Manipulation of soil microbes using higher biomass cropping systems to sustain soil health in cotton-based agroecosystems

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Abstract

The semiarid Texas High Plains produces ~30% of U.S. cotton (*Gossypium hirsutum* L.). Agricultural production, however, is experiencing a transition from irrigated to dryland crop production due to reductions in water availability from the Ogallala aquifer. Additional challenges are imposed by extreme droughts, heat waves and increased dust storms due to climate change. Most soils are sandy and have been under continuous cotton since the 1940s, contributing to low organic matter (<1% OM) and fertility/water holding capacity and thus, increasing wind erosion. Thus, incorporating practices to improve soil health will be essential to sustaining production in this water limited region under this new reality. Sorghum (*Sorghum bicolor* L. Moench) genetic diversity results in stress tolerant features to heat and drought conditions that makes it more adaptable to this region. We conducted a two-phase study on a representative sandy loam soil (16.4% clay, 67.6% sand, 0.65 g kg^{-1} OM) with Phase I (2003-2007) focused on evaluating improvements in soil health from incorporation of up to three times more residue than cotton (Ctn) using forage sorghum (referred as haygrazer; Hay), grain sorghum (Srg) and/or rye as a winter cover crop in different systems (Hay-Rye, Ctn-Rye-Srg, Srg-Ctn) and reference samples were taken from continuous cotton (Cont. Ctn). Improvements in soil health (0-5cm) were evaluated according to: total C&N, microbial biomass C&N, fatty acid profiling of microbial community composition, and enzyme activities (EAs) of C (β-glucosidase, α-galactosidase), C&N (β-glucosaminidase), P (alkaline phosphatase, phosphodiesesterase) and S (arylsulfatase) biogeochemical cycling. After Phase I, several soil properties were greater under Hay-Rye than the other systems (Hay-Rye>Srg-Ctn=Ctn-Rye-Srg) and the same was found for all systems compared to Cont. Ctn. Phase II (2008-2010) involved increasing the frequency of cotton (i.e., at least two out of three years) in all systems to test how long the increases in soil health would be maintained. In 2008, all plots were planted in cotton and higher cotton yields (73-137%) occurred in Hay-Rye, which also showed higher total C&N (10-14%), microbial biomass C&N (10-26%) and EAs (15-97%) compared to Srg-Ctn=Ctn-Rye-Srg. Cotton yields were positively correlated to soil properties across all samples. A year of rotation crops during 2009 was followed by the second year of all cotton in 2010, but no differences were found in yields probably due to the higher precipitation that fell during this year compared to other years. At the end of phase II, the geometric mean of all EAs significantly decreased for Hay-Rye by 32% with the incorporation of cotton into the cropping systems demonstrating negative impacts on soil health. However, there were still higher total C&N (10%), microbial biomass (20-45%) and EAs (33-83%) under Hay-Rye (except phosphodiesterase activity) than the other systems. This study provides evidence that improving soil health is an essential part of sustainable cropping systems to combat the negative effects of climate change in semiarid regions.