Pyrolytical Appraisal of Structural Changes in Soil Organic Matter Resulting from Long-Term Sustainable Practices in a Dryland Farming System

J. Dorado a, J.F. González-Vila b, M.C. Zancada a, G. Almendros a and C. López-Fando a

a Centro de Ciencias Medioambientales, CSIC, Serrano 115B, 28006-Madrid, Spain
b Instituto de Recursos Naturales y Agrobiología, CSIC, P.O. Box: 1052, 41080-Seville, Spain

Introduction

The use of external organic inputs has been extensively encouraged for the sustainable management of fragile Mediterranean soils, particularly subject to severe risks of erosion and desertification. Nevertheless, it is not clear whether these inputs contribute or not to the long-term increase of the humified pool of soil organic matter; or, on the contrary, the stability of the whole agroecosystem depends on the continuous application of external sources of organic matter which are readily biodegraded under the biogeoclimatic conditions of Mediterranean soils. Recent studies on agricultural soils have paid especial attention to analytical features related to quality than to total quantity of soil organic carbon.

In the present research a pyrolytical approach of the long-term effect of organic inputs on mineralized soil organic matter was carried out in an experimental farm where the effect of management practices have been monitored for the last 16 years. The purpose of this study is to: (i) to assess the structural and functional characteristics of humic substances after the historical application of organic inputs; (ii) to compare the use of raw and matured organic amendments in humin quality and quantity; and (iii) to establish quantitative indicators on the extent to which the different experimental plots could actually underwent different humic acid formation mechanisms.

Materials and Methods

The experiment performed in a pyrolytical station “La Herberga” (Central Spain) under a semi-arid continental climate was arranged as a split-plot. The organic amendment was set as the main plot, the N fertilization as the split plot. The treatments included: 0 kg organic input (control); 10 kg ha⁻¹ barley straw per year; and 15 kg ha⁻¹ of rape crop as green manure, every 3 years, and 30 kg ha⁻¹ 17 ha⁻¹-year old feathered maize every 3 years. When inputs were added 156 kg N ha⁻¹ and 32 kg P ha⁻¹ NPK (10-30-10).

The pyrolytical rocks (HMs) from soil samples were analyzed by Curie-Point pyrolisis in a Herbas Instruments unit attached to a Varian Saturn 2000 GC/MS system. The HA samples were treated at 500 °C for 1 h. In order to ensure that the extraction process was not affected by the presence of the inorganic fraction, a HA sample was subjected to 500 °C and then to 300 °C at 20°C min⁻¹ and then to 300 °C at 20°C min⁻¹. The extractions were performed with N2 at 50°C and then to 300°C at 20°C min⁻¹. A 25 µL 0.4 µmol/lactic acid capillary column coated with CPS was used. Reconstructed ion chromatograms were built up from the peak intensity of the major diagnostic ions. Then, pyrolysates from all input and plant tissues were used in total specific provenance to the chromatograms.

Results and Discussion

Substantial changes in the bio-geochemical mechanisms of humic substances have been observed in HAs, the products of organic matter inputs, accumulation patterns based on diagnostic transformation of recalcitrant plant biomacromolecules. The highest yield of pyrolysates was observed in HAs from the plots with N inputs. This fact could be interpreted as the increased performance of the lignin degradation in N-limited media. As in the case of lignicotic inputs (barley straw and rape crop), increases yield of lignin-derived pyrolysates were also observed in plots with plant residue, but the occurrence in the latter case of a diagnostic pattern of aliphatic molecules suggested an incorporation of recalcitrant woody-derived lipids in the humic fraction. The increased yield of aliphatic and fatty acids from the samples collected from the manure-amended plots were significantly more prominent than in the control fertilized soil, what could be interpreted as the expected enhancement of microbial degradation processes of plant-derived aromatic molecules. The relative abundance of alkylphenols was the most representative number to the application of external inputs of N. Systemically, showing increases in values in plots receiving N fertilization, in control plots, or plots receiving the different organic inputs.

In general, the yield of phenols and aliphatic products in the HAs extracted from plots receiving organic inputs were comparatively higher than those from the untreated plots. These changes do not suggest the formation of high-maturity HAs. The increased phenolization transformation mechanisms in the amended soils may be an effect of the biogeochemical constraints on semiarid conditions, where the maturation of the organic matter is limited to a short period when moisture and temperatures conditions are more favorable for the transformation of plant residues. In such situation continuous inputs of plant residues lead to increased levels of soil organic matter made up of slightly transformed lipids.