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Sugars in soil: Review of sources, contents, fate and functions

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Sugars are the most abundant organic compounds in the biosphere because they are monomers of all polysaccharides. We summarized the results of the last 40 years on sources, content and fate of sugars in soil and discussed their main functions in soil. We especially focused on uptake and utilization of sugars by microorganisms as this is by far the dominating process of sugars transformation in soil.

Two databases have been created and analyzed. The 1^{st} database was focused on the contents of cellulose, non-cellulose, hot water and cold water extractable sugars in soils (348 data from 32 studies). This database was also used to determine the primary (plant derived) and secondary (microbially and soil organic matter (SOM) derived) sources of carbohydrates in soil. The galactose+mannose/arabinose+xylose (GM/AX) ratio was calculated to analyze the origin of sugars in soil. The 2^{nd} database was focused on the fate of sugar C in soil (734 data pairs from 32 studies), and only the papers used ^{13}C or ^{14}C labelled sugars were included. All data to the fate were analyzed and presented in dynamics. This allowed to calculate: 1) maximal rate of glucose-C decomposition, 2) mean residence time (MRT) of C of the initially applied sugars, 3) MRT of glucose-C incorporated into microbial biomass (MB) and SOM pools.

Content of hexoses was 3-4 times higher than that of pentoses for both cellulose and non-cellulose sugars, because hexoses have two sources in soil: plants and microorganisms. The GM/AX ratio revealed higher contribution of hexoses in forest (ratio was 1.5) than in cropland and grassland soils (ratio was 0.7-1), reflecting high input of hexoses with forest litter.

The MRT of sugars in soil solution was much less than 30 minutes. Based on the experiments with ^{13}C or ^{14}C labelled glucose, the maximal rate of glucose C decomposition in microbial biomass was $\approx 1\%$ min^{-1}. Considering this rate, the glucose input from plants and content of sugar C in soil, we estimated that only about 20% of all sugars in soil originate from the primary source – decomposition of plant biomass and root exudation. The remaining 80% originated from the secondary source – from microbial recycling.

Estimated MRT of sugar C in MB was about 230 days, showing intense and efficient recycling of sugars in microorganisms. In contrast, MRT of sugar C in SOM was about 360 days, reflecting essential accumulation of sugar C in dead MB.

Thus, very fast uptake of sugars by microorganisms as well as intensive microbial recycling clearly shows the importance of sugars for microbes in soil. Based on the assessed MRT we conclude that real contribution of sugar C (not only whole sugar molecules, which are usually determined) in SOM is much higher than commonly measured 10-15%.