Investigating Mechanisms of Soil Carbon Accrual and Protection in Bioenergy Cropping Systems

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Project Goals: The goals of this study were to understand mechanisms controlling the protection and accrual of soil carbon in bioenergy cropping systems. Specifically, we aimed to characterize differences in potential for soil C contributions versus loss as CO_2 of different plant residue types. We use controlled, laboratory soil incubation experiments to quantify the respiration from decomposition of soil organic matter and plant residues. Additionally, we quantify the importance of physical versus chemical (bioaccessibility) protection of soil organic carbon in soil aggregates of various size fractions from bioenergy cropping systems. These data will help us better understand which bioenergy systems and soils are best suited for promoting soil C accrual with the ultimate goal of creating C neutral or C negative systems.

Perennial bioenergy cropping systems offer the potential to accrue soil carbon, potentially making them a carbon-neutral energy source. We seek to understand patterns of soil carbon accrual using a series of laboratory incubations to characterize soil carbon dynamics in bioenergy cropping systems. In our first incubation, we characterized differences in soil respiration for soils amended with plant tissue residues. We used soils from a Conservation Reserve Program (CRP) field that has been dominated by the C3 grass smooth brome (*Bromus inermis*) and residues from C4 grass bioenergy crops, corn (*Zea mays*) and switchgrass (*Panicum virgatum*). The soil organic matter has a $\delta^{13}C$ signature reflective of the C3 grass of -27‰, while the corn and switchgrass residues have a $\delta^{13}C$ signature of -13‰. This isotopic difference allows us to differentiate between the C respired during decomposition of soil organic matter and that respired from decomposition of the residues. We added 0.45 g of either corn or switchgrass roots, shoots, or roots and shoots to 30 g of CRP soil. We assessed respiration rates for 39 days, and found that across both species, residue addition of any kind stimulated total respiration compared to control soils with no residues additions. Total C respired from soils and residues was highest in soils plus shoots; 32% greater than soil plus root and 17% greater than soil plus roots and shoots. Across all treatments, residue additions increased peptidase activity and decreased chitinase activity. Isotope analyses indicated that across all treatments residues were the primary source of C respired, and addition of residues suppressed respiration from soil organic carbon, relative to soil only controls. In our second incubation, we characterized the physical and chemical protection of soil carbon using soils collected from large-scale experimental fields that have been in corn, switchgrass or maintained as CRP land for the past 9 years. We partitioned 100 g of soil from these fields into three aggregate size fractions (<0.5 mm, 0.5-2 mm, >2 mm). We initiated a soil incubation with aggregates from these different size classes, using crushed and un-crushed aggregates to assess physical protection, while chemical protection was assessed via addition of glucose. Glucose provides a very accessible high-energy C source that would potentially prime soil bacteria to break down less energetically favorable (chemically protected) SOC. After 109 days of incubation, we see no consistent effect of crushing aggregates on soil respiration rates, indicating that physical protection of C in these systems may not be an important mechanism for C accrual. During the first 109 days of the incubation we’ve added glucose twice. Overall, glucose addition did increase respiration rates, but this effect was inconsistent across crop species and aggregate sizes. Within the aggregates from corn, glucose addition increased soil respiration rates in the <0.5 mm and >2 mm aggregates, but not the 0.5-2 mm aggregates. There was no effect of glucose addition on any aggregate sizes from both switchgrass and CRP fields. These incubations have thus far revealed that patterns of soil C protection and accrual are affected by plant residue inputs and additions of glucose, a common root exudate, but these effects are highly dependent on the crop type. A better understanding these patterns of soil C dynamics is necessary to achieve the potential of making bioenergy crops a carbon-neutral energy source.

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