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How does litter become soil organic matter? Tracing the fate of needle- and root-derived soil organic matter through 10 years of decomposition

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All soil organic matter (SOM) is derived from plant material. However, little is known about the process by which plant litter becomes SOM (as opposed to the better-studied controls on rates of carbon (C) and nitrogen (N) loss from litter). We investigated the transformations of above- and below-ground plant inputs in soil over ten years, and whether litter type (roots versus needles) affects the form and location of litter-derived C and N in soil after 10 years. We placed 15N and 13C-labeled Pinus ponderosa needle and fine root litter in the Blodgett Experimental Forest in the Sierra Nevada foothills in 2001. A two-way factorial design was used with needle and root litter placed into O and A soil horizons. Litter was inserted into the given horizon within soil mesocosms (10.2 cm diameter x 24 cm long PVC) that had two 5 x 5 cm mesh windows to allow contact with the surrounding soil. After 0.5, 1, 1.5, 4.5, and 10 years, the mesocosms were collected from the field. Isotopes were used to measure the percent recovery of the litter C and N in the bulk soil of the O and A horizons. To investigate mineral associations of the added litter C and N after 10 years, we sequentially fractionated the soils by density. The fractions were a free light fraction (<1.75 g cm-3), a fraction dominated by secondary phyllosilicate minerals (1.75-2.5 g cm-3), a quartz and feldspar-dominated fraction (2.5-2.78 g cm-3), and a fraction dominated by biotite with kaolinite and iron oxide coatings (>2.78 g cm-3). These fractions differ in the type of organic matter they are associated with according to C:N ratios and molecular characterization via FTIR. The biotite fraction had the lowest C:N ratios, indicating it was the most microbially-processed. After 10 years, more root litter C (about 44%) was retained in the soil than needle litter C (about 28%). In line with slower rates of decomposition, root C and N remained in the particulate (>2 mm) fraction and the free light fraction longer than needle C. However, there were similar amounts of root and needle C and N in the mineral-associated pools with 12-17% of the remaining C associated with secondary phyllosilicates and less than 1% associated with biotite. C:N ratios of the litter-derived OM were much lower in the mineral fractions than in the free light fraction. In conclusion, litter type affects how long organic matter is retained in soils by affecting the earlier stages of decomposition when microbes are utilizing substrates that are part of larger OM particles, but litter type does not appear to affect later stages of decomposition, when microbially-processed OM becomes associated with minerals.