Dynamics of soil microbial respiration of rotations with durum as winter crop in Arizona: Role of durum production in maintaining soil health. 2023 Season. Final Project Report

AGRPC Award # 23-03

Introduction:

Soil health is a dynamic condition, an expression of the seasonal changes occurring in soil microbial activity molded by soil, crop, and water management. The intensity of such soil microbial interactions supports the productive capacity of soils by regulating physical, chemical and biological processes taking place in this living system. In spite of its importance, we recognize that there is a void in our understanding of key principles governing soil health in the local agricultural context of Arizona. By generating information related to crop management and soil health, this project will lay the foundation for future efforts in improvement and preservation of the sustainability of Desert Durum production systems. For this reason, this project was formulated with a systems approach looking at the specifics of crop management and rotational sequences. Participation of grower cooperators is a key element of this proposal given the applied research nature of this study. For the 2023 wheat season we received the support from Ramona Farms in Sacaton AZ to implement high-frequency soil respiration measurements and soil compositional analyses in three fields grown with wheat under conventional and organic production.

Project Goals and Objectives:

The overall objective of this research project in 2023 was to continue generating information on the intensity of microbial activity associated with crop rotations that include durum production in the winter. This information is accurate and representative of the conditions found in Arizona and the crop management practices that take place in our local context. Generating this information is of great value because there is no comparable information published and/or available. Moreover, this information will be useful in the assessment of farming practices affecting the state of soil health. The immediate goal during the execution of this project was the generation of a data set with the necessary quality in space and time resolution to enable further analyses.

Research Tasks:

I. Sensor construction. The first objective in the execution of this project was the construction of ten sensor units. Manual surface-mounting of components on electronic boards is very time consuming and prone to mistakes. Therefore it would have been very impractical to build ten units manually. For this reason we prototyped the boards using PCB (printed circuit board) software, and placed an online order for PCB assembly and manufacture (https://jlcbcb.com/). The plastic housing and docking rings were 3-D printed in-house. Fabrication of the ten units was completed by late January 2023 and ready for field deployment in early February, 2023.

II. Field Selection and sensor deployment. Three fields were selected for this study, the goal was to capture the response of the soil expressed as microbial respiration in a broad set of soil types and management practices in wheat production. The fields selected included: a) conventional farming in light textured soil; b) organic farming in loam texture soil of recent (less than 5 years) conversion to agricultural use; and c) organic farming in heavy texture soil of long term (more than 40 years) conversion to agricultural use. Three sensors were deployed in each field starting in mid-February when the crop was at the first stage of tillering. Figure one presents the location of sensors in each field, and the central coordinates of each field in this study. For illustration purposes, Figure two presents images of sensor deployment across the season.

Figure 1. Location of wheat fields under study in 2023. Wheat field on the left (33.158873N, 111.808763W) was grown conventionally on light-textured soil; wheat field at the center (33.127622N, 111.787203W) was grown organically on loamy-texture soil of recent conversion; and wheat field on the right (33.082237N, 111.731141W) was grown organically on heavy texture soil of long term conversion. Sacaton, AZ. 2023

Figure 2. Pictures of sensor deployment from early season (tillering, left) till maturity (right). Sacaton, AZ. 2023

Field and Laboratory Data Collection:

I. In-situ soil respiration data. Soil sensors were deployed from mid- February till the end of May. Raw data was acquired continually at a rate of 3 observations per minute. The complete data set consisted of 462 24-hr cycles and produced a total of ~ 2M data points. Figure 3 contains daily averages for all nine sensors showing trends of increasing soil respiration rates as the season progressed towards complete growth of wheat plants, then this rate decreased as the wheat plants reached maturity. These trends of soil respiration measurements follow the same theoretical expectation of microbial activity.

Figure 3. Soil respiration daily average rates of all nine in-situ sensors deployed across the wheat growing season. Sacaton, AZ. 2023.

II. Soil and plant sampling. A large battery of soil parameters were evaluated on samples taken in mid-March and mid-May in close proximity to the location of the in-situ soil respiration sensors. The prime microbial parameter evaluated was Phospholipid Fatty Acid Analysis (PLFA). Soil parameters included Carbon and Nitrogen forms such as: NO3-N, Organic C:N, NH4-N, ACE protein, Total N, microbially active carbon, organic Nitrogen release, and organic Nitrogen reserve. Additional soil parameters included: pH, organic matter, water stable aggregates, 24-hour soil respiration, and soil health score. Elemental composition parameters: Olsen Phosphorous, Potassium, Sulfate-S, Zinc, Iron, Manganese, Copper, Calcium, Magnesium, and Sodium.

Plant samples were taken right before harvesting to measure root, stem, heads, and above ground biomass on a gram per meter square basis. Geo-referenced field-level yield data were recorded by the electronic yield monitor installed in the grain combine. Files were graciously provided by the harvest contractor.

Results:

Historically, these three fields have substantial differences in their productivity potential. Therefore the first level of analysis was carried out to characterize the main differences between them. Figure four presents the values of a selected list of soil parameters aggregated by field.

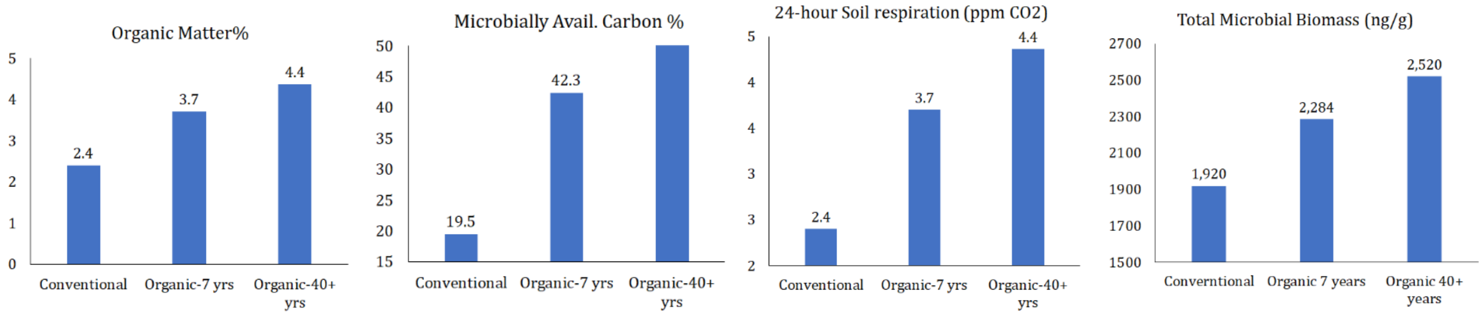

Figure 4. List of selected soil parameters aggregated by field. Sacaton, AZ. 2023.

There were substantial differences between fields in terms of in-situ soil respiration. Figure 5 below describes the main differences between fields aggregated by time, where soil protein had a particularly strong association and similar pattern with the intensity of in-situ soil respiration recorded over time.

Additionally, extensive multivariate analyses were performed on the complete data set to explore the extent of correlations existing between the soil parameters (independent variables) and plant biomass/grain yield as measures of response variables. Table one below shows a list of microbial soil health parameters and their corresponding values of correlation coefficient with yield organized by time of sampling.

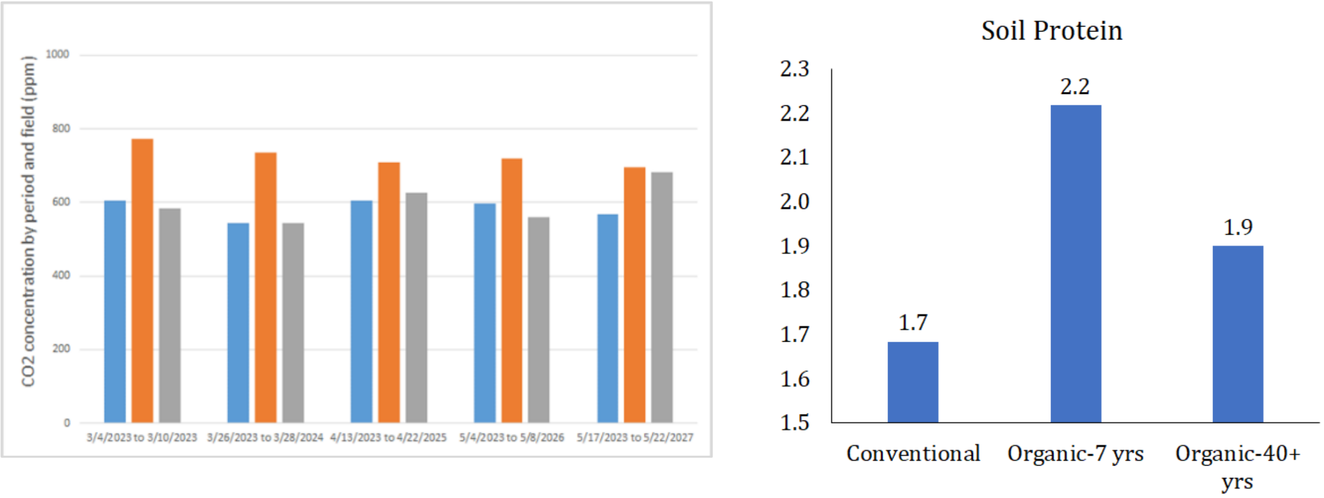

Figure 5. Similarity of patterns between soil protein and in-situ soil respiration aggregated by field. Left graph shows daily averages arranged by blocks of time and fields; blue orange and gray color bars correspond to Conventional, Organic-7 yrs, and Organic-40+ yrs respectively. Sacaton, AZ. 2023

Table 1. Microbial soil health parameters with corresponding values of correlation coefficient with yield

Soil Health Parameter	March sampling	May sampling
Soil health score	0.301	0.601
Soil respiration -24 hrs	0.403	0.571
Soil organic matter	0.908	0.903
Microbially available Carbon	0.569	0.607
Total microbial biomass		0.266
Bacteria biomass		0.819
Mycorrhizae		0.309
Actinomycetes		0.857
Gram (+) bacteria		0.756
Fungi:bacteria ratio		0.333

Interpretation of Results and Conclusions:

We found strong associations between wheat grain yield productivity and soil parameters associated with microbiology and soil health. These associations highlight the important role that crop residue management plays over the productive potential of soil through microbiology. This study supports the notion that improvements is soil health go hand-on-hand with crop rotations and residue incorporation practices. In-situ soil respiration measurements show potential to express the intensity of microbial activity, but the spatial resolution of sensor deployment limits the quantification of sensor output – soil health relationships. For this reason it was proposed to concentrate all sensor units in a single field during the 2024 wheat season.