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Carbon flux from plants to soil microbes is highly sensitive to nitrogen addition and biochar amendment

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The release of carbon through plant roots to the soil has been recognized as a governing factor for soil microbial community composition and decomposition processes, constituting an important control for ecosystem biogeochemical cycles. Moreover, there is increasing awareness that the flux of recently assimilated carbon from plants to the soil may regulate ecosystem response to environmental change, as the rate of the plant-soil carbon transfer will likely be affected by increased plant C assimilation caused by increasing atmospheric CO_2 levels. What has received less attention so far is how sensitive the plant-soil C transfer would be to possible regulations coming from belowground, such as soil N addition or microbial community changes resulting from anthropogenic inputs such as biochar amendments.

In this study we investigated the size, rate and sensitivity of the transfer of recently assimilated plant C through the root-soil-mycorrhiza-microbial continuum. Wheat plants associated with arbuscular mycorrhizal fungi were grown in split-boxes which were filled either with soil or a soil-biochar mixture. Each split-box consisted of two compartments separated by a membrane which was penetrable for mycorrhizal hyphae but not for roots. Wheat plants were only grown in one compartment while the other compartment served as an extended soil volume which was only accessible by mycorrhizal hyphae associated with the plant roots. After plants were grown for four weeks we used a double-labeling approach with ^{13}C and ^{15}N in order to investigate interactions between C and N flows in the plant-soil-microorganism system. Plants were subjected to an enriched $^{13}CO_2$ atmosphere for 8 hours during which $^{15}NH_4$ was added to a subset of split-boxes to either the root-containing or the root-free compartment. Both, ^{13}C and ^{15}N fluxes through the plant-soil continuum were monitored over 24 hours by stable isotope methods (^{13}C phospho-lipid fatty acids by GC-IRMS, $^{15}N/^{13}C$ in bulk plant material, microbial biomass and dissolved organic matter by IRMS, ^{13}C and ^{15}N in plant roots cells and intraradical mycorrhizal hyphae by NanoSims).

Our results show that (1) C assimilated by plants was delivered within 4 hours to the soil microbial community both via roots and the mycorrhizal network (2) N addition during the labeling period strongly and rapidly increased the ^{13}C flux of recently assimilated carbohydrates to the soil microbial biomass (3) the effect of N addition was not as rapid but was of the same magnitude when N was delivered to the plant exclusively by mycorrhizal hyphae as compared to taken up by roots (4) soils which had been amended with biochar (which were characterized by an increased abundance of mycorrhizal fungi) also showed a significant increase of C flux from plants to the soil.

We conclude that plant belowground C allocation is highly sensitive to alterations of microbial community structure and nutritional status in the soil. Moreover, our results indicate that plants respond rapidly (within hours) to changing soil N availability by altering the rate of C transported belowground. Our results emphasise the ecological significance of plant-belowground interactions for ecosystem C cycling.