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SHORT COMMUNICATION

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Dynamics of humic fractions and microbial activity under no-tillage or reduced tillage, as compared with native pasture (Pampa Argentina)

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Abstract Humic fractions, arginine ammonification and soil respiration were monitored in spring, summer and autumn 1999 in natural pasture soil and in no-tillage or reduced-tillage soil under maize. The Typic Argiudoll soils, typical of the Argentine rolling pampa, can be structurally unstable, particularly when conventionally tilled, a form of soil management affecting the humification process. The no-tillage soil had a lower content of fulvic acids than the reduced-tillage soil in spring and summer, probably because the humification process was favored by residue management in no-tillage soil, with a significant increase in the most stable fraction. Both arginine ammonification and CO_2 were significantly correlated with the humic acids and humin contents. No significant correlation was found with fulvic acids,probably due to the lability and high variability of this fraction. A high correlation was found between arginine ammonification and CO_2. The highest index values were generally observed in natural pasture soil, whereas no-tillage soils showed a higher index value than reduced-tillage soils throughout, confirming the hypothesis that humification is more intense in the presence of organic residues.

Keywords Humic fraction · Microbial activity · Tillage systems · Typic Argiudoll soil

Introduction

The Typic Argiudoll soils in the Argentine rolling pampa are characterized by a silty loam texture. Due to the fact that its silt fraction is mostly comprised of phytolites (Pecorari et al. 1990; Cosentino 2000), these soils have a tendency toward structural instability.

Soil organic matter increases in the surface of soils under no-tillage or reduced tillage, with respect to conventionally tilled soils. A higher content of carbohydrates and amino acids are found in whole soils and in carbon-enriched fractions from no-tillage systems than in conventionally tilled systems (Arshad et al. 1990; Duiker and Lal 1999; Lilienfein et al. 2000). The elemental composition and the humic acid content of reduced-tillage and conventionally tilled (Entic Haplustol) soils are similar but differ from those of the virgin soil (Miglierina and Rossel 1995).

Microbial biomass and microbial activity increase in the surface layer of no-tillage or reduced-tillage soils sampled in North American, European and Australian soils, whereas similar studies on South American soils are scarce (Doran 1987; Nannipieri 1994). Information is also scarce on how the humification process and microbial activity of soil are affected by tillage.

The aims of this work were: (1) to study the dynamics of the humification process in a Typic Argiudoll soil during the maize crop cycle and (2) to evaluate the relationship between humin, humic acid and fulvic acid with microbiological activity under no-tillage and reduced tillage of Typic Argiudoll soil and (3) to compare these parameters with those of the corresponding native pasture.

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Materials and methods

Typic Argiudoll soil, located in Marcos Juárez, Córdoba, Argentina, has the following main characteristics: pH=6.1 (1:2.5 in water), C:N ratio=9.7, silty loam texture, 36 g organic matter kg^{-1}, 32 mg extractable P kg^{-1} and a cation exchange capacity of 19.3 $cmol_c$ kg^{-1}.

The climate is temperate and humid, with an annual mean temperature of 18±1 °C and a mean precipitation of 900 mm. The field experiment, involving plots (15×21 m) cropped to maize, started in 1994 and included the following treatments: (1) no-tillage (NT), using a no-tillage planter, (2) reduced tillage (RT) using a chisel plow at a depth of 15 cm, with one pass of a tandem disk harrow at a depth of 10 cm and (3) natural pasture (NP). The experiment consisted of a randomized complete block design with five replications. After the maize harvest, five sub-samples were collected from each plot at a depth of 0–10 cm and mixed together to give a composite soil sample per plot. The soil organic matter

(SOM) content, humic fractions and microbiological activity were monitored in September and December, 1998, and in April, 1999.

The organic carbon (C_O) content was determined by the Walkley and Black method (Nelson and Sommers 1982), the carbon content of fulvic acids (C_{FA}), humic acids (C_{HA}) and humins (C_{HU}) was determined as reported by Ritcher (1979) and the microbiological activity (AM) was determined either by the arginine ammonification assay (Alef and Kleiner 1987) or by CO_2 evolution by trapping in alkaline solution and measurement by acid titration (Anderson and Ingram 1993).

All measurements were replicated three times and the data are expressed on the basis of soil dried at 105 °C.

ANOVA analysis was performed to establish correlations between humic forms and microbiological parameters.

Results and discussion

Figure 1 shows the patterns of the measured parameters. Under NP, C_{HA} remained constant throughout the period of study whereas, under NT, a C_{HA} increase was observed in summer and was associated with the increase in arginine ammonification during the decomposition of maize residues (Conti et al. 1997).

NT soils had a lower C_{FA} content than RT soils (P<0.05) in spring and summer, probably because the humification process was favored by residue management in NT, with a significant increase in the most stable fraction. Indeed, the average percentage of C_{HA} through the years was 18% lower for RT than for NT (P<0.05),

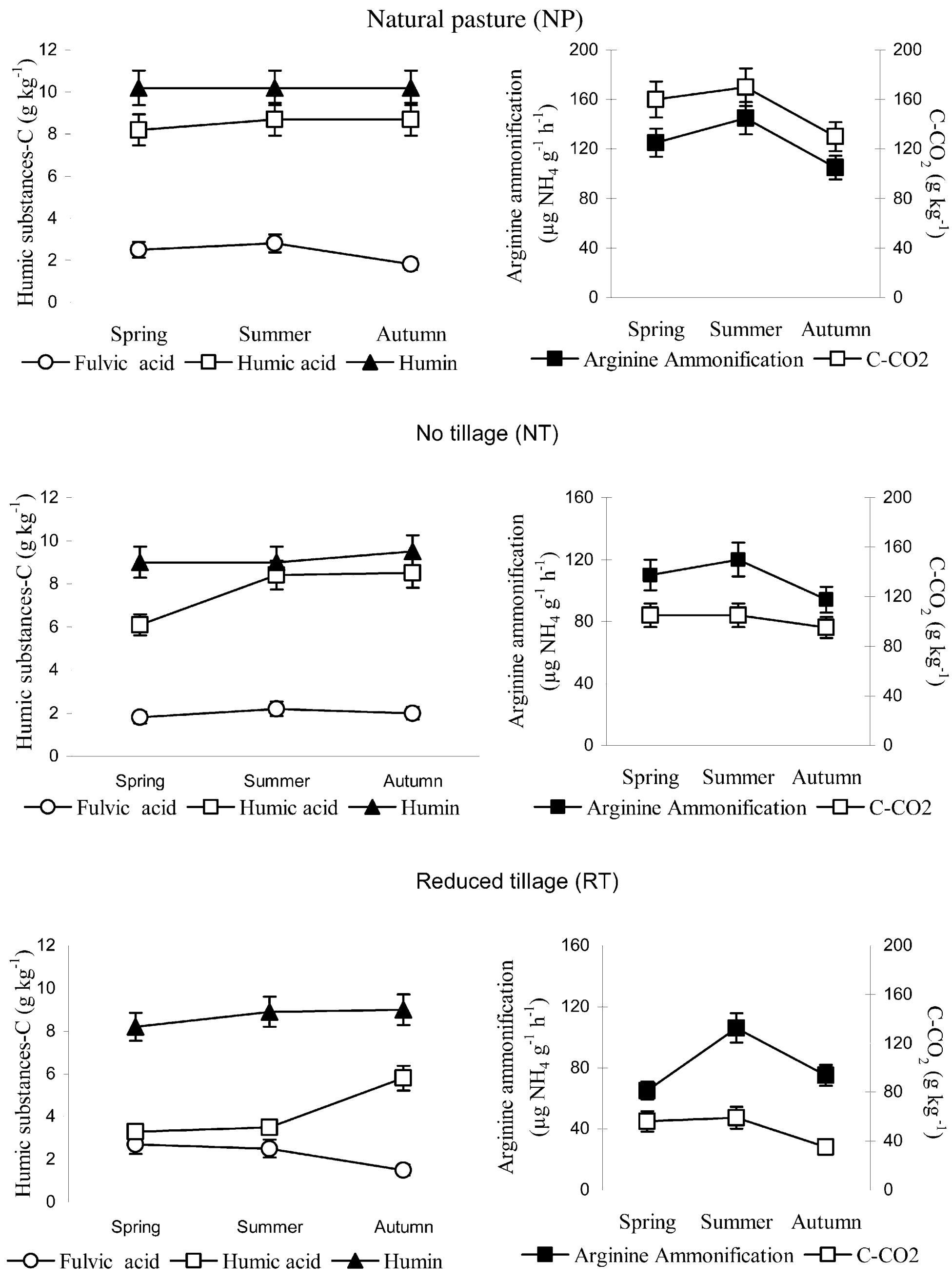

Fig. 1 Soil respiration, arginine ammonification and carbon content (-C) of humic acid-C, fulvic acid-C and humin-C in natural pasture (*NP*), no tillage (*NT*) and reduced tillage (*RT*). *Bars* indicate standard deviations

Table 1 Correlation coefficients between microbiological activity or CO_2 respiration and soil content, in terms of organic carbon, humic acids, fulvic acids and humins. *Asterisks* indicate $P<0.05$

Activity	Organic carbon	Fulvic acids	Humic acids	Humins
Arginine ammonification	0.96*	0.26	0.80*	0.78*
CO_2 respiration	0.87*	0.42	0.77*	0.73*

Table 2 Humification index, humification type (Orlov 1995) and percentage of humic acids in natural pasture (*NP*) and in no-tillage (*NT*) and reduced-tillage (*RT*) soils. Lower-case letters (*a*, *b*, *c*) indicate the level of significance ($P<0.05$) between treatments for each sample

Treatment	Spring			Summer			Autumn		
	NP	NT	RT	NP	NT	RT	NP	NT	RT
Humification index	35.6 a	30.3 b	20.6 c	39.5 a	35.6 b	21.8 c	39.5 a	40.3 a	30.2 b
Humification type	3.3 a	3.4 a	1.2 b	3.1 a	3.8 a	1.4 b	4.8 a	4.5 a	2.0 b
Humic acids (%)	0.82 a	0.65 b	0.33 c	0.87 a	0.79 b	0.35 c	0.87 a	0.85 a	0.49 b

while the C_O content decreased approximately by 10% ($P<0.05$). The C_{HA} content of NT soil nearly reached the same level as the NP soil value (Fig. 1), whereas the $C_{HA}+C_{FA}$ percentage fraction was about 37% for all treatments.

The percentage of carbon in fulvic acids, humic acids and humins ranged from 3% to 13%, from 24% to 33% and from 62% to 64%, respectively, and the $C_{HA}:C_{FA}$ ratio ranged from 1.6 to 4.3.

The constant values of the C_{HU} fraction throughout the year agree with the stability of this fraction (Almendros et al. 1996).

Disturbance caused by tillage altered the quality of humic matter, because the concentration of humic fractions was highest under NP, intermediate under NT and lowest under RT, which demonstrates that the type of tillage influences the humification/mineralization relationship (Alvarez et al. 1995; Palma et al. 2000).

Both arginine ammonification and CO_2 evolution showed similar patterns during the year, with maximum values in summer. The highest values were found in the NP soil, intermediate values in the NT soil and the lowest values in the RT soil. Such a decrease was particularly evident for CO_2 evolution. Under NT, the presence of residues on the surface generates a more adequate environment for the maintenance of microbiological activity, which shows a higher respiration index than under RT. Both arginine ammonification and CO_2 were significantly correlated with the C_O, C_{HA} and C_{HU} contents (Table 1). No significant correlation was found with C_{FA},probably due to the lability and high variability of this fraction. A high correlation coefficient (r=0.85; $P<0.05$) was found between arginine ammonification and CO_2 (Table 1).

The humification index was calculated by the following relationship: $(C_{HA}/C_O)\times100$, according to Orlov (1995). The highest index values were generally observed in NP soil, whereas no-tillage soils showed a higher index than RT soils throughout (Table 2), thus confirming the hypothesis that humification is more intense in the presence of organic residues.

According to Orlov (1995), the value of the C_{HA}/C_{FA} ratio can indicate the type of humus, i.e.: humate (>2.0), humate/fulvate (1.0–2.0), fulvate/humate (0.5–1.0) and fulvate (<0.5). Humate was always present in the NP and NT soils, whereas humate/fulvate was present in the RT soils. This further confirms that humification is favored by the presence of organic residues in soil (Arrigo et al. 2000).

In conclusion, the lower degree of humification and percentage of humic acids found under RT with higher SOM loss indicate that soils under RT are not adequate for ecosystem sustainability, as compared with NT.

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