THE UNIVERSITY OF ADELAIDE

Effect of Clay on Plant Residue Decomposition

by

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Declaration

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Summary

Plant residues added to soil are a source of nutrients for plants and soil organisms and increase soil organic matter which has an important role in improving soil structure and fertility, hence maintaining soil quality for sustainable agriculture. In order to utilize plant residues for increasing soil organic matter more effectively, it is necessary to understand the mechanisms of plant residue decomposition. Soil organic matter decomposition is influenced by several factors such as plant residue quality, temperature, water availability, soil structure and soil texture, particularly clay content. The interaction of clay and decomposition of organic matter has been studied in the past. Nevertheless, many studies investigated this interaction in natural soil or under field conditions over long periods of time. Variation in environmental factors may influence the interaction of clay and decomposition of organic matter, thus in most previous studies their effect cannot be separated from the direct effect of clay on decomposition. To study the direct effect of clay on organic matter decomposition, four experiments with different objectives were carried out using isolated natural clay, under controlled conditions (e.g. temperature and organic matter input) and a short incubation period (approximately one month).

All experiments were carried out using a sand matrix to which different clay types, clay fractions (natural or with iron oxide partially removed) or clay concentrations were added together with mature wheat straw (C/N 122 in most experiments, except Experiment 2 where the wheat straw had a C/N of 18) and a microbial inoculum. To investigate the effect of clay type, two clay types were added. They were isolated from Wiesenboden (W) and Red Brown Earth (RBE) soil. Clay types from both soils contained kaolinite and illite, but smectite only occurred in W clay. Iron oxide is thought to be important for the binding of organic

matter to clay, therefore two clay fractions were used, the clay with native iron oxide (natural clay) and clay from which iron oxide was partially removed by citrate-dithionite-bicarbonate treatment (citrate-dithionite clay, CD clay). The following parameters were measured: pH, water loss, respiration rate, microbial community structure using phospholipid fatty acid analysis and, in some experiments, particulate organic matter. In all experiments, the water content of the substrate mixes was adjusted only at the start; water loss was greatest in the control and decreased with increasing clay content.

The aim of the first experiment was to study the effect of the concentration of W clay on decomposition of wheat residues. Respiration (i.e. decomposition of the wheat straw) was affected by clay in two ways (i) decreased decomposition, thus protection of organic matter, in the initial phase at all concentrations (5, 10, 20 and 40%) and throughout the incubation period at ≤ 20% clay, and (ii) greater water retention at higher clay concentration particularly 40% clay that allowed maintenance of higher respiration rates towards the end of incubation. Generally, clay concentration had an effect on microbial community structure but not on microbial biomass.

The effect of clay concentration was also investigated in the second experiment, but using RBE clay and a narrower range of concentrations (0, 2.5, 5, 10 and 20 % clay) than in the first experiment with W clay. The wheat residue used in this experiment had a lower C/N ratio compared to the other three experiments (C/N 18 compared to 122). In contrast to the first experiment, cumulative respiration of the clay treatments was greater than that of control throughout the incubation, thus clay increased rather than decreased decomposition. This may be due to the properties of the wheat residue used in this experiment which contained more water-soluble compounds, the diffusion of which would be enhanced in treatments with clay compared to the control due to their higher water availability. However, considering only the treatments with added clay, cumulative respiration followed the same pattern as in the first experiment, with highest cumulative respiration at 20% clay. In general, microbial community structure, microbial biomass and microbial groups (i.e. bacterial and fungal fatty acids) were affected by the presence of clay and sampling time, but there was no clear relationship between these factors and the richness and diversity of the microbial community.

The aim of the third experiment was to determine the effect of clay concentration (5 and 40% of W clay) and fraction (natural or citrate-dithionite clay) on decomposition of wheat straw and microbial community structure. Clay fraction and concentration strongly affected the respiration rate and microbial community structure as well as microbial biomass but not the concentration of particulate organic matter (POM). Compared to the control, partial removal of iron oxide strongly increased decomposition at both concentrations whereas clay with iron oxides reduced the decomposition. Microbial community structure was affected by clay fractions, particularly at 40% clay.

The aim of the fourth experiment was to determine the effect of clay fraction (natural and citrate-dithionite clay) and clay type (W clay or RBE clay) at 5% clay on decomposition of wheat straw and microbial community structure. Clay type and the partial removal of iron oxide had a significant effect on the decomposition rate but did not affect POM concentration. As in the third experiment, partial removal of iron oxide increased respiration rate, the effect was less pronounced in RBE clay than in W clay. Clay type and fraction strongly affected microbial community structure.

In conclusion, the experiments showed that native clay generally reduces organic matter decomposition by binding and occlusion. The importance of iron oxide for the protective effect of clay on organic matter decomposition was shown by the fact that partial removal of iron oxide strongly increased decomposition rate compared to the native clay. The two clay types differed in their effect. The W clay containing smectite protects organic matter to a greater extent than RBE clay with predominantly illite and kaolinite due to its higher surface area and CEC that lead to binding and or occlusion. The results also showed that although clay reduces organic matter decomposition under optimal water availability, this effect can be reversed as the substrates dry out because the greater water retention of substrates with clay concentrations > 10% compared to the pure sand matrix allows maintenance of a greater microbial activity. Clay type, fraction and concentration affected microbial community structure via their effect on organic matter and water availability.