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Microbial utilization of low molecular weight organics in soil depends on the substances properties

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Utilization of low molecular weight organic substances (LMWOS) in soil is regulated by microbial uptake from solution and following incorporation of into specific cell cycles. Various chemical properties of LMWOS, namely oxidation state, number of carbon (C) atoms, number of carboxylic (-COOH) groups, can affect their uptake from soil solution and further microbial utilization. The aim of the study was to trace the initial fate (including the uptake from soil solution and utilization by microorganisms) of three main classes of LMWOS, having contrast properties - sugars, carboxylic and amino acids.

Top 10 cm of mineral soil were collected under Silver birch stands within the Bangor DIVERSE experiment, UK. Soil solution was extracted by centrifugation at 4000 rpm during 15 min. Soil was spiked with ^{14}C glucose or fructose; malic, succinic or formic acids; alanine or glycine. No additional non-labeled LMWOS were added. ^{14}C was traced in the dissolved organic matter (DOM), CO_2, cytosol and soil organic matter (SOM) during one day. To estimate half-life times ($T_{1/2}$)of LMWOS in soil solution and in SOM pools, the single and double first order kinetic equations were fitted to the uptake and mineralization dynamics, respectively.

The LMWOS $T_{1/2}$ in DOM pool varied between 0.6-5 min, with the highest $T_{1/2}$ for sugars (3.7 min) and the lowest for carboxylic acids (0.6-1.4 min). Thus, initial uptake of LMWOS is not a limiting step of microbial utilization. The $T_{1/2}$ of carboxylic and amino acids in DOM were closely related with oxidation state, showing that reduced substances remain in soil solution longer, than oxidized.

The initial $T_{1/2}$ of LMWOS in SOM ranged between 30-80 min, with the longest $T_{1/2}$ for amino acids (50-80 min) and the shortest for carboxylic acids (30-48 min). These $T_{1/2}$ values were in one-two orders of magnitude higher than LMWOS $T_{1/2}$ in soil solution, pointing that LMWOS mineralization occur with a delay after the uptake. Absence of correlations between LMWOS $T_{1/2}$ in SOM with C oxidation state, number of C atoms or number of -COOH groups in LMWOS demonstrates that intercellular metabolic pathways are more important.

Mineralization of LMWOS amounted for 20-90% of total applied amount. Maximum mineralization was found for carboxylic acids and minimum for sugars, whereas ^{14}C incorporation into cytosol and SOM pools followed the opposite trend. There were close positive correlation between the portion of mineralized C and substance oxidation state, but negative with the amount of C incorporated into the cytosol and SOM pools. This shows that substance properties affect the final partitioning of LMWOS-C between mineralized and utilized pools.

Thus, initial uptake of LMWOS from soil solution and final partitioning of LMWOS-C between the mineralized and microbially utilized pools are related to their chemical properties. In contrast, LMWOS mineralization dynamics is regulated by intercellular metabolization pathways.