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Changes in Soil Microbiology Under Conventional and No-Till Production During Crop Rotation

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Abstract

Soil microbial activity is important for crop production. Soil microbes are involved in nutrient and water cycling within the soil, and interact with crop plants to provide the basic nutrient and water resources needed for crop production. Claypan soils have unique physical characteristics that impact soil biology. This study explored the temporal changes in soil microbiology in a claypan soil under conventional and no-till production during a crop rotation of corn/winter wheat/soybean/fallow commonly planted in southeast Kansas. We found soil microbial activity changed more in the top two inches of soil than in the lower soil layers. Wheat resulted in higher soil microbial activity and biomass than corn. Soybeans had a more stable microbial activity in the soil than either corn or wheat. The no-till plots had greater microbial biomass and activity than conventionally tilled systems, and the temporal changes in soil microbial properties were more apparent in no-till plots. These results offer an interesting insight into the soil biological properties that impact soil health for crop production.

Keywords

soil microbiology, soil health, crop production, temporal change

Cover Page Footnote

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Summary
Soil microbial activity is important for crop production. Soil microbes are involved in nutrient and water cycling within the soil, and interact with crop plants to provide the basic nutrient and water resources needed for crop production. Claypan soils have unique physical characteristics that impact soil biology. This study explored the temporal changes in soil microbiology in a claypan soil under conventional and no-till production during a crop rotation of corn/winter wheat/soybean/fallow commonly planted in southeast Kansas. We found soil microbial activity changed more in the top two inches of soil than in the lower soil layers. Wheat resulted in higher soil microbial activity and biomass than corn. Soybeans had a more stable microbial activity in the soil than either corn or wheat. The no-till plots had greater microbial biomass and activity than conventionally tilled systems, and the temporal changes in soil microbial properties were more apparent in no-till plots. These results offer an interesting insight into the soil biological properties that impact soil health for crop production.

Introduction
Soil is the foundation on which our world depends, one of the major components in ecology, and the link between air and water. Soils are rich ecosystems. Soil microbes decompose organic matter, allowing growth of plants, animals, insects, and microbes. Microbial communities can respond to environmental changes more rapidly than plant communities. Therefore, soil microbial properties can potentially indicate how well the soil microenvironment supports growth and hence the productive capacity of the soil.

Enzymes in the soil have specific activities and can be used as indicators of soil quality. Hydrolases are enzymes that break particular chemical bonds, decomposing material in the soil such as plant biomass and residue. Beta-glucosidase (bG) is a hydrolase involved in the degradation of cellulose, a component of plant residue. The activity of bG is an indication of the carbon cycling within the soil. Similarly, acid phosphatase (AP) is a hydrolase involved in phosphorus cycling, releasing inorganic P from soil organic matter into forms that are available to plants. N-acetyl glucosaminidase (NAG) cleaves the amino sugar from chitin and is involved in nitrogen cycling within the soil. These enzyme activities are essential for organic matter decomposition and nutrient cycling.

Soil microbial activity is determined by the bacterial and fungal components of the soil. The microbial components and community structure can be determined using the phospholipid fatty acid (PLFA) analysis that detects relative components of microbial cell walls. The microbial biomass and fungal to bacterial ratios are also indicative of soil quality. Microbial biomass is the measure of the mass of living microorganisms in soil. Both fungi and bacteria degrade plant residues, but fungi are generally more efficient at assimilating and storing nutrients than bacteria. Fungi are also more sensitive to changes in the soil environment due to management practices. In general, soils with greater fertility have greater soil microbial biomass. The fungal population will increase faster than that of bacteria in fertile soil, leading to a higher fungal to bacterial ratio.

While soil microbial properties are important in soil function, most studies of soil microbial properties have primarily focused on the spatial variability. The temporal variability in soil microbial properties, especially the influence of various crops on soil biological components, is poorly characterized. This study examined changes in key soil quality indicators as a function of time in a corn/winter wheat/soybean/fallow rotation sequence in claypan soil and across different tillage practices.

Experimental Procedures

The research was conducted at the Southeast Research and Extension Center research fields near Columbus, KS. The fields are Parsons silt loam soil. The fields have been in a crop rotation of corn/winter wheat/soybeans for more than five years. Tilled plots were tilled using a chisel and disk prior to planting corn, and disk harrow after harvesting corn and prior to planting wheat. No-till was used prior to planting soybeans in both tilled and no-till plots.

Soil samples were taken every other month for two years using a 1-in. soil corer. Soil samples were taken at 0- 2-in. depth, dried and ground. Standard sample analysis was performed to determine the content of water and carbon (Hsiao et al., 2018). Soil nutrient analysis was performed at the Kansas State University Soil Testing Laboratory. Only total carbon is reported here. Soil enzyme activities were measured using standard protocols (Hsiao et al., 2018). Soil microbial biomass was estimated using phospholipid fatty acid analysis (Hsiao et al., 2018), and was used to determine the amount of fungi and bacteria in the soil.

Results and Discussion

Soil water content was higher in no-till (NT) than conventional tillage (CT) after corn harvest and during wheat growth (Figure 1A). Soil water content decreased after corn flowering, increased after corn harvest and remained constant during the wheat growing period. The low water content after corn flowering resulted from two potential reasons: the higher water consumption during corn growth and lower precipitation. Soil water content was highest during the winter, and decreased in summer.

Active carbon tended to be higher under NT than CT management (Figure 1B). Temporal patterns in both CT and NT soils followed similar trajectories, indicating a consistent influence of crop stage on soil microbial properties. Active carbon increased in the winter in both wheat production and fallow compared to the summer growth in both corn and soybeans in both NT and CT soils (Figure 1B). The greater proportion of labile C substrates during wheat growth and winter fallow may be a consequence of the buildup of crop residue from the preceding crop, senescent roots, and wheat root exudates. The higher active C also led to greater soil extracellular enzyme activities and microbial biomass (Figures 2 and 3A).

Enzyme activities (Figure 2) and microbial biomass (Figure 3A) increased during the winter wheat production period, and tended to be higher in NT than in CT management. The temporal pattern showed a decline in activity during corn growth, a rapid and substantial increase during wheat production, nearly level activity or declining activity during soybean production, followed by an increase during the winter fallow period (Figure 2A, 3A). This temporal pattern was most apparent in bG and microbial biomass. While the overall pattern was similar in AP and NAG, it was not nearly as robust. The pattern was also more pronounced in NT than in CT management. In our study, soybean production was followed by a fallow period prior to planting corn. Soybean produces only one-third of the amount of residue that is produced by corn, resulting in lower soil organic matter and enzyme production after soybean harvest compared to after corn harvest. Soybean residue decomposes rapidly in soils due to low lignin content and C:N ratio. Therefore, soybean residue input could have increased microbial biomass as well as bG and NAG activities during the fallow period after soybean harvest as the soybean residue rapidly broke down.

The fungal to bacterial ratios were higher in winter and lower in summer (Figure 3B), probably because fungi are the major decomposer of plant residues and biomass in the topsoil.

These results demonstrate the temporal changes during the crop growing season and the impact of management practices on soil microbial properties. Most of the changes in soil microbial properties occur in the very top 0–2 in. of soil, irrespective of tillage management. No-till production has greater microbial biomass and activity than conventional tilled systems. Incorporating wheat in the crop rotation may provide additional soil C inputs and further improve microbial properties. Changes in management practices and crop rotation systems can have profound impacts on the health of the soil, and hence on its productive capacity.

Acknowledgment

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References

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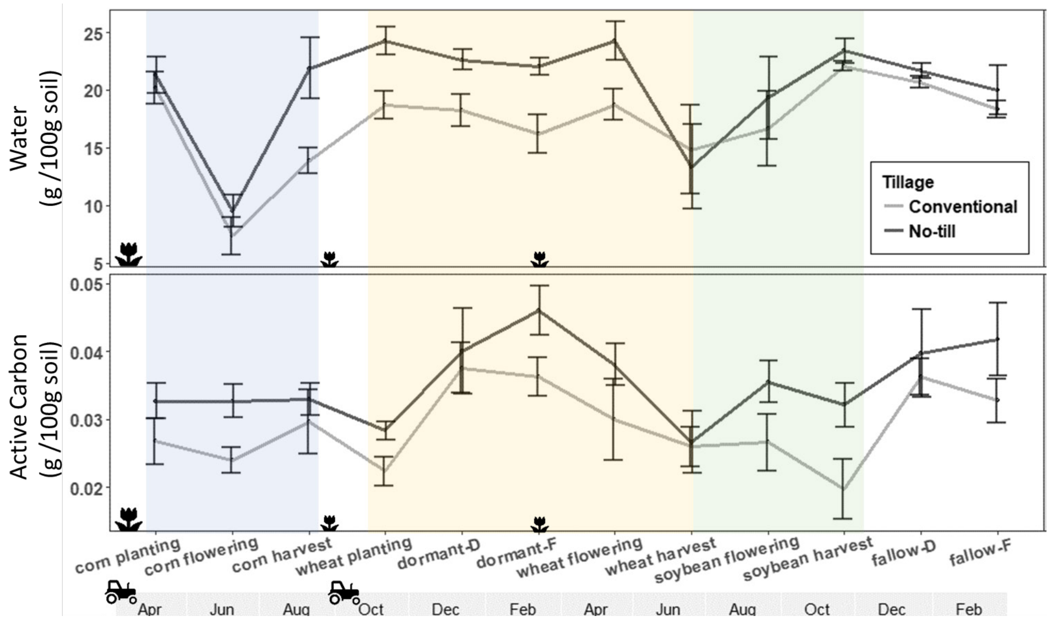

Figure 1. Temporal changes in soil water and active carbon for conventional tillage and no-till during the crop development stages. Dormant-D, wheat dormant stage in December; dormant-F, wheat dormant stage in February; fallow-D, fallow in December; fallow-F, fallow in February. Crop sequence is corn/wheat/soybean/fallow in two years. Crop stages are indicated by shaded areas: corn (blue), wheat (yellow), soybean (green), and fallow (white). Flowers ( ) indicate mineral fertilizer application; tractors ( ) indicate tillage event. Results are given as the average of all replications with standard error.

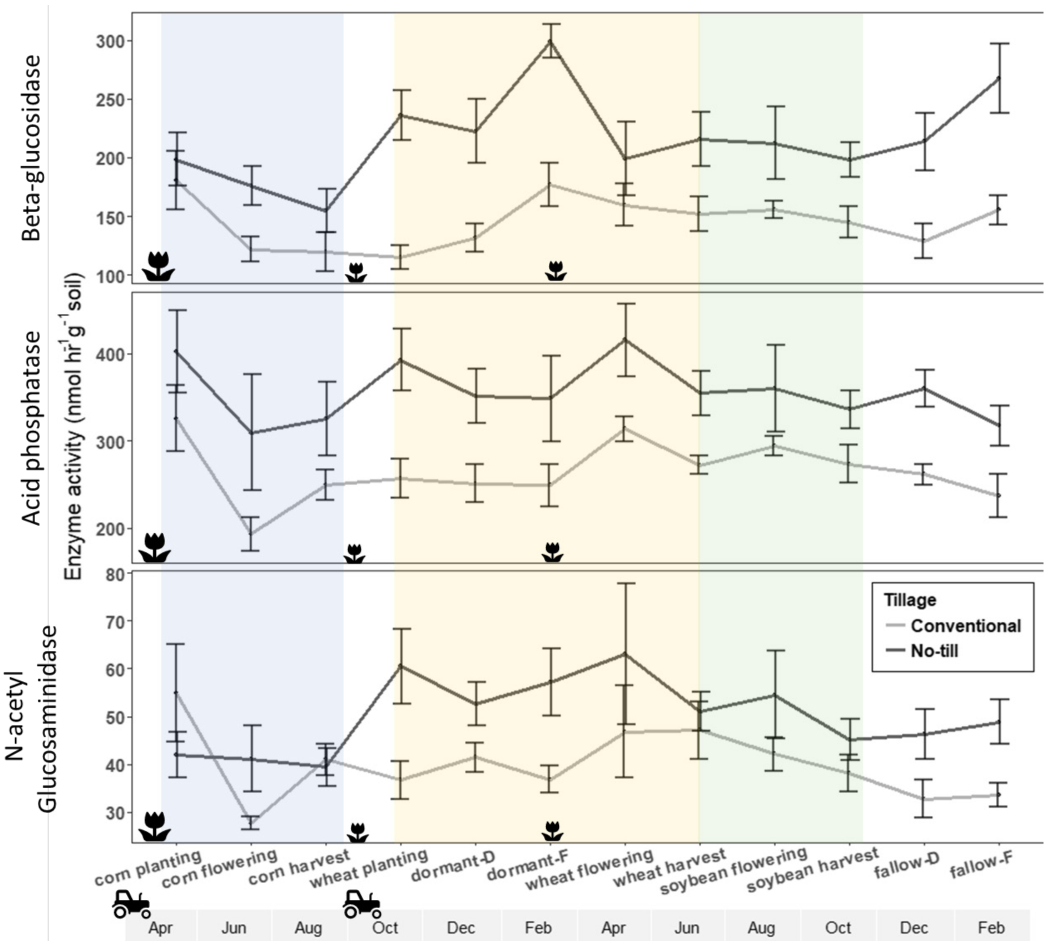

Figure 2. Temporal changes in soil enzyme activities for conventional tillage and no-till during the crop development stages. Dormant-D, wheat dormant stage in December; dormant-F, wheat dormant stage in February; fallow-D, fallow in December; fallow-F, fallow in February. Crop sequence is corn/wheat/soybean/fallow in two years. Crop stages are indicated by shaded areas: corn (blue), wheat (yellow), soybean (green), and fallow (white). Flowers ( ) indicate mineral fertilizer application; tractors ( ) indicate tillage event. Results are given as the average of all replications with standard error.

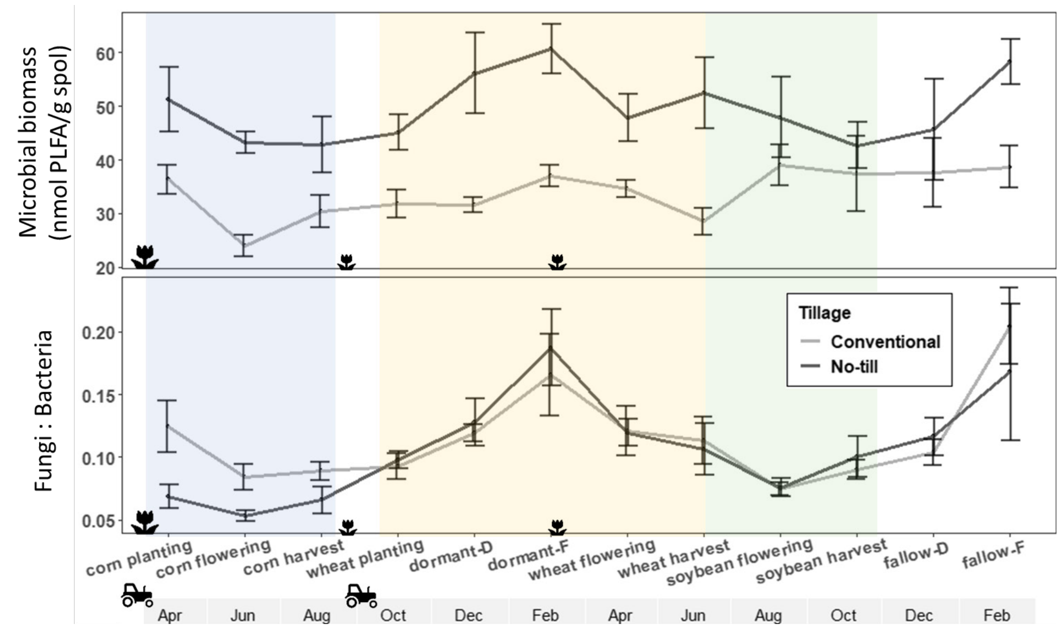

Figure 3. Temporal changes in microbial biomass and the ratio of fungi to bacteria for conventional tillage and no-till during the crop development stages. Dormant-D, wheat dormant stage in December; dormant-F, wheat dormant stage in February; fallow-D, fallow in December; fallow-F, fallow in February. Crop sequence is corn/wheat/soybean/fallow in two years. Crop stages are indicated by shaded areas: corn (blue), wheat (yellow), soybean (green), and fallow (white). Flowers (🌷) indicate mineral fertilizer application; tractors (🚜) indicate tillage event. Results are given as the average of all replications with standard error.