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Decomposition Dynamics of Soybean Residues in Two Soils of Different Fertility

¹Rose Luiza Moraes Tavares and ²Ely Nahas

¹Program of Postgraduate in Soil Science, FCAV/UNESP Jaboticabal, Brazil

²Department of Crop Production, FCAV/UNESP, 14884-900 Jaboticabal, SP, Brazil

*Corresponding Author: E. Nahas, Department of Crop Production, FCAV/UNESP, 14884-900 Jaboticabal, SP, Brazil
Tel: +55 16 3209 2652 Fax: +55 16 3202 4275*

ABSTRACT

The study objective was to evaluate the influence of the addition of soybeans residues on the chemical properties of Eutrudox and Hapludox soils. Soybean leaves and stems were incubated for 0-200 days. The statistical model used was a 5×4 factorial (plant×incubation period) with three replications. Soils without addition of plants were used as controls. Total Organic Carbon (TOC), Soluble Carbon (SC), Total Carbohydrates (TC), Humic Acid (HA), Fulvic Acid (FA) and Humification Rate (HR) were determined. Higher values of chemical attributes (TOC, SC and TC) were found in the Eutrudox soil than in the Hapludox soil and these values increased significantly ($p<0.05$) after 50 days of incubation in relation to the initial period. The TOC, SC and TC increased in soils amended with soybean plants when compared to controls without plants. HA and FA contents and HR were not affected by the addition of soybean residues. Maximum HA contents were found after 100 days and maximum FA contents and HR were found after 200 days incubation in both soils. It can be concluded that the addition of soybean residues increased the soil chemical properties when compared to the controls.

Key words: Fulvic acid, humic acid, humification rate, soluble carbon, total carbohydrates, total organic carbon

INTRODUCTION

Organic residues deposited in the soil decompose and the inorganic nutrients released are used by plants for their nutrition and growth (Zhang *et al.*, 2011). The rate of decomposition and transformation of plant residues from various sources that may occur in nature is linked to the effects of both climate and chemical, physical and biological soil factors (Ussiri and Johnson, 2003; Egli *et al.*, 2007). Different chemical soil attributes may indicate the variation of soil fertility. Parameters based on the determination of soil carbon content are the most commonly used. Attributes such as total organic carbon, soluble carbon and carbohydrates are sensitive indicators of changes in the ecosystems studied (Saviozzi *et al.*, 2001). In addition, humic acid and fulvic acid have been suggested as sensitive indicators of soil organic matter mineralization (Zhang *et al.*, 2011). However, the response to the decomposition of soybean residues added to the soil has not been sufficiently studied.

Kalbitz *et al.* (2000) studied the effect of substrate quality on the dynamics of soluble organic matter degradation. The composition of different fractions of plants can influence the rate of

decomposition and release of plant nutrients (Summerell and Burgess 1988; Greggio *et al.*, 2008). Thus, CO₂ production and nitrogen mineralization of roots added to soil were lower than those of stems and leaves (Yanni *et al.*, 2011).

One of the attributes that govern the decomposition of plant residues is the C/N ratio. The content of HA of various litter plants increased with time and enhanced the C/N ratio, which ranged from 18.2 to 38.4, but the content of FA remained unchanged (Szanser *et al.*, 2011). A trend of increasing HA content from 2.1 to 15.7% of the carbon amount in litter of a *Pinus strobus* forest after one year was determined by Qualls *et al.* (2003).

Moreover, the location of the plant residues on the soil surface or incorporated into the soil influences the process of decomposition and nutrient release. The retention of wheat straw residues on the soil surface retarded the decomposition, but the rate of decomposition was higher when the residues were incorporated in the soil (Summerell and Burgess, 1988).

Brazil is the second world's largest soybean producers (27%, 70.0 million tons) after United States (35%, 90.6 million tons) in 2010 (ASA, 2011). According to Liu *et al.* (2009), a significant amount of residue remains in the soil after soybean crop. But, in traditional soil management, soybean residues are incorporated using ploughing and disking to prepare the land (Kluthcouski *et al.*, 2000). In no-tillage practices, plant residues are maintained on soil surface to reduce soil erosion, conserve organic matter and stimulate microbial activity (Balota *et al.*, 2004). Also, plant residues degraded more slowly than in the traditional system, favoured by higher temperatures and more stable soil carbon reserves (Hungria *et al.*, 2009). Chaer *et al.* (2009) showed that the organic carbon content of soil ranged from 3 to 13% in the A horizon and from 18 to 40% in the O horizon of a forest soil. These results indicate that the organic carbon content can be influenced by the location of residues in soil.

The aim of this study was to evaluate the decomposition of soybean leaf and stem residues placed on the soil surface and at a depth of 0.05 m in two soils (one clayey and the other sandy). The chemical properties were evaluated after incubation of the soils for 0, 50, 100 and 200 days.

MATERIALS AND METHODS

Soils studied: The soils used in the laboratory experiment were a clayey Eutrudox and a sandy Hapludox, with different fertility characteristics (Table 1), both from UNESP/Jaboticabal. The soils were collected in forest (Eutrudox) and agricultural (Hapludox) areas. The forest soil was covered by litter. The agricultural soil had been planted with maize that was being cultivated under the traditional tillage system. After removal of plant litter, the soils were collected from the surface layer

Table 1: Chemical and physical properties of the Eutrudox and Hapludox soils

Properties	Unit	Eutrudox	Hapludox
pH	-	6.1	5.7
Organic matter	%	3.1	1.5
P	mg g ⁻¹	12	52
K ⁺	mmolc g ⁻¹	3.6	1.8
Ca ²⁺	mmolc g ⁻¹	79	24
H ⁺ +Al ³⁺	mmolc g ⁻¹	18	16
Clay	%	43	30
Silt	%	17	4
Sand	%	40	66
Texture	-	Clayey	Sandy

(0-10 cm), transported to the laboratory, air dried for 48 h and sieved through a 2 mm sieve. The plant residues used were from soybean cultivar RR 214 CD. The leaves and stems were separated, dried in an oven at 50°C for 24 h, ground in a mill and sieved through a 2 mm sieve. The compositions of the leaves and stems were 43.6 and 40.2% C, 4.3 and 1.1% N and 10.1 and 26.5 C/N, respectively.

Jars with a capacity of 2000 mL were filled with 180 g of dry soil and a layer of 3.2 g of either leaf or stem soybean residues (equivalent to approximately 36 t ha⁻¹) was placed on the surface or at 0.05 m depth (to simulate buried plants), as follows: (a) Control, no plant, (b) Leaves on the soil surface; (c) Stems on the soil surface; (d) Leaves buried at 0.05 m depth, (e) Stems buried at 0.05 m depth. The soil was moistened to 60% water-filled pore space, capped with an air-tight lid and incubated under natural light. The moisture lost during the experiment was restored weekly.

Jars were incubated for 0, 50, 100 and 200 days. At the end of each period, the soil was removed from each jar with the aid of a spatula. Soil samples from the jars were collected as follows: all soil was collected from the jars without the addition of soybean (control); from the jars with soybean buried or added on the surface, the plant was removed and discarded and the remaining soil was collected. Soil samples were dried at 50°C until constant weight was attained.

Chemical analyses: Total Organic Carbon (TOC) was determined by the dichromate oxidation procedure (Sims and Haby, 1971). Water Soluble Carbon (SC) was determined by the method of Davidson *et al.* (1987) and Total Carbohydrate (TC) by the method of Angers and Mehuys (1989). The carbon content of the humic (HA) and Fulvic Acids (FA) was determined by the method described by Swift (1996), using NaOH 0.1 M as solvent. The Humification Rate (HR) was calculated as the percentage of humified compounds with respect to TOC in the sample as follows (Ciavatta *et al.*, 1990):

$$\text{HR (\%)} = \frac{\text{HA} + \text{FA}}{\text{TOC}} \times 100$$

Statistical analysis: The effects of the leaves and stems were tested using the GLM procedure on SAS software (SAS Institute, 1990). All data were checked for normality and statistical analysis of treatments effects was conducted separately for each soil, using a completely randomized design with a factorial arrangement (5 treatments×4 incubation periods). Where the F-values were significant, the comparison of the treatments and incubation periods was performed using the Tukey test (p<0.05).

RESULTS AND DISCUSSION

The mean content of Total Organic Carbon (TOC) ranged from 4.08 to 8.58 in the Hapludox soil and from 11.22 to 17.86 in the Eutrudox soil (Fig. 1). The influence of plant residues on the soil chemical characteristics has been reported by several authors (Egli *et al.*, 2007; Carvalho *et al.*, 2009; Jien *et al.*, 2011). In this study, we found that the TOC increased significantly (Tukey, p<0.05) due to the addition of soybean leaves and stems in the Hapludox soil in relation to the control without plant residue (Fig. 1b). Only the addition of stems on the surface of Eutrudox soil enhanced TOC in relation to the control (Fig. 1a). Similarly, no significant effect of the application of soybean meal on TOC content compared with the original soil was reported by Chang *et al.* (2008).

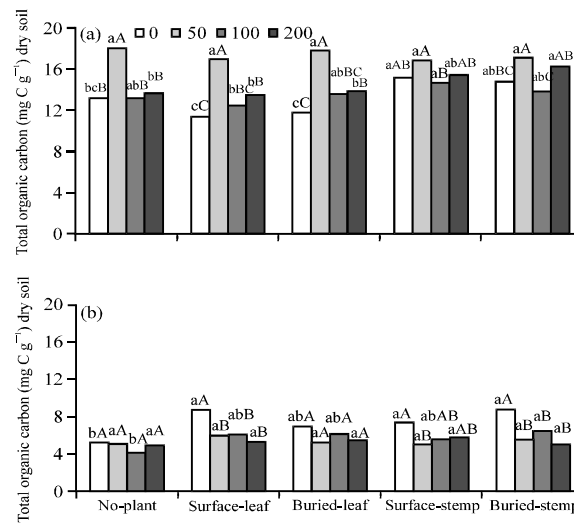


Fig. 1(a-b): Changes with time of the total organic carbon contents of the soils added with soybean leaves and stems placed on the surface or at 0.05 m depth (buried), Bars with the same upper case (soybean treatments in each period) or lower case (incubation period) letters are not significantly different (Tukey test, $p < 0.05$)

TOC content of Eutradox soil decreased significantly ($p < 0.05$), by 23-29% on average, in relation to the initial time of incubation (Fig. 1). However, TOC content of Hapludox soil increased after 50 days' incubation and then decreased. Eutradox soil has higher fertility and twice the TOC content compared to Hapludox soil (Table 1). The Hapludox soil was collected from an agricultural area that was being subjected to management practices that reduce soil organic matter (Balota *et al.*, 2004). A decrease in TOC content was expected due to organic matter mineralization.

Soluble Carbon (SC) content ranged on average from 0.01 to 5.32 mg C g⁻¹ soil (Fig. 2), these values being lower than those observed by Zmora-Nahum *et al.* (2005; 1-28 g kg⁻¹ C) and higher than those observed by Azevedo Melo *et al.* (2008); 20-500 µg kg⁻¹ C). SC content was 18-42% higher in Eutradox and 148-208% in Hapludox than in the controls. This increase in SC content was due to decomposition of the soybean leaves and stems. Also, SC content was increased in both soils by the addition of stems instead of soybean leaves.

It has been shown that SC decreases during the decomposition of plant residues (Guppy *et al.*, 2005). This tendency was observed in this work and it was noted that the SC content initially increased until the 50th day of incubation and then decreased until the 200th day (Fig. 2). In the first stage the enhanced content of SC can be attributed to decomposition of the soil organic matter. During the early stages, SC could have been consumed by the microbial biomass, being used as a carbon source (Azevedo Melo *et al.*, 2008). SC content was lower in Hapludox than in Eutradox soil. As a consequence, SC decreased more rapidly in Hapludox soil.

Water-soluble carbohydrate were studied because produces complex structures that have been proposed as precursors of the humification processes (Sanchez-Monedero *et al.*, 1999). The Total Carbohydrate (TC) content ranged from 509.77 to 1485.38 µg C g⁻¹ soil in the Eutradox soil (Fig. 3a) and from 83.62 to 554.11 µg C g⁻¹ soil in the Hapludox soil (Fig. 3b), corresponding to a 2.6-fold increase. TC amounts were smaller than SC content. Our data agree with those already reported (Tate, 1987). In both soils, the TC amounts increased significantly after 50 days of

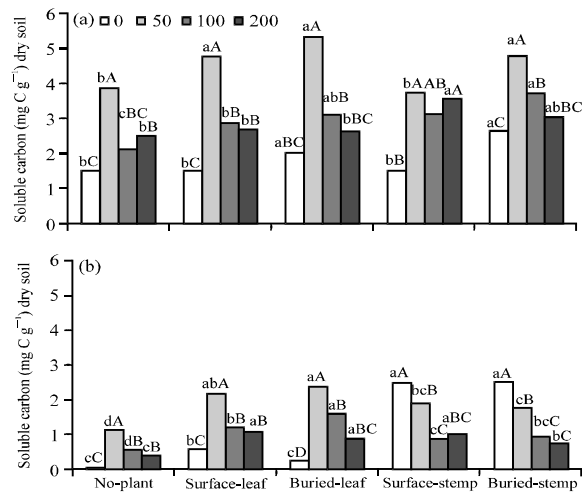


Fig. 2(a-b): Changes with time of the soluble carbon contents of the soils added with soybean leaves and stems placed on the surface or at 0.05 m depth (buried), Bars with the same upper case (soybean treatments in each period) or lower case (incubation period) letters are not significantly different (Tukey test, $p < 0.05$)

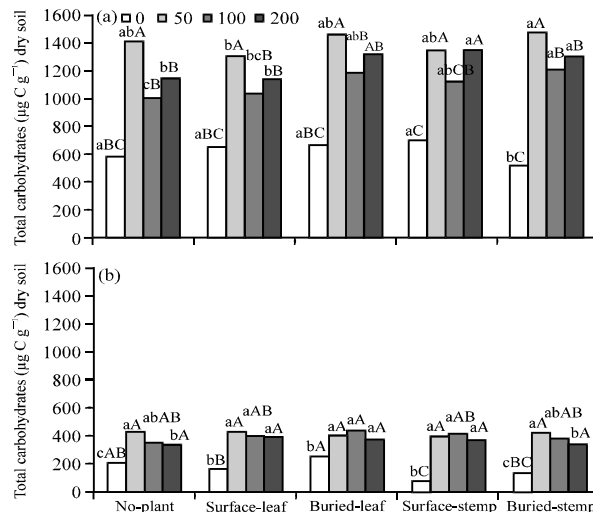


Fig. 3(a-b): Changes with time of the total carbohydrates contents of the soils added with soybean leaves and stems placed on the surface or at 0.05 m depth (buried), Bars with the same upper case (soybean treatments in each period) or lower case (incubation period) letters are not significantly different (Tukey test, $p > 0.05$)

incubation and then decreased. TC contents varied with the decomposition time of soybeans, similarly to the variation in SC contents, as both are groups of organic compounds with greater availability for microbial attack in the soil (Theng *et al.*, 1989). The addition of stems to Eutradox soil increased the TC amount more than addition of leaves did. In contrast, addition of stems to Hapludox soil decreased the TC content more than addition of leaves did.

Humic Acid (HA) content ranged from 0.90 to 2.52 in Eutradox soil and from 0.11 to 1.71 mg C g⁻¹ dry soil in Hapludox soil and there was a mean ratio of 2.5 between the two soils

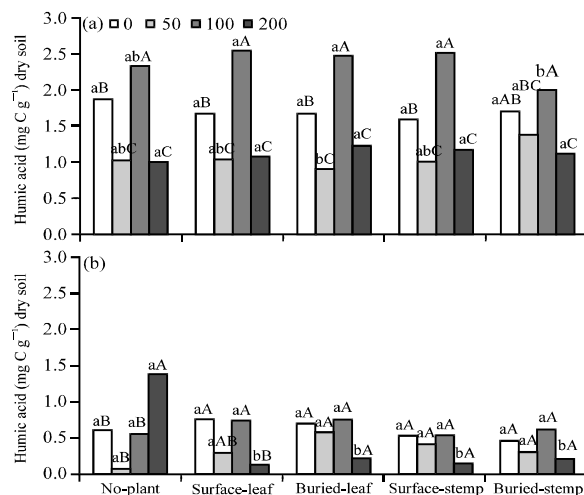


Fig. 4(a-b): Changes with time of the humic acids contents of the soils added with soybean leaves and stems placed on the surface or at 0.05 m depth (buried), Bars with the same upper case (soybean treatments in each period) or lower case (incubation period) letters are not significantly different (Tukey test, $p < 0.05$)

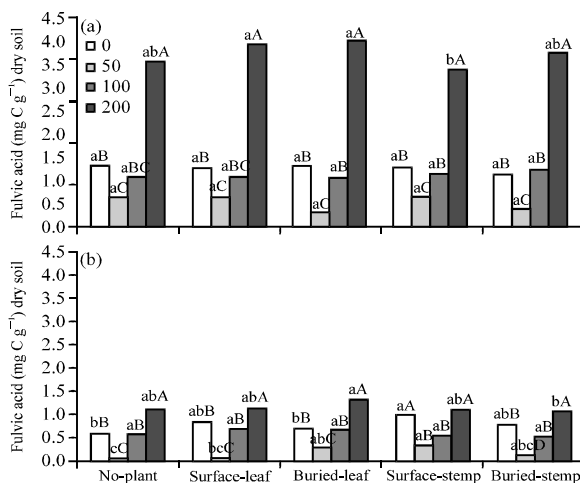


Fig. 5(a-b): Changes with time of the fulvic acids contents of the soils added with soybean leaves and stems placed on the surface or at 0.05 m depth (buried) for 0-200 days, Bars with the same upper case (soybean treatments in each period) or lower case (incubation period) letters are not significantly different (Tukey test, $p < 0.05$)

(Fig. 4). No significant effect of soybean was found on HA content in both soils when compared to the control. The largest HA amounts were found after incubation of both soils for 100 days, after which HA amounts decreased.

In general, variation in the Fulvic Acid (FA) content showed the same tendency as HA in the soils studied. The concentration of FA was 0.33-4.20 in Eutradox soil and 0.04-1.53 mg C g⁻¹ dry soil in Hapludox soil and there was a mean ratio of 2.2 between the two soils (Fig. 5). Similarly, no

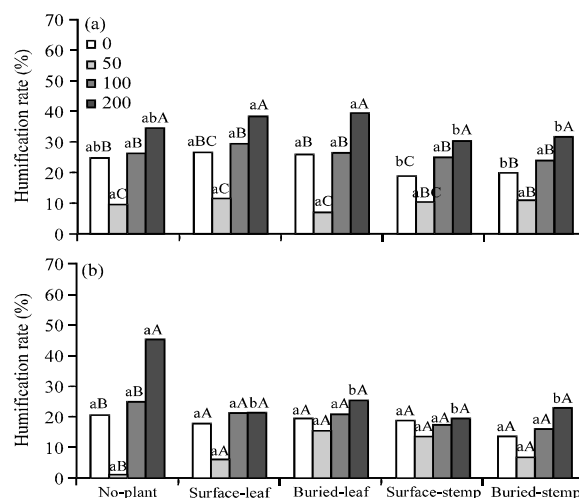


Fig. 6(a-b): Changes with time of the humification rate of the soils added with soybean leaves and stems placed on the surface or at 0.05 m depth (buried) for 0-200 days, Bars with the same upper case (soybean treatments in each period) or lower case (incubation period) letters are not significantly different (Tukey test, $p < 0.05$)

significant effect of soybean on FA was found in the Eutrudox soil when compared to the control. But the FA content of Hapludox soil added with buried leaves or stems on the soil surface was significantly ($p < 0.05$) higher than that of other systems. Also, the largest FA amounts were found in both soils after 100 days, after which they decreased.

The decomposition of organic matter can be evaluated according to the Humification Rate (HR), that is, the increase in HA and FA relative to TOC (Ciavatta *et al.*, 1990). HR ranged from 20 to 40% in Eutrudox soil and from 18 to 60% in Hapludox soil, with the highest rates being obtained after 200 days of decomposition (35-36%) as a result of higher levels of humic substances in relation to TOC (Fig. 6). These results are comparable to the HR reported by Marinari *et al.* (2007) of 23 to 36%. In a study of plant residues decomposition after 135 days of incubation, Jouraiphy *et al.* (2005) established a limit of 28% for HR to distinguish between partially and fully composted materials. In this sense, the HR of soybeans in this study indicates a good level of humification as it was between 20 and 30%. The HR average of the Eutrudox soil amended with leaves was higher than that amended with soybean stems, thus confirming the hypothesis that HR depends on vegetation type (Bonifacio *et al.*, 2008). Although, the HR means were greater in Hapludox soil amended with leaves in comparison to stems, they were not significantly ($p < 0.05$) different. According to Van Kessel *et al.* (2000), the low C/N ratio of soybean meal resulted in a high rate of mineralization and this response was found in the soils amended with soybean leaves in our experiment.

CONCLUSION

In conclusion, the addition of soybean leaves and stems as a source of organic matter in both Eutrudox and Hapludox soils may help to increase the total organic carbon, soluble carbon and total carbohydrate contents during up to 50 days of incubation. As a result, enhancement of the chemical attributes occurs mainly in the Eutrudox soil, which is more fertile than Hapludox soil.

This characteristic leads to a lower humification rate in Eutrudox than in Hapludox. The humic acid and fulvic acid contents vary with duration of soybean decomposition; while the humic acid content was higher after 100 days of incubation, the fulvic acid content was higher after 200 days.

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