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Evaluating the effectiveness of mulch application to store carbon belowground: Short-term effects of mulch application on soluble soil and microbial C and N in agricultural soils with low and high organic matter

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Agricultural soils have the potential to contain a large pool of carbon and, depending on the farming techniques applied, can either effectively store carbon belowground, or further release carbon, in the form of CO_2, into the atmosphere. Farming techniques, such as mulch application, are frequently proposed to increase carbon content belowground and improve soil quality and can be used in efforts to reduce greenhouse gas levels, such as in the "4 per 1000" Initiative. To test the effectiveness of mulch application to store carbon belowground in the short term and improve soil nutrient quality, we maintained agricultural soils with low and high organic carbon content (disturbed top soil from local Cambisols and Chernozems) in greenhouse mesocosms (70 cm deep with a radius of 25 cm) with controlled moisture for 4 years. Over the 4 years, maize and soybean were grown yearly in rotation and mulch was removed or applied to soils once plant material was harvested at 2 ton/ha dry matter. In addition, soil disturbance was kept to a minimum, with only surface disturbance of a few centimeters to keep soil free from weeds. After 4 years, we measured effects of mulch application on soluble soil and microbial carbon and nitrogen in the mesocosms and compared effects of mulch application versus no mulch on soils from 0-5 cm and 5-15 cm with low and high organic matter. We predicted that mulch would increase soil carbon and nitrogen content and mulch application would have a greater effect on soils with low organic matter than soils with high organic matter.

In soils with low organic carbon content and larger predicted potential to increase soil carbon, mulch application did not increase soluble soil or microbial carbon or nitrogen compared to the treatments without mulch application. However, mulch application significantly increased the δ13C of both microbial and soluble soil carbon in these soils by 1 ‰ each, indicating a shift in belowground processes, such as increased decomposition coupled with increased carbon inputs. In soils with more organic content and lower potential to increase soil carbon, mulch application decreased microbial carbon by 0.01 mg C g soil-1 and increased soluble soil nitrogen by 0.01 mg N g soil-1. Soluble soil carbon also decreased by 0.04 mg C g soil-1 and microbial nitrogen increased with mulch application by 0.006 mg N g soil-1, but only in 5-15 cm soil. Mulch application only decreased δ13C of soluble soil carbon by 1.5 ‰ likely indicating a decrease in decomposition. Contrary to our initial predictions, mulch did not increase soil carbon content and only increased nitrogen content in soils that already had relatively higher organic matter content. These results suggest that mulch application (with only soil surface disturbance) may not play a significant role in increasing soil carbon content and overall soil quality, at least in a short 4-year term.