Proceedings of the Organic Agriculture Research Symposium
LaCrosse, WI February 25-26, 2015

Soil Health Improvement in an Organic Orchard Production System in Northwest Missouri

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Abstract

Prairie Birthday Farm (PBF), a diversified, organic enterprise on the loess hill landscape in northwestern Missouri, was previously managed as a conventional corn-soybean production system. Transition to organic farming began in 1995 and included soil organic matter restoration with native prairie establishment and organic amendments. Assessment of soil health was initiated in 2003 to monitor organic management impacts on soil productivity. The purpose of the PBF orchard study was to evaluate ecologically-based practices of integrating native plants and organic amendments into the orchard on biological indicators of soil health. Ecologically-based management restored and improved soil health on degraded landscapes. Soil organic C (SOC) gradually increased by 25% to > 60 g kg^{-1} over six years compared with relatively stable SOC contents of about 30 g kg^{-1} during the same period at control sites. Soil aggregate stability increased by 70% in orchard alleys, reflecting contributions of established root systems of native vegetation and high SOC. Soil enzyme activities increased by ≥30% in alley and organically-amended sites, demonstrating substrate contributions from vigorous roots and systematic amendments with organic materials that enhanced soil microbial activity. Microbial community structure and biomass determined by phospholipid fatty acid analysis was similar in compost amended- soils and alley sites under either native vegetation or tall fescue (non-treated orchard). Microbial diversity improved slightly, however, improved functional diversity (soil enzyme activity, aggregate stability) suggests that microbial assemblages within organically managed soils were more effective in mediating biological processes to achieve improved soil health than in non-organically managed sites.

Introduction

Prairie Birthday Farm (PBF) is a diversified, organic, ecologically-based farm established on gently sloping soils predominated by Sharpsburg silt loam (Typic Argiudolls) in northwest Missouri. The deep loess soils at this site were degraded by erosion and soil organic matter (SOM) depletion under previous conventional cropping systems of rotational corn and soybean. Transition to organic farming began in 1995 with a strategy to restore SOM through organic amendments of composts, mulches, and biochar and establishment of a reconstructed, native prairie ecosystem. An orchard including a variety of heirloom fruit trees was established with native prairie plants established in the alleys. The success of the organic management system in optimizing soil productivity and improving soil properties has been monitored through annual soil health assessments since 2003 (Hezel and Kremer 2008, Kremer and Hezel 2013). Soil health considers soil as a vital living system that functions under natural or managed conditions to sustain biological productivity and diversity, promote plant and animal productivity, and maintain environmental quality and ecosystem stability (Doran and Zeiss 2000, van Bruggen et al. 2000, Karlen et al. 1997). For ecological agricultural systems, soil health indicators including soil aggregate stability, soil organic C and total N, and enzyme activities reliably detect responses after transition to and establishment of ecologically based management practices (Dick et al. 1996). Thus, a better understanding of overall microbial activity and C dynamics in these agroecosystems will contribute to estimates of environmental and economic benefits, and aid policy and management decisions for these systems (Delate 2002).

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Our objective is to evaluate ecologically-based practices of integrating native plants and organic amendments (composts, biochar) into an orchard production system on biological indicators of soil health. Our hypothesis was that the soil health of previously intensively tilled cropland can be improved using ecologically based practices of organic amendments and integration of perennial vegetation.

Materials and Methods

The soil (Sharpsburg silt loam; fine, montmorillonitic, mesic Typic Argiudolls) is mapped as an 'eroded soil phase' due to erosion under previous management that resulted in shallow topsoil depth of ≤5 cm on shoulder to 20 cm on summit landscape positions.

Soil samples (10-cm [4-in] depth) were collected annually from PBF sites:
Non-treated orchard (NT Orch)**,** trees maintained with minimal organic amendment; soil collected within tree dripline area; Non-treated alley (NT Alley), inter-row space of fescue grass vegetation managed by periodic mowing; Organic Orchard (Org Orch)**,** trees under organic management with composts, mulches within dripline area, where soils were collected; Organic Alley (Org Alley)**,** inter-row space established with native prairie plant species, which was subjected to annual burns; Organic + Biochar (Org +BC)**,** portion of organic orchard (dripline area to alley interface) amended with locally-sourced biochar at 17 kg m^{-2} (3.5 lbs ft^{-2}); Reconstructed Prairie (Rest Prairie), area established with native prairie plants in 1993 (Hezel & Kremer, 2008) with backslope, matching orchard landscape, sampled in triplicate; Grass, permanent cool-season grass and forb pasture adjacent to orchard; Conventionally Cultivated Field (CC), planted to rotational corn and soybean under minimum tillage and synthetic fertilizer and pesticide inputs.

Selected soil health indicators measured on all samples included:
Plant nutrients and organic C (SOM) and N as relative indicators of substrate reserves in support of soil biological activity and plant growth; Water-stable aggregates, indicator of soil structure stability for water and air movement and plant root development; Biological assays comprised assays for activity of the soil enzymes dehydrogenase (general soil microbial activity), β-glucosidase (representative C-cycling activity during decomposition), β-glucosaminidase (representative N-cycling [N mineralization] enzyme); and phospholipid fatty acid (PLFA) analysis), which indicates soil microbial biomass and individual groups representing soil microbial community structure. Descriptions of enzyme assays are presented in Kremer and Hezel (2013); details of the PLFA analysis are found in Veum et al. (2014). Because this was an on-farm experiment, blocks for sampling were established within each production system. Data were analyzed assuming a completely randomized design with eight production systems and five sample years with three replications (blocks). Analysis of variance was conducted to test differences between production systems and year of sampling. Fisher's protected least significant difference (LSD) was calculated to find differences for each measured parameter with significance considered at $\alpha = 0.05$

Results and discussion

Soil organic matter increased under ecologically-based management. Soil C (representative of SOM) and total soil N increased during the 5-year period by ≈ 25% to >6.0% in organic orchard sites compared with relatively stable SOC of about 30 g kg^{-1} during the same period at control sites (data not presented). Soil structure (aggregate stability) increased under native perennial vegetation. Soil aggregate stability increased by 70% in orchard alleys, reflecting contributions of established root systems of native vegetation and high SOC (Figure 1).

Annual increases in aggregate stability in all sites managed with native prairie species suggest soils stored increased C and N inputs from perennial root systems. However, all sites were considerably higher than the conventional row-cropped site. Overall soil microbial activity, indicated by hydrogenase, and nutrient cycling improved under native perennial vegetation. Soil enzyme activities followed similar annual patterns for each treatment therefore data for only glucosaminidase is presented (Figure 2) that shows N cycling increased under sites managed with native prairie species (and compost and biochar) suggesting improved nutrient availability for plants due to increased soil microbial activity. Soil microbial community structure improved under native perennial vegetation.

Soil microbial biomass (Figure 3) was highest in the organic orchard as were selected microbial groups (Figure 4). Gram-negative bacteria were increased in all organic treatments including the reconstructed prairie suggesting that functions provided by this group including plant growth promotion, pathogen suppression, and nutrient cycling were enhanced. Mycorrhizae (VAM) were also more abundant in organic treatments indicating improvement in nutrient (N, P, K) mobilization and water availability for plants associated with these symbiotic fungi. Biochar amendment increased major microbial groups (gram-negative and –positive bacteria, total fungi, mycorrhizae) and microbial biomass compared with other treatments (Figure 4). Our results are similar to previous reports on promotion of microbial biomass, diversity, and activity by biochar combined with or without compost amendment to soils Bamminger et al. 2014).

Conclusions

The soil microbial community within ecologically managed systems at PBF are more effective in mediating biological processes to achieve soil health and impact fruit production in an orchard integrating native perennial plants relative to non-organically managed sites. Soil health assessment conducted showed how an ecologically based farming system integrating perennial vegetation with orchard production can be an effective management system for optimizing horticultural crop production while promoting soil conservation. The soil health indicators were sensitive in detecting soil-property changes as a result of ecologically based management, and allowed interpretation related to the consequences of altered ecosystem processes. Results of this long-term study have important implications for understanding how ecologically based management practices can enhance soil biological and biochemical processes, to improve overall soil health and promote the production of horticultural crops without synthetic chemical inputs, and improve environmental quality. Farmers might readily adapt similar strategies to those described for the PBF system to improve soil health and crop productivity in other ecologically based enterprises.

References:

Bamminger, C., N. Zaiser, P. Zinsser, M. Lamers, C. Kammann, and S. Marhan. 2014. Effects of biochar, earthworms, and litter addition on soil microbial activity and abundance in a temperate agricultural soil. *Biology & Fertility of Soils* 50:1189-1200.

Delate, K. 2002. Using an agroecological approach to farming systems research. *HortTechnology* 12:345–354.

Dick, R.P., D.P Breakwell, and R.F. Turco. 1996. "Soil Enzyme Activities and Biodiversity Measurements as Integrative Microbiological Indicators." In *Methods of Assessing Soil Quality*. ed. J.W. Doran and A.J. Jones, 247–271.Madison, WI: Soil Science Society of America.

Doran, J.W. and M.R. Zeiss. 2000. Soil health and sustainability: managing the biotic component of soil quality. *Applied Soil Ecology* 15:3–11.

Hezel, L.F. and R.J. Kremer. 2008. Healing and building soil on Prairie Birthday Farm. *Missouri Prairie Journal* 29(3):14-20.

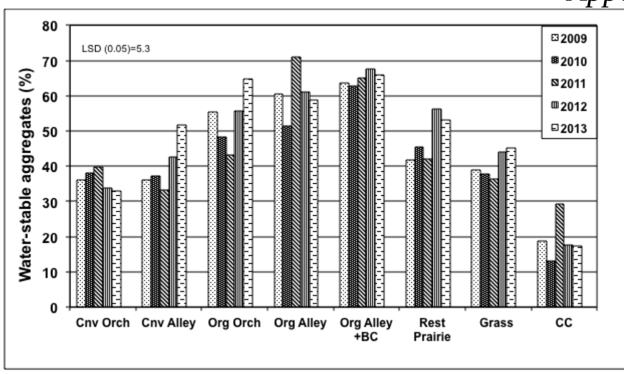
Karlen, D.L., M.J. Mausbach, J.W. Doran, R.G. Cline, R.F. Harris, G.E. and Schuman. 1997. Soil quality: a concept, definition, and framework for evaluation. *Soil Science Society of America Journal* 61:4–10.

Kremer, R.J. and L.F. Hezel. 2013. Soil quality improvement under and ecologically based farming system in northwest Missouri. *Renewable Agriculture & Food Systems* 28:245-254.

van Bruggen, A.H.C. and A.M. Semenov. 2000. In search of biological indicators for soil health and disease suppression. *Applied Soil Ecology* 15:13–24.

Veum, K.S., K.W. Goyne, R.J. Kremer, R.J. Miles, and K.A. Sudduth. 2014. Biological indicators of soil quality and soil organic matter characteristics in an agricultural management continuum. *Biogeochemistry* 117:81-99.

Appendix



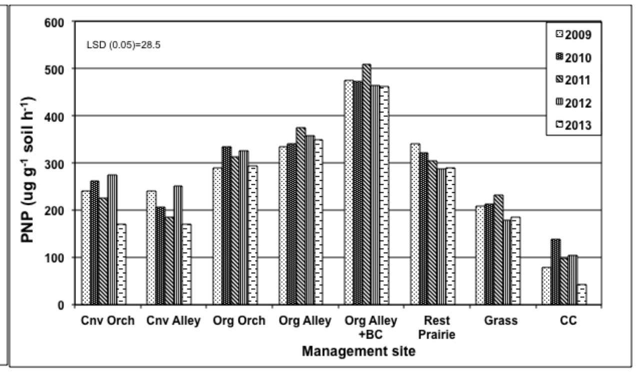
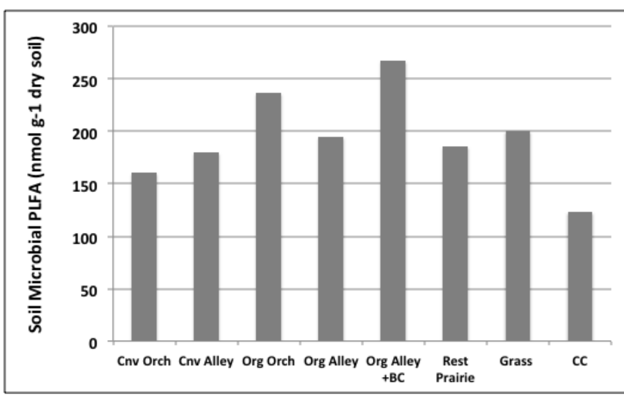


Figure 1. Stable soil aggregation developed in surface 10 cm (4 in.) of soils under various management systems at PBF.

Figure 2. Soil glucosaminidase activity (N cycling indicator) under various production systems.



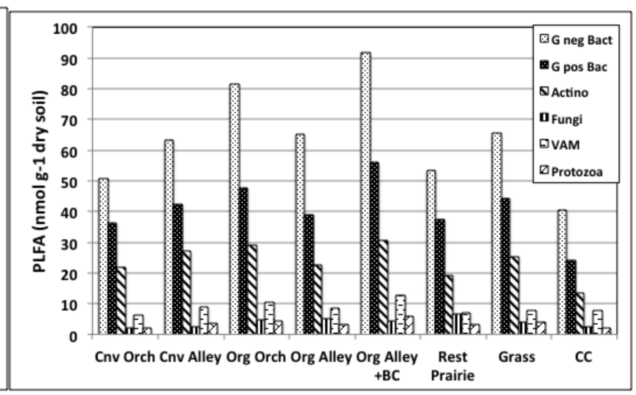


Figure 3. Soil microbial biomass determined as total soil PLFA under various production systems at PBF.

Figure 4. Soil microbial community structure represented by major PLFA microbial groups under various production practices at PBF.