USE OF ORGANIC RESIDUES IN THE RECOVERY OF ORGANIC MATTER POOLS, AFTER FOREST FIRES

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1 INTRODUTION

In Portugal, as in other Mediterranean countries, fire events are common primarily due to climate and progressive rural abandon, and contribute largely to desertification. Top layers of soil are constituted mostly by organic residues and decomposed organic matter, and are the most sensitive layers to fire damages. Soil organic matter is an important factor on physical, chemical and biological properties of soil. Quantity and duration of heat transfer and soil thermal conductivity, which varies according to soil conditions (humidity, organic matter, texture, etc), are the main responsible factors for the more or less physical, chemical and biological changes in soil after fire (Neary et al,1999). A soil temperature of only forty degrees is enough to initiate biological changes that may begin with plant and roots death caused by dehydration, and protein degradation. Microbial populations have different thermal resistances and most are killed between 50 and 120 ºC. Organic matter (OM) losses may occur at low temperatures, through the volatilization of volatile compounds which may occur between 100º and 180 ºC or OM distillation at 200 to 315 ºC (DeBanno et al, 1998). Under 200 ºC, decomposition of resistant compounds as hemicelullose and lignin starts (Chandler et al, 1983, cit by González-Pérez et al, 2004). At 300 ºC, decarboxylation and loss of Oxigen-containing functional groups (as phenols) occur in the Humic (HA) and Fulvic acids (FA) (Knoepp, 2005). Humin content increases, due to formation of aromatic compounds, because the more soluble fraction, the FA fraction, is transformed into insoluble acids like HA, and this last ones suffer dehydratation and decarboxylation, becoming insoluble – Black Carbon – resembling the Humin fraction (González-Pérez et al, 2004, Tinoco et al, 2006, Hatten and Zabowski, 2009). Above 450 ºC, all OM is loss.

The main purpose of this work was to evaluate the effect of soil heating in forest soils, using a natural burned (B) and an unburned (U) soils and thermally treated soils at different temperatures (65, 105 and 250ºC). Further, we examined the benefic effects of application of organic residues to soils that had been exposed to fire, we added digested pig slurry, municipal solid waste compost and a mixture of both, and evaluated organic matter composition after 2 months of incubation.

2 MATERIAL AND METHODS

Burned soil was collected from the A horizon (0-5cm) of a granite Litosoil in *Serra de Sintra* (38º 45’ 35.37’’ N, 9º 25’ 51.36’’ W), with a sub-humid, and mesothermal climate, 10 days after a natural fire in March 2008. Burned soil was collected after removing the ash, dead leaves and branches at the surface of the soil, and collecting a number of samples representative of the hill. Soil was sampled to perform a composite sample, collected in randomized design. In a contiguous area, samples of soil were taken from an unburned location, after removing vegetation and routs cover. Each soil was sieved with a 2 mm mesh and mixed to obtain homogenized samples. Part of the unburned soil was treated thermally. Unburned soil was placed in trays at 5cm depth, and treated at three different temperatures (65, 105 and 250 ºC for 12 h) in a furnace, to simulate soil heating. Batches of 300 g of each one of the different soils, burned (B), unburned (U) and treated at three different temperatures (65, 150, 250), were placed in plastic containers. Organic residues were mixed with soils, and aerobically incubated for approximately 60 days in the dark, under controlled room temperature (24 ± 2ºC) and at 60% of the maximum water holding capacity of the soils. Water holding capacity was determined prior to starting the incubation studies. The organic residues used were digested pig slurry, municipal solid waste compost (further referred as compost) and a mixture of both (8mL pig slurry/1g compost) (further referred as mixture). The application rate of each one, was equivalent to 170 kg N/ha (ED 91/676/CEE). A control treatment of each soil without organic amendments was also included, and will be referred to as simple soil treatment.

A modified method of weight loss on ignition (LOI) (Ratnayake et al., 2007) and a proximate carbon fractions (PCF) (Ryan et al., 1990) determination were performed. In the former method, soil litter (LT), fulvic (FA)

and humic (HA) fractions were determined sequentially, by weight loss after burning in a muffle furnace at 200, 300 and 500 ºC, during 4 h, where weigh loss after each burning corresponded to the fractions referred above, respectively. In the latter, fats, oils and waxes (Lipids) determination was performed after a non-polar extraction with methylene chloride and ultra-sound, a polar extraction with water for sugars and water-soluble polyphenols (Sugars) and an acid extraction with H_2SO_4 for primarily cellulose. Lignin was determined by ashing. The lost on ignition method was performed to all soil/residue combination in the beginning and end of the incubation period, and Proximate Carbon fraction was performed in soils and residues separately, in the beginning, and to soil/residues combinations, in the end of the experiment.

Data was analyzed statistically by a two-way ANOVA, using LSD test.

3 RESULTS AND DISCUSSION

When no residues were applied, in the naturally burned soil (B) the organic matter content was higher than in the other soils, and this was related to the content in the litter (LT), fulvic acids (FA) and humic acids (HA) fractions. This may have occurred due to the incorporation of organic residues, as dead plants and decomposed burned litter, after fire (Chandler et al, 1983, cit by González-Pérez et al, 2004). The FA fraction was the one that increased most due to burning, in average FA in burned soils was 5% higher than in unburned soils. LT fraction in B soil was 1.7 % greater and Ha fraction only 1.3 % (data not shown). In the 250 soil, a decrease in LT and FA fractions was observed both at the beginning and at the end of the incubation, comparing to the original soil (U) while the HA fraction did not reveal significant differences. After this, we could say that the maximum temperature applied at laboratory heating (250 ºC) was sufficient to decrease the most thermolabile fractions (Litter and Fulvic Acids), but not enough to decrease the HA, which is more heat resistant.

For B soil, the effect of the application of residues varied according to the OM fraction in question. In the litter fraction, the application of organic residues had positive effects, increasing this fraction content, more significantly in the digested pig slurry treatment at the beginning and at the end of the incubation period, and in the compost only at the beginning. The FA fraction was significantly higher when compost was added to the soils rather than after addition of other residues, at the end of the incubation period, although it wasn't significantly different from the simple soil without amendments. The HA fraction was clearly lower in treatments with mixture than with compost at the beginning, and simple soil at the end of the incubation.

Litter fraction significantly increased with mixture application compared to simple soil treated at 105ºC at day 0. For FA fraction after 60 days, there was a significant increase with compost use, when compared to plain, in the 105ºC soil. In the other soils, no differences were observed, in all fractions. In soils where no residues were added, the following results were found after Proximate Carbon Fraction. For B soil, at the beginning of the incubation, the content of lipid and sugar fractions were low (< 1.3 %) compared to other fractions, primary cellulose and lignin (> 8 %)

Except for B and 105 soils, there was a significant increase in lipid fraction after 2 months of incubation. In the beginning of the incubation, lipids content increased slightly with temperature to which the soil had been subjected, except for higher temperature (250 ºC), which was not significantly different from the U soil. After 60 days, the initial temperature treatment promoted an increased of the level of lipids in the 65 ºC treated soil, similar to B soil. The sugar fractions content of B and 250 soils were similar, revealing an increase of sugar fraction in soil burned at 250 ºC, in the beginning of the incubation. After 60 days, significant differences were seen in 250 and 65 treated soils sugar fractions, which decreased significantly. 250 soil cellulose value was significantly lower than the others, showing thermal decomposition of cellulose, due to temperature treatment before incubation, and related also with sugar increase in the same soil. Cellulose values in the beginning and end of the incubation were similar for all soils, except for B soil, which decreased after 60 days. Incubation period had no significant differences in the lignin fraction, although values of B soil where higher than others.

At the end of the incubation, there were no significant differences between soil with and without organic amendments in the B soil. In the B soil addition of pig slurry increased the cellulose content in absolute values (Figure 1). In the U soil, the compost produced a decrease in the lipids content, and compost and mixture treatments also increased sugar fraction, while pig slurry increased slightly the cellulose content. In the 65 soil, organic residues application produced significant decreases in lipids fractions and significant increases in sugar fraction content (Figure 1). Content of lipids in unburned soil, and 105 soil with compost and mixture amendments, were not significantly different amongst them, although the compost promoted a significantly higher lipids content than pig

slurry applications. Sugar and cellulose content were similar, while lignin values in 105 simple soil, compost and pig slurry application were identical between them, mixture being the lower value (Figure 1).

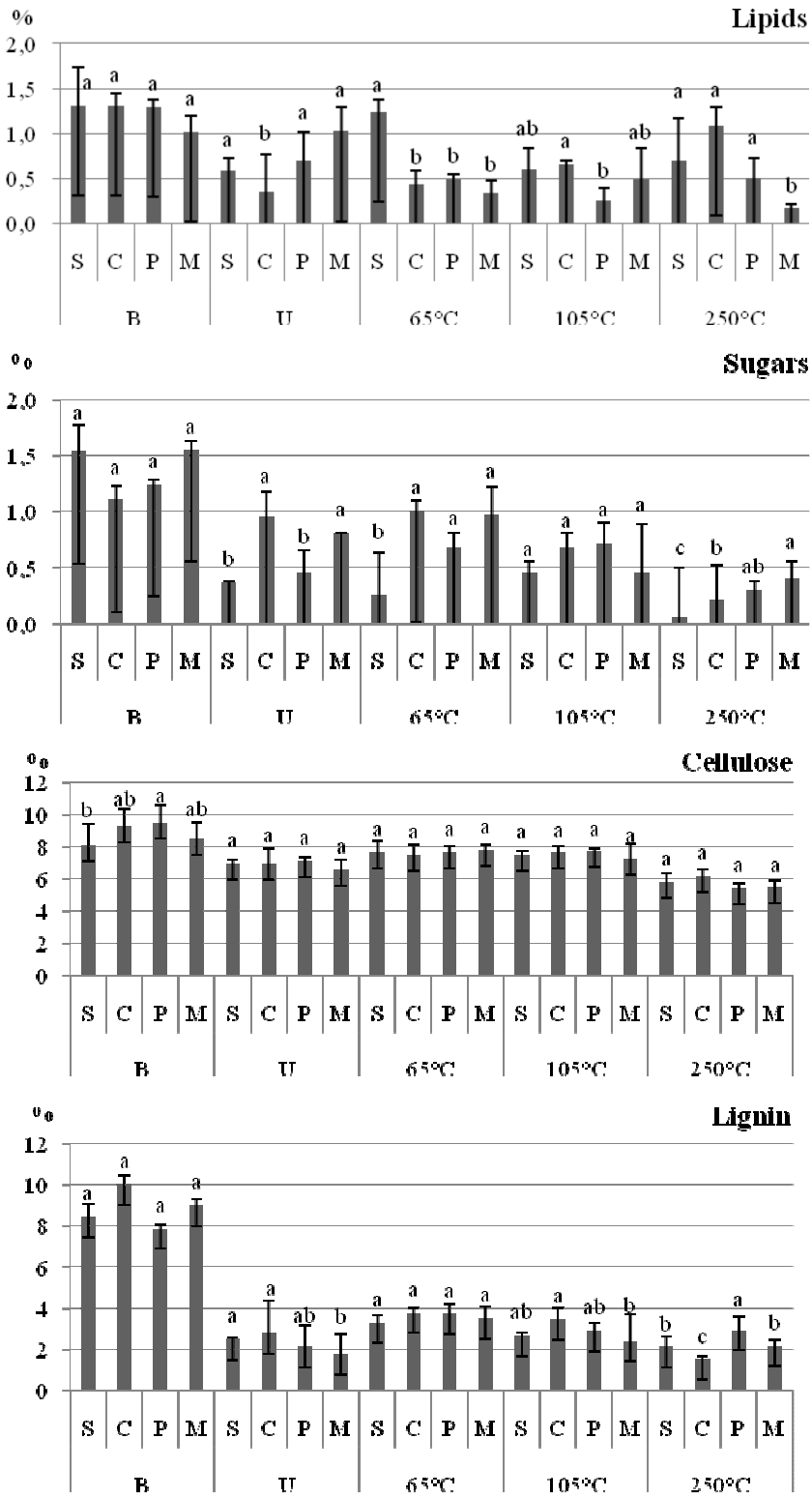

FIGURE 1 **Proximate Carbon Fraction of different soil with and without organic residues application (S – without residues, C – municipal solid waste compost, P – digested pig slurry, M – mixture)**

Application of mixture to the 250 soil, produced decreases in lipid fraction content compared to other residues applications and to control. For the sugar fraction, all residues application had positive effects comparing to plain soil, mostly mixture. Cellulose content did not suffer alteration when residues were applied, and lignin increased with pig slurry application, and was reduced beneath control level with compost application. This was opposite to the fact that compost has a higher content of recalcitrant compounds.

4 CONCLUSION

Natural burned soil had higher contents of all the organic matter pools, probably due to the incorporation of dead biomass during fire. Increased burning temperature was only enough to alter the more thermolabile fractions (Litter and FA). The pig slurry application seemed to increase the litter fraction of burned soil, while compost increased a more resistant fraction, the FA fraction, in 105 soil. There were no significant differences in other combinations soil-residue.

Laboratory burning of the natural soil increased lipid and sugar fractions and decreased the cellulose fraction, while lignin remained stable. In B and U soil pig slurry increased the cellulose content, while compost increase lipid and sugar fraction, in the U soil.

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