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Potential changes in arctic seasonality and plant communities may impact tundra soil chemistry and carbon dynamics

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On the Svalbard archipelago, as in other high Arctic regions, tundra soil organic matter (SOM) is primarily plant detritus that is largely stabilized by cold, moist conditions and low nitrogen availability. However, the resistance of SOM to decomposition is also influenced by the quality of organic matter inputs to soil. Different plant communities are likely to give different qualities to SOM, especially where lignin-rich woody species encroach into otherwise graminoid and bryophyte-dominated regions. Arctic woody plant species are particularly sensitive to changes in temperature, snow cover, and growing season length. In a changing environment, litter chemistry may emerge as an important control on tundra SOM stabilization. In summer 2007, we collected plant material and soil from the highly-organic upper horizon (appx. 0-5 cm) and the mineral-dominated lower horizon (appx. 5-10cm) from four locations in the southwest facing valleys of Svalbard, Norway. The central goal of the ongoing experiment is to determine whether a greater abundance of woody plants could provide a negative feedback to warming impacts on the carbon (C) balance of Arctic soils. Towards this, we used a combination of plant biopolymer analyses (cupric oxide oxidation and quantification of lignin-derived phenols and cutin/suberin-derived aliphatics) and radiocarbon-based estimates of C longevity and mean residence time (MRT) to characterize potential links between plant type and soil C pools.

We found that graminoid species regenerate above- and belowground tissue each year, whereas woody species (Cassiope tetragona and Dryas octopetala) regenerated only leaves yearly. In contrast, C within live branches and roots persisted for 15-18 yr on average. Leaves from woody species remained nearly intact in surface litter for up to 20 yr without being incorporated into the upper soil horizon. Leaves from both graminoid and woody species were concentrated in lignin-derived phenols relative to roots, but were dominated by cinnamyl-lignin forms that are easily degraded and thus not likely to persist as SOM. In contrast, roots and branches were comprised of more decay-resistant vanillyl and syringyl forms of lignin-derived phenols. Leaves of woody species were 10 times more concentrated in cutin/suberin-derived aliphatics than roots (which could provide a direct source of potentially stabilized C into the mineral soil). In the upper soil horizon, the MRT of isolated roots and organic debris was about 50 yr and the 'resistant' C (i.e., C resistant to digestion in 6N HCl acid) was about 500 yr. In the lower soil horizon, the MRT of the 'resistant' C was about 3500 yr, indicating that long-term C storage occurs in the near-surface layers of Arctic soil where environmental changes are likely to have a strong impact. Observed warming in high latitudes is most pronounced over land and a series of positive feedbacks between climate and net primary productivity are developing. Litter input quality may provide a rare negative feedback within this system and whether these feedbacks will ultimately result in SOM accumulation or losses due to increases in decomposition of older, stabilized C is unknown.