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Full Length Research Paper

Decomposition rates of plant residues under different land uses

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We evaluated the mode of decomposition in relation to biochemical quality of plant residues and land use. Alfisols under different uses (woodland, grassland and cultivated soils) mixed with alfalfa (*Medicago sativa* L.) and wheat straw (*Triticum aestivum* L.) in doses of 10 t ha^{-1} (dry weight) were incubated in laboratory, in triplicate. CO_2 emitted from soil was measured after 20, 40, 60, and 80 h of incubation, and the amount of released C was calculated (mg C g^{-1} soil). The difference between the amount of C added by the plant residue and C liberated as CO_2, was named residual C. The C loss was greater and residual C retained was lower ($p<0.05$) for Alfisols where alfalfa was applied than for those were wheat straw was added, which was a function of the biochemical composition differences between the alfalfa and wheat straw residues. Regarding the land use, residue C loss was lower ($p<0.05$) in woodland (*Haematoxylon campechianum* and *Bucida buceras*) soils (rates from -0.12 to -1.02 µg g^{-1} /day), and greater in grassland (*Gramineae*) and cultivated soils (*Sorghum vulgare* and *Yucca* sp.) (rates from -0.28 to -1.37 µg g^{-1} /day). We conclude that the C loss, by decomposition, increases in order of woodland > grassland > cultivated soils, and less residual C is retained.

Key words: Organic matter, organic wastes, alfisols, land use, soil respiration.

INTRODUCTION

Organic residues from the agricultural production, in general, appear to be a potential sink for carbon in cultivated soils (Six et al., 1999; Bossuyt et al., 2002; Aziz et al., 2010). There has been considerable research into the effects of organic residues, C/N relation, temperature, humidity, and management on decomposition rates; but there have been relatively few attempts to relate the soil C pool, as a result of management and soil characteri-stics, to decomposition rates in crop residue incorporation systems. Decomposition rates, mostly calculated from the net mineralization of C or N, usually, but not always, show an initial rapid mineralization, after which mineralization becomes much slower (Ajwa and Tabatabai, 1998). Decomposition rates vary with the composition of the organic residues, the experimental conditions, and the nature of the soil (Ajwa et al., 1988; Hadas et al., 2004). Theng et al. (1989) points out that besides the aspects related to soil organic matter (SOM) quality, its decomposition rate may also be modified by the reaction of SOM on the surface of clays, or by physical barriers, such as materials that remain occluded inside the soil aggregates. These results were attributed to the mineral structure of clays, which is known to interact with organic C of the soil, thus protecting it from decomposition. The highest content of soil organic carbon in Mexico, is mainly located at the southeast of the country (States of Campeche, Chiapas, Quintana Roo and Yucatán), which is related to tropical and rainy climate (Segura-Castruita et al., 2005). However, the natural vegetation has been quickly changed by agricultural systems, producing an

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Abbreviations: SOM, Soil organic matter; **CO_2,** carbon dioxide; **MSD,** minimum significant difference; **SOC**, soil organic carbon.

Table 1. Soil classification, vegetation and land use.

Classification (Great group)	Land Use	Vegetation (Scientific name)
Ferrudalf	Woodland	*(Haematoxylon campechianum)*
Ferrudalf	Woodland	*(Bucida buceras)*
Kandiudalf	Grassland	*(Gramineae)*
Kandiudalf	Cultivated soil	*(Yucca sp)*
Kandiudalf	Cultivated soil	*(Sorghum vulgare)*

Table 2. Characterization of alfalfa (*Medicago sativa* L.) and wheat straw (*Triticum astevium* L.) residues.

Organic residue	Organic C (%)	N (%)	C:N	Protein (%)	Fibers* (%)	Hemicellulose (%)	Cellulose (%)	Lignin (%)
Alfalfa	44.68	3.35	13	20.9	27.4	1.7	21.2	4.5
Wheat straw	46.00	0.60	77	3.8	71.1	23.1	39.6	8.4

*Percentage of fibers (hemicelluloses +cellulose + lignin).

ecological negative impact. The fast deforestation is accelerating the lost of fertility of soils (Sivakumar et al., 1992), where Afisols are distributed in a surface of 270,000 ha, in the State of Campeche (Ku et al., 2005). As a result, an understanding of the processes that control SOM dynamics and their response to plant residues management is essential for informed use of agricultural land. As a consequence, the aim of this research was to evaluate the variation of the decomposition by biochemical quality of plant residues in Alfisol soils under different uses.

MATERIALS AND METHODS

We selected six Alfisols from the State of Campeche in Mexico, and samples were collected under different use (woodland, grassland and cultivated soils). Soils were classified (Table 1) according to soil taxonomy (Soil Survey Staff, 2006). From each soil, 10 subsamples were taken from the surface 20 cm, in order to form composite samples. These were dried outdoors in the shade, ground and sieved through a mesh of 2 mm. pH was measured with the potentiometric method, soil/water ratio 1:2, and electrical conductivity, with a conductimeter at a soil/water ratio of 1:5 (v/v). Plant residues used were alfalfa (*Medicago sativa*, C/N = 13) and wheat straw (*Triticum aestivum* L., C/N = 77). Residues were previously dried at 65°C, ground and sieved through a 40 mesh sieve. Amounts of residue applied to soil were equal to 10 t ha^{-1} of dry matter; each treatment was repeated three times. In the plant residues, total N was determined by the semimicro-Kjeldahl method (Bremner, 1965), and organic C by wet digestion with the Walkey and Black method (Nelson and Sommers, 1982). Protein was estimated indirectly from the total N content (AOAC, 1975). Total fiber content (hemicellulose, cellulose and lignin) was determined by the procedure of neutral and acid detergent fiber (Van Soest, 1963). Soils were incubated according to the Isermeyer method, quoted by Alef (1995) modified by Avilés (2000). Samples were incubated under 65% of field capacity at a temperature of 30°C for 80 h. CO_2 emanated from the soils was measured after 20, 40, 60 and 80 h of incubation, and the amount of released C was calculated (mg C g^{-1} soil). The difference between the amount of C added by the plant residue and C liberated as CO_2, was named residual C. This was considered as an indirect measure of the C pool present in each soil. The residual C after incubation was related to each type of plant residue applied to soil. The tendency was described by a lineal function ($y = -bt + a$) where a is the amount of C added in the residue, b is the rate of C loss by decomposition, and y is the residual C. With the values of b determined from linear regression, a statistical means trial test was carried out (Tukey α=0.05) to determine if there were significant residue decomposition effects related to soil use.

RESULTS AND DISCUSSION

Soil pH values ranged from 5 to 8, and electrical conductivity was no higher than 1 dS m^{-1}, so avoiding extreme values of acidity or alkalinity that could affect the decomposition processes. The characterization of residues applied is shown in Table 2. The C/N ratio for alfalfa and wheat straw was 13 and 77, respectively.

In order to analyze the tendency of time of residence of plant residues evaluated for different conditions of land use, rates of residue decomposition were determined by regression of the carbon loss from 0 to 20, 40, 60 and 80 h. The mean coefficient of determination was $r^2 = 0.98$ for the 30 trials. Table 3 shows the rate of residue C loss, coefficient *b*. The more negative is the value of the slope (*b*), the less is the amount of plant residue that remains after time t. There was a significant relation between the rate of plant residue loss and the residue C/N ratio for each condition of land use. Values of residue C loss with the application of alfalfa were -0.81 to -1.37 µg g^{-1} /day, and in contrast those obtained with wheat straw were -0.12 to -0.42 µg g^{-1} /day. The alfalfa residue (C/N = 13) broke down quicker in time, so that C that remained was less compared to wheat straw (C/N = 77). This was ascribed to the biochemical composition of the residues;

Table 3. Rates of carbon loss from added residues by each land use.

Land Use	Vegetation	Residue	C loss rate (value of b = rate) μg g^{-1} /day	MSD
Cultivated soil	*Sorghum vulgare*	Wheat	-0.28a	
		Alfalfa	-1.36b	0.11
Grassland	*Gramineae*	Wheat	-0.42a	
		Alfalfa	-1.34b	0.16
Cultivated soil	*Yucca sp.*	Wheat	-0.37a	
		Alfalfa	-1.37b	0.09
Woodland	*Haematoxylon campechianum*	Wheat	-0.12a	
		Alfalfa	-1.02b	0.19
Woodland	*Bucida buceras*	Wheat	-0.14a	
		Alfalfa	-0.81b	0.14

Mean values with different letters (a and b) in the same pair of rows are statistically different, Tukey (α=0.05). MSD=Minimum significant difference

Table 4. Rates of carbon loss from added residues by biochemical composition.

Plant residue	Land use	Vegetation	C loss rate (value of b = rate) μg g^{-1} /day	MSD
Alfalfa	Woodland	*Haematoxylon campechianum*	-0.81a	
	Woodland	*Bucida buceras*	-1.02b	
	Grassland	*Gramineae*	-1.34c	
	Cultivated soil	*Sorghum vulgare*	-1.36c	
	Cultivated soil	*Yucca sp.*	-1.37c	0.18
Wheat	Woodland	*Haematoxylon campechianum*	-0.12ab	
	Woodland	*Bucida buceras*	-0.14abc	
	Cultivated soil	*Sorghum vulgare*	-0.28bcde	
	Cultivated soil	*Yucca sp.*	-0.37de	
	Grassland	*Gramineae*	-0.42e	0.12

Mean C loss rate values with different letters in the same column, for alfalfa and for wheat trials, are statistically different, Tukey (α = 0.05). MSD = Minimum significant difference.

alfalfa showed a C/N ratio, with more protein content (20.9%) and less fiber content (cellulose + hemicelluloses + lignin = 27.4%), facilitating microbial decomposition (emanated C), thus diminishing residual C more rapidly than wheat straw. Ajwa and Tabatabai (1994) point out that the amount of total mineralized organic C in soils treated with organic material, showed variations as a function of the kind of organic material that had been applied. Ladd et al. (1992) report that release as $C^{14}O_2$ of C^{14} applied to different soils, went from 15 to 27% after an incubation of 3 days, with significant differences among the studied soils. In contrast, the biochemical composition of wheat straw showed a high C/N ratio (77), less protein content (3.8%) and more fiber content (71.1%), limiting the activity of microbial biomass and thus diminishing breakdown and retaining more residual C in the soil.

Kumar and Goh (2000), mention that residues with a high C/N ratio decompose at a slower rate than those with a low C/N proportion. Yousif and Abdalla (2009) have reported that the contents of manure N lignin and cellulose was affecting the initial nitrogen mineralization. Trinsoutrot et al. (2000) have found that the biochemical features may only explain the initial decomposition rate of the residues, because C coming from the residue declines as time goes. In order to evaluate how the organic C pool of the soils was affecting the decomposition of plant residues, the C loss rates from each set of land use trials were compared for the two kinds of plant residue by ANOVA. The variance ratio (F) was significant ($p<0.05$) for both alfalfa and wheat straw trials (Table 4). Results showed that in woodland soils, the daily loss of C was from -0.81 to -1.02 µg g^{-1} with alfalfa and from -0.12 to -0.14 µg g^{-1} with wheat straw. In contrast, in grassland and cultivated soils (*Sorghum vulgare* and *Yucca* sp.) the values were from -1.34 to -1.37 µg g^{-1} with alfalfa and from -0.28 to -0.42 µg g^{-1} with wheat straw. It can be explained in part, because the agricultural management affect soil CO_2 flux by changing the soil environment (e.g. soil moisture, soil temperature, and C/N ratio of substances), which can have a significant impact on soil microbial activity and the decomposition processes that transform plant-derived C to soil organic matter and CO_2 (Franzluebbers et al., 1995).

The application of a same residue to Alfisols under different use (from natural vegetation to intensive cultivation) show clear differences in the availability and recycling of organic matter in the soils, as well as in soil C pool level. Campbell et al. (2005) showed that changes in SOC depend on the degree to which the soil has been degraded: the greater the previous degradation, the greater the likelihood that a change in management will reverse the process.

The daily loss of C in grassland and cultivated soils, give us evidence of level of soil C pool. In agricultural systems, the organic matter and structure can be reduced due to low levels of organic inputs and regular disturbance from tillage practices, (Veenstra, 2007). Janzen et al. (1998) indicated that many of traditional crop cultural practices (that is tillage, fallow, and others) both increase the rate of SOM decomposition, and release of old (relic) soil C into the atmosphere. In this sense, Doran et al. (1998) mentioned that over decades of crop production in the U.S. Corn Belt and Great Plains, organic matter originally contained in these soils was lost through accelerated decomposition and erosion. Thus, appropriate changes in crop management practices such as conservation tillage and reducing or eliminating fallow and increasing the amount of crop residue returned to the soil, SOM content could be increased (Doran et al., 1998; Lal, 2007). In this sense, Lee et al. (2007) have found that approximately 45% of added C with manure application was respired; and a large portion was retained in the soil. The results obtained in this study, give us evidence that the decomposition of C that is added to the soil by means of the plant residues not only depends on the quality of the residue, but also by the land use, which is affecting the organic pool and plays an important role.

Conclusion

The C loss was greater and residual C retained was lower ($p<0.05$) for Alfisols where alfalfa was applied than for those were wheat straw was added, which was a function of the biochemical composition differences between the alfalfa and wheat straw residues. Regarding the land use, residue C loss was lower ($p<0.05$) in woodland (*Haematoxylon campechianum* and *Bucida buceras*) soils (rates from -0.12 to -1.02 µg g^{-1} /day), and greater in grassland (*Gramineae*) and cultivated soils (*Sorghum vulgare* and *Yucca* sp.) (rates from -0.28 to -1.37 µg g^{-1} /day). We conclude that the C loss, by decomposition, increases in order of woodland > grassland > cultivated soils and less residual C is retained.

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