (14.1)	42.9 (15.0)	71.6 (14.5)	53.5 (14.5)
	Chilopoda	Geophilomorpha and Scolopendromorpha	15.7 (6.3)	13.2 (4.6)	65.8 (13.3)	56.9 (15.4)
	Diplopoda	Juliformia	34.7 (13.9)	58.0 (20.3)	32.7 (6.6)	30.8 (8.4)
	Arachnida	Araneae	1.7 (0.7)	2.2 (0.8)	3.6 (0.7)	4.3 (1.2)

In July-August 2002 and 2004, soil macrofauna did not differ between tillage systems ($P = 0.5004$ and 0.4552, respectively) (Fig. 1a). In contrast, in 2003 the macrofauna population was more abundant under NT compared to CT ($P = 0.0385$), averaging 517 and 373.5 individuals m^{-2}, respectively (Fig. 1a). In October-November, tillage systems did not affect the macrofauna population density ($P = 0.4945$, $P = 0.2823$ and $P = 0.1246$, in 2002, 2003 and 2004, respectively) (Fig. 1a).

In general, Oligochaeta Megadrilli density was not affected by tillage systems ($P > 0.05$). In July-August of 2004 their density was very low under NT, 22.0 individuals m^{-2} and differed significantly compared to CT that was 75.5 individuals m^{-2} ($P = 0.0002$) (Fig. 1b).

The Chilopoda were relatively more abundant in NT than CT, but only in October-November of 2002 significant differences were found ($P = 0.0070$). Furthermore, in July-August of 2003 the density of those individuals was higher in CT ($P = 0.0109$) (Fig. 1c).

On the other hand, the density of Diplopoda, a detritivore group, was similar in both tillage systems and seasons, although significant differences were found before wheat planting in 2004, where more individuals were found in NT system ($P = 0.0010$) (Fig. 1d). The Enchytraeidae, another detritivore group, was the only one belonging to the mesofauna. Their density in July-August of 3 years sampled was always significantly higher under CT than under NT ($P < 0.05$) (Fig. 1e). However, tillage effects were not consistent for these organisms in October-November of 3 years sampled. The population density was higher under NT than under CT ($P < 0.0001$) in 2003, while no significant differences were found between tillage systems ($P = 0.3158$) in 2004 (Fig. 1e).

Discussion

No till systems are believed to be less aggressive to soil fauna (Paoletti, 1999; Kladivko, 2001), thus promoting a greater soil fauna density and biodiversity (Rios de Saluso and Frana, 1998; Marasas *et al.*, 2001; Blanchart *et al.*, 2006; Brévault *et al.*, 2007). Large organisms in general appear to be more sensitive to tillage operations than smaller organisms, due to the physical disruption of the soil, burial of crop residue, and the change in soil water and temperature resulting from residue incorporation (Kladivko, 2001). Nevertheless, results here obtained show tillage system not to have significant impact on soil macrofauna density. According to Wardle (1995), the response of bigger organisms to tillage is less predictable than those of smaller organisms. This may be related to variation in the timing of field operation, as well as the degree of physical disturbance and litter burial in different

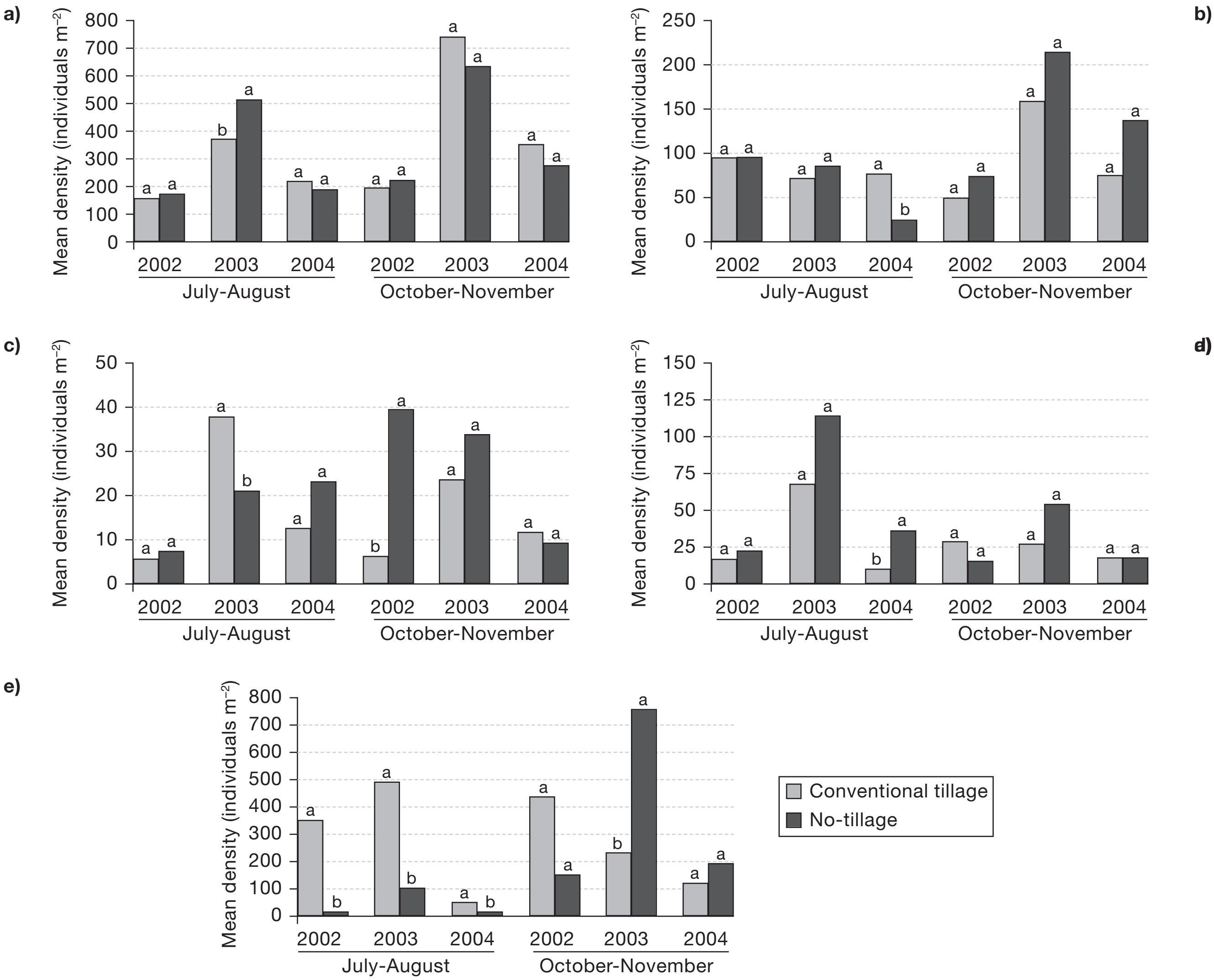

Figure 1. Number of macrofauna individuals (a), Oligochaeta Megadrilli (b), Chilopoda (c), Diplopoda (d) and Enchytraeidae (e) per square meter in July-August and October-November under conventional and no-tillage cropping systems in 2002, 2003 and 2004. Bars within a year and in the same season sampling with the same letter over them do not differ significantly ($P > 0.05$).

studies. The lack of significant differences between tillage systems here observed could be due to tillage practices that were not enough aggressive or to the presence of similar food (organic matter) for organisms to develop under both systems (Domínguez *et al*., 2004).

The macrofauna community was represented by Annelida and Arthropoda, being the Insecta the most abundant class within the Arthropoda. This observation agrees with results found by other authors, such as Brévault *et al.* (2007). They found that Arthropoda were predominant (92.7%) in the invertebrate community in soils under CT and NT systems, and the Insecta was the most numerous and diverse class within the Arthropoda phylum.

Results from this study show a relative abundance of invertebrates in the macrofauna community. Likewise, Fragoso and Lavelle (1992) also observed that the Oligochaeta Megadrilli, Coleoptera and Diplopoda were the most abundant taxa. Similar results were found by Ríos de Saluso *et al.* (2001), with the difference that Diplopoda was more numerous than Coleoptera. The Oligochaeta Megadrilli, Coleoptera, Diplopoda and Hymenoptera were relatively more abundant among the macrofauna taxa. In addition Jordan *et al.* (1997) found higher number of earthworms in NT compared to chisel-disk plots. In our study Oligochaeta Megadrilli density was not affected by tillage. Momo *et al.* (1993) concluded that the absence of earthworms was related to intensive agricultural practices, and Reeleder *et al.* (2006) reported that earthworm density was greater under NT systems while tillage reduced their populations. Furthermore, Edwards and Lofty (1982) stated that tillage practices decrease Oligochaeta Megadrilli density due to physical injury, reduction in soil moisture and by exposure to predatory birds. Kladivko *et al*. (1997) observed that in production farms a reduction in tillage intensity encourages earthworm populations. In the southeastern of Buenos Aires Province, Clemente *et al.* (2003), observed a lower density of those individuals (225 individuals m^{-2}) in CT systems as compared to non tilled systems like high input pasture, low input pasture and natural pasture (1,668; 572, and 418 individuals m^{-2}, respectively). Kladivko (2001) summarized that in systems with intermediate levels of soil disturbance and surface residue usually have populations intermediate between moldboard plowing and NT systems. In NT systems, the residues on the soil surface are available as food supply to the Oligochaeta Megadrilli for a longer period of time than if the residues are incorporated with a tillage implement. It is probable that our studied CT systems have only intermediate levels of soil disturbance, thus causing Oligochaeta Megadrilli population not to be affected. In Paraná, Brazil, Oligochaeta Megadrilli density was found to be higher under NT than CT in the rainy summer season, but not in the dry winter season (Brown *et al.*, 2003). In the rainy season, Oligochaeta Megadrilli density was positively related to the number of years under NT. In the study are, southeastern Buenos Aires Province, there are not contrasting dry and rainy seasons, so that both sampling periods behaved similarly. López-Fando and Bello Pérez (1997) suggested that, even though earthworm activity increases with the greater soil water content under NT, compacted NT soils can reduce soil oxygen levels and negatively impact earthworm activity.

A greater Diplopoda density was found under NT than CT. These organisms are more abundant in NT systems because they find food and shelter (Wolters and Eksschmitt, 1997). Our results partially agree with those of Brévault *et al*. (2007) and Ríos de Saluso *et al.* (2001), who observed a greater Diplopoda density in fields under NT for 4 to 5 years.

In coincidence with several authors (Baquero *et al.,* 2003; López *et al.,* 2005; Gizzi *et al.,* 2009), Enchytraeidae were here also found in higher percentages in CT soils. Tillage incorporates and accumulates organic residues at a greater depth than NT, enabling a more widespread growth and development of these organisms (Lägerlof *et al.*, 1989). In addition, tillage practices improve growth of Enchytraeidae, because such practices produce a favorable pore distribution and higher pore space in the soil (Lägerlof *et al.*, 1989). Enchytraeidae live within aggregates and are not affected by the disturbance caused by tillage implements. Also, residue incorporation leads to more bacterial growth and hence increased abundance of bacterial-feeding organism such as Enchytraeidae (Gupta and Yeates, 1998).

The adoption of NT system in southeastern Buenos Aires Province increased some groups of organisms like slugs and pill bugs in some fields, which became pests in crops (Faberi *et al*., 2006; Clemente *et al*., 2008; Salvio *et al*., 2008; Faberi *et al*., 2009). In recent works Diovisalvi *et al*. (2008) and Domínguez *et al*. (2009) determined that there are slightly changes in some properties of the soil related to the soils sustainability between CT and NT. It can be then concluded that in the study region tillage systems only caused slight effects on soil macrofauna while some effects on the Enchytraeidae populations. Soil fauna should be monitored frequently in order to detect trends to negative changes, such as appearance of fauna pest, and therefore take management decisions to correct them.

Acknowledgements

This work was financially supported by a project N°ARG 142/02 Universidad Nacional de Mar del Plata and a project N° 525102 Instituto Nacional de Tecnología Agropecuaria (INTA).

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