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SOIL MICROBIAL ACTIVITY IN ANNUAL SPRING WHEAT AND WHEAT-FALLOW ROTATIONS IN THE VERY LOW RAINFALL AREAS OF THE COLUMBIA PLATEAU

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Introduction

Maintaining or enhancing soil organic matter (SOM) is essential for sustaining the soil resources of Pacific Northwest agroecosystems. Increasing SOM ameliorates soil health, provides for enhanced food production, contributes to soil stabilization, and improves both air and water quality. In addition, increasing SOM levels contributes to the capacity of agricultural soils to sequester carbon (C), thereby reducing the release of carbon dioxide (CO_2) to the atmosphere.

Soil organic matter content is affected by many agricultural activities, including tillage, crop rotations, residue management, and associated environmental effects such as erosion. Tillage practices may have a measurable influence on long-term soil C storage, and no-till has been proposed as a means to increase soil C sequestration (Rasmussen et al., 1998; Paustian et al., 1997).

Soil organic matter consists of a range of C based compounds which function in the structure, nutrient storage, and biological activity of soils. Not only is SOM a source of plant nutrients, it is also a water reservoir for plants. Soil organic matter serves as a binding agent, making it important in maintaining soil tilth, aiding the infiltration of air and water into soil, providing a soil buffering capacity, and contributing to erosion reduction (Wagner and Wolf, 1998). The wheat (*Triticum aestivum* L.)/fallow system, which reduces the risk of crop failure due to inadequate soil moisture, is subject to rapid SOM loss during the fallow part of the rotation.

The flux of CO_2 to the atmosphere from soil governs the extent to which C from plant residues is retained in the soil or released to the atmosphere. Soil CO_2 fluxes are primarily dependent on the metabolic activity of soil microbes, and are strongly affected by both temperature and moisture. Soil microbiological activity can be sensitive to management, including crop species, tillages, and fertilizers. Soil disturbance by tillage has been observed to increase CO_2 fluxes in the short-term (Seto, 1982; Reicosky and Lindstrom 1993), but the long-term contribution of soil disturbance to CO_2 efflux has not been quantified adequately. If C sequestration is to be enhanced without increasing C inputs into the soil, CO_2 loss from the soil must be reduced.

The success of soil conservation efforts to maintain soil quality depends on an understanding of how soils respond to agricultural management systems over time. Therefore, methods to quantify soil quality must assess changes in selected soil attributes over a prescribed period of time and space. Information on the influence of management on soil CO_2 fluxes is required to identify practices that maintain soil productivity and retard the conversion of soil C to atmospheric CO_2. The objective of this study is to evaluate several microbiological and soil quality parameters during the transition from a winter wheat/fallow to an annual no-till spring wheat management system in a very low rainfall agroclimatic zone (Douglas, 1992).

Materials and Methods

The experimental plots are on the Doug Rowell Farm, located on Lincoln Road in the Horse Heaven Hills southwest of Prosser, WA. The Warden coarse-silty loam soils, developed under a grass prairie, first were tilled in the early 1900s. The major rotation in the area is winter wheat/fallow. The Rowell farm site receives only 6 to 7 inches mean annual precipitation, which makes it one of the world's driest for wheat production. Winter wheat yields at the Rowell test site range from 3 to 42 bushels per acre (bu/a), with a long-term average of 20 bu/a. Average above-ground residue production for the 2-year fallow cycle is about 2,000 pounds per acre.

The plot area covers 8 acres (1,164 x 300 ft). The experiment, initiated in 1996, has three treatments: (1) annual no-till, hard red spring wheat (ASW); (2) soft white winter wheat (in the odd year)/summer-fallow (WW/F); and (3) summer-fallow (in the odd year)/soft white winter wheat (F/WW). The experimental design is a randomized complete block with six replications. A primary spring tillage with a tandem disk or V-blade sweep followed by two or three rodweedings is typical during the fallow cycle. No-till spring wheat plots were sown with an ultra low-disturbance cross-slot disc drill which delivers seed and all fertilizer in one pass through the field.

The CO_2 flux from the soil in all treatments was measured *in situ* on September 1, 1999, from 9:45 to 11:00 AM using a LI-COR soil-respiration chamber and portable infrared gas analyzer (LI-COR, Lincoln, NE). In addition, soil temperature at 4 inches, chamber air temperature, and chamber relative humidity were recorded. Fluxes, expressed in amount of CO_2 per area per time (lb CO_2/acre/day), were calculated from the increase in the chamber CO_2. A minimum of three CO_2 flux rates were determined for each replication, and the average was calculated for each determination. Volumetric soil moisture content, from 0 to 6 feet of profile, was determined following harvest on July 12, 1999.

The bacterial populations in the soil were enumerated by the dilution spread plate method (Alexander, 1998). Serial dilutions were plated on nutrient agar and incubated at 77°F. Colonies on each plate were counted at 24, 48, 72, and 96 hours after plating. The number of cells per ounce of soil were estimated by multiplying the average number of colonies for each replicate by the reciprocal of the total dilution applied to the nutrient agar plates and reported as colony forming units (CFU) per ounce of soil.

Results and Discussion

The soil temperature at 4 inches in the WW/F treatment averaged 67.9ºF, and was significantly less than that recorded in the standing stubble of either the F/WW or the annual SW treatments, which averaged 70.0ºF and 72.5ºF, respectively. Average soil temperature for all treatments was 70.2ºF.

Soil moisture data for 0 to 6 inches, taken on July 12, are presented in Figure 1.

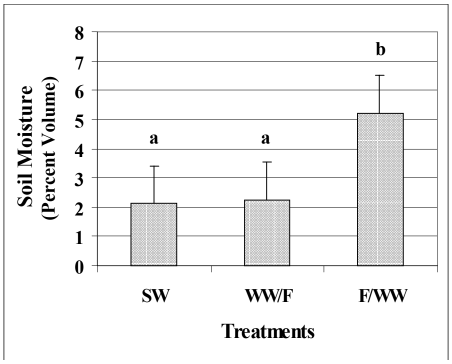

Figure 1. Soil moisture at the 0- to six-inch depth after wheat harvest at the Rowell Farm, Horse Heaven Hills, WA, on July 12, 1999. ASW=Annual Spring Wheat; WW/F= Winter Wheat/Fallow; F/WW = Fallow/Winter Wheat. A difference in letters indicates that differences by treatment are significant (P<0.05)

The ASW and WW/F treatments are not significantly different from each other, but the F/WW treatment has almost 2.5 times more moisture, by volume, than the other treatments, as would be expected after a year of fallow. Very little rainfall (0.2 inch) occurred from the time the soil moisture measurements were taken in July until the time the CO_2 flux determinations were made, and it was assumed that the moisture relationships among the treatments on September 1, 1999 were similar to soil moisture in July. The greater soil moisture in the F/WW treatment certainly is due to the removal by the wheat crops grown in the other two treatments during the previous months.

Immediate CO_2 flux from the soil, following the placement of the collection chamber, was quite rapid and the flux rate was linear with time (Figure 2). The average time required for the flux determination was 106 seconds. The

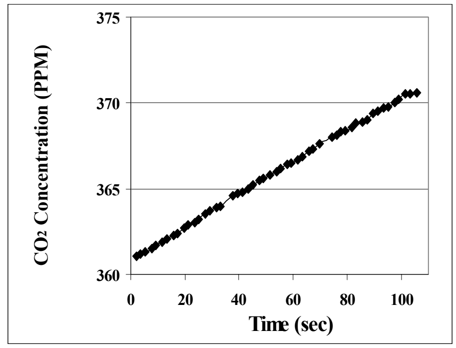

Figure 2. Gradual increase in CO_2 in a chamber placed over the soil on September 1, 1999, at the Rowell Farm, Horse Heaven Hills, WA. The increase in CO_2 is linear and due to the normal microbial respiration in the soil.

flurates ranged from a low of 9.3 lb CO_2/acre/day to a high of 13.0 lb CO_2/acre/day (Figure 3). The CO_2 flux rate

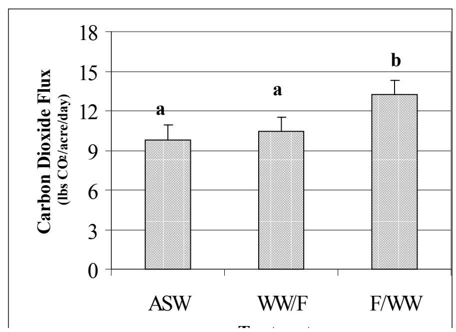

Figure 3. Carbon dioxide flux from the soil on September 1, 1999, at the Rowell Farm, Horse Heaven Hills, WA. ASW = Annual Spring Wheat; WW/F = Winter Wheat/Fallow; F/WW = Fallow/Winter Wheat. A difference in letters indicates that differences by treatment are significant (P < 0.05)

from the F/WW treatment was significantly greater than from either the WW/F treatment or the annual SW treatment. The flux rates are directly proportional to soil moisture and indicate the effect that increased soil moisture can have on microbial metabolism and thus soil respiration.

While low soil moisture can reduce soil respiration drastically, as shown in this study, dry soils do not completely eliminate the CO_2 flux from the soil. This suggests that microorganisms in very dry soils are still capable of metabolic activity. It has long been known that soil microorganisms are capable of metabolic activity at soil moisture stresses that would be extremely detrimental to crop plants (Harris, 1981).

Summer-fallow systems have a two-fold negative effect on SOM. First, they generally contribute less residue over a 2-year period than an annual crop.
This decreases the amount of carbon, which is the source of SOM, being returned to the soil. Second, they generally have substantially more soil moisture than annually cropped soils. This increase in soil moisture allows increased metabolic activity by soil microorganisms, which may come at the expense of existing SOM, reducing its concentration in the soil and further degrading soil quality. In addition, the annual spring wheat treatment is not tilled, decreasing the amount of residue inversion. The inversion of residue promotes decomposition, because it increases the surface area available for microbial contact, and the soil buffers the microorganisms responsible for residue decomposition from possible extremes of either temperature or moisture.

Estimates of soil bacteria (Figure 4) using the dilution plate count method can be extremely variable. However, this method is useful for a first estimate, because many soil bacteria have relatively simple nutritional requirements and grow readily on solid culture media. The estimates of bacteria in this soil are about 10 times less than what generally is expected in agricultural soils (Alexander, 1998). However, the relatively

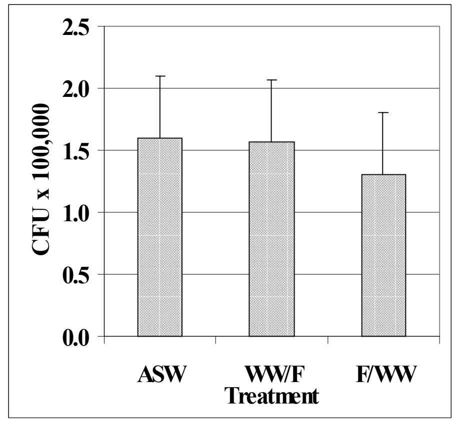

Figure 4. Estimated populations of soil bacteria at the Rowell Farm, Horse Heaven Hills, WA. ASW = Annual Spring Wheat; WW/F = Winter Wheat/Fallow; F/WW = Fallow/Winter Wheat. CFU = colony forming units.

low bacterial populations are not inappropriate considering that the upper soil levels have low C and N concentrations (data not shown) and are subjected to periods of drought and high temperatures. There were no significant differences in the estimated numbers of soil bacteria among treatments. While this is not consistent with the CO_2 flux results, which indicate increased microbial activity in the F/WW treatment with a greater soil water content, it does suggest that, while the numbers of soil microorganisms are relatively similar in each treatment, they cannot maintain similar metabolic rates.

Summary

Soil moisture and CO_2 flux were greater in the fallow treatment than the cropped treatments. Microbial activity (in this case the CO_2 flux from the soil), even though limited by low soil moisture, was not eliminated completely. This is consistent with other reports of microbial activity (Stott et al., 1986) at reduced soil moisture. Many soil microorganisms can remain active in soils that are sufficiently lacking in moisture to be harmful or even lethal to crops. While the lack of soil moisture undoubtedly contributes to the reduction of bacterial metabolic activity, it did not significantly alter the numbers of bacteria. However, the species composition and the distribution of the bacterial population may have changed as the soil moisture decreased. The elevated level of microbial respiration in the fallow treatment represents a factor that contributes to the loss of SOM during summer fallow and may significantly contribute to an overall reduction in soil quality.

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References

Alexander, D.B., 1998. Bacteria and Archaea. pp. 44–71 *IN* Principles and Applications of Soil Microbiology. D.M. Sylvia, J.J. Fuhrmann, P.G. Hartel, and D.A. Zuberer, eds. Prentice Hall, Upper Saddle River, NJ.

Douglas, C.L., Jr., R.W. Rickman, B.L. Klepper, J.F. Zuzel, and D.J. Wysocki. 1992. Agroclimatic zones for dryland winter wheat producing areas of Idaho, Washington, and Oregon. Northwest Sci. 66:26–34.

Harris, R.F. 1981. Effect of water potential on microbial growth and activity. pp. 23–96. *IN* Water Potential Relations in Soil Microbiology. J.F. Parr, W.R. Gardner, and L.F. Elliott, eds. Soil Sci. Soc. Of Am., Madison, WI.

Paustian, K., H.P. Collins, and E.A. Paul. 1997. Management controls on soil carbon. pp. 15–49. *IN* Soil Organic Matter in Temperate Agroecosystems. E.A. Paul, K. Paustian, E.T. Elliott, and C.V. Cole, eds. CRC Press, Boca Raton, FL.

Rasmussen, P.E., S.L. Albrecht, and R.W. Smiley. 1998. Soil C and N changes under tillage and cropping systems in semi-arid Pacific Northwest agriculture. Soil and Tillage Res. 47:197–205.

Reicosky, D.C. and M.J. Lindstrom. 1993. Fall tillage method: Effect on short-term carbon dioxide flux from the soil. Agron. J. 85:1,237–1,243.

Seto, M. 1982. A preliminary observation of CO_2 evolution from soil in situ measured by an air current method—an example in rainfall and plowing sequences. Japanese J. Ecol. 32:535–538.

Stott, D.E., L.F. Elliott, R.I. Papendick, & G.S. Campbell. 1986. Low temperature or low water potential effects on the microbial decomposition of wheat residue. Soil Biol. Biochem. 18:577–582.

Wagner, G.H. and D.C. Wolf. 1998. Carbon transformations and soil organic matter formation. pp. 218–258. *IN* Principles and Applications of Soil Microbiology. D.M. Sylvia, J.J. Fuhrmann, P.G. Hartel, and D.A. Zuberer, eds. Prentice Hall, Upper Saddle River, NJ.